TC 6-02.20

CABLE AND WIRE SYSTEMS HANDBOOK

JANUARY 2018

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HEADQUARTERS, DEPARTMENT OF THE ARMY

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Handbook
TC 6-02.20

Headquarters
Department of the Army
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CABLE AND WIRE SYSTEMS HANDBOOK

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Preface

TC 6-02.20, *Cable and Wire Systems Handbook*, is a reference based handbook for personnel who install, maintain, test, troubleshoot, repair, fabricate, replace, and recover wire and cable for Army communications networks. This publication is a guide to implement unit sustainment training for military occupational specialty (MOS) 25L and Soldiers requiring knowledge of signal wire and cable installation to support the mission.

Commanders, staffs, and subordinates ensure their decisions and actions comply with principles and expectations of the Army profession and any applicable United States, international, and, in some cases, host-nation laws and regulations. Commanders at all levels ensure their Soldiers operate in accordance with the law of war and the rules of engagement. (FM 27-10)

TC 6-02.20 contains general information on wire, cable, connectors, outside plant operations, inside plant operations, local area network (LAN) and wide area network (WAN). It covers installing and recovering wire and cable lines, pole climbing, splicing, wire ties, troubleshooting, wire line construction, and wire records. It mentions characteristics of typical communications equipment that utilize wire and cable technologies.

TC 6-02.20 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. Terms for which TC 6-02.20 is the proponent publication (the authority) are marked with an asterisk (*) in the glossary. The text of Definitions for which TC 6-02.20 is the proponent publication are boldfaced. For other definitions shown in the text, the term is italicized and the number of the proponent publication follows the definition.

This publication applies to Active Army, the Army National Guard, and the United States Army Reserve unless otherwise stated. The proponent of this publication is the United States Army Cyber Center of Excellence. Send comments and recommendations on DA Form 2028 (Recommended Changes to Publications and Forms) directly to: Commander, United States Army Cyber Center of Excellence and Fort Gordon, ATTN: ATZH-DT-(TC 6-02.20) 506 Chamberlain Avenue, Fort Gordon, GA 3005-5735, or via e-mail to: usarmy.gordon.cyber-coe.mbx.gord-fg-doctrine@mail.mil.

Introduction

TC 6-02.20, *Cable and Wire Systems Handbook*, addresses the role of wire and cable installations including substation installations, LANs, and WANs. Wire and cable systems remain the primary physical infrastructure for all of our communications networks. Cables systems installation includes the use of wire, wire laying and recovery equipment, cable, battery-operated and sound-powered telephones, terminating equipment, and LAN and WAN equipment.

Significant areas that TC 6-02.20 addresses are LAN, WAN, substation, aerial and underground installation, inside plant operations, and maintenance. These capabilities are a direct response to the ever-growing reliance on wire and cable systems to establish the physical backbone of the networks that comprise the Army's portion of the Department of Defense information network (DODIN) known as the Department of Defense information network-Army (DODIN-A).

TC 6-02.20 contains five chapters and five appendices—

Chapter 1 provides an overview of cable and wire systems, outside plant operations, and inside plant operations. Chapter 1 will also describe the additional cable and wire training offered by the Army. This chapter also discusses various tactical wire systems, tactical reel units, and communications equipment installed by the cable and wire installer. It also discusses the different cables employed while describing how to mark cables and circuits. This chapter also describes how to build various constructions necessary to employ aerial cable installation, establish test stations, how to retrieve wire and cable, and basic troubleshooting procedures for tactical wire systems.

Chapter 2 covers fiber optics and the theory of light wave communications. It provides an in-depth description of the various types of fiber optic cables, fiber optic cable applications, and fiber optic connectors. Chapter 2 also discusses fiber optic termination techniques, fiber optic splicing, and testing and troubleshooting procedures, to include the testing equipment used to perform these tasks.

Chapter 3 discusses outside plant operations. It covers aerial cable systems installation, to include accessories for cables when installing an aerial suspension. This chapter also covers underground cable systems installation.

Chapter 4 discusses inside plant operations. It discusses the engineering installation plan, various hands and power tools used for inside plant operations, marking and site layout, and anchoring devices. It also covers cable rack and wireways, distribution frames, conduit, facility grounding, direct current (DC) power systems, and alternating current (AC) power systems, followed by an overview of equipment marking. This chapter also covers communications substations and category cable.

Chapter 5 provides a brief overview of LAN and WAN. It also gives a brief description of virtual local networks.

Appendix A discusses safety precautions that should take place during installation of wire and cable systems. It discusses how to faulty electrical equipment, dangers of electrical shock, ladder safety, dangers of confined spaces, and use of power supplies.

Appendix B provides tables that lists the collective and critical individual tasks of cable systems installers/maintainers (25L) by skill levels.

Appendix C discusses additional training provided by the Army provides for cable and wire installers.

Appendix D discusses global, national and international standards to consider when installing electrical cable and wire.

Appendix E provides a formula to measure the amount of conduit for installation. It also has a table for determining the amount of shrinkage (distance loss) that occur when bending conduit.

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Chapter 1
Cable and Wire Systems

This chapter provides an overview of cable and wire systems used by Army cable and wire installers. This chapter will begin by providing an in-depth description of wire and cable conductors, as well as fiber optic cable. This chapter also provides two sections that cover tactical wire with associated accessories and devices; tactical cable; and non-tactical cable used for installing power, wiring devices, and as transmission media for internet protocol networks in communications facilities.

CABLE AND WIRE SYSTEMS OVERVIEW

1-1. This section provides a brief description of the three primary conductors (wire, cable (metal conductor type), and fiber optic cable) that will be discussed throughout this handbook. This overview will assist the reader with understanding the distinction between the various conductor types. This section will also cover the various tactical accessories used to employ cable and wire systems, to include accessories for creating tactical analog voice and data networks. In addition to tactical wire and cable systems, the section will also provide an overview of non-tactical wire and cable used in communications facilities for alternating and direct current power distribution and internet protocol (IP) based communications.

WIRE

1-2. A wire is a single flexible strand or rod of metal. It is usually cylindrical. Use wire to transfer electricity and telecommunications signals from one device to another. Wire gauges (size of the wire) come in various sizes. The size of the wire utilized depends on the purpose of its use. When combined together, wires create a cable.

1-3. A sheath made of various types of material can insulate a wire. Wire can either be solid (one solid piece of metal), stranded (composed of a number of small strands of wire bundled or wrapped together to form a larger conductor) or braided (composed of a number of small strands of wire braided together). Wire can be made of various types of metals; however, copper remains the preferred metal in nearly every electrical application due to its high electrical conductivity, tensile strength, ductility, corrosion resistance, resistance to electrical overloads, and ease of installation.

1-4. Wire communications are possible in most terrain and tactical situations. The range of wire communications vary, depending on the weather and the condition of the wire. To extend the range of wire circuits, the use of attended or unattended repeaters is required.

1-5. Wire communications take longer to install than any other means. The time required greatly depends on the length of wire line and the method of employing it (ground vehicle or manpack). It is necessary to consider the number of personnel available and their training, terrain, routes, weather, and visibility when estimating the time required.

1-6. Units may connect closely located activities tactically by employing wire, such as within command posts and between radio-relay terminals and switching centrals. The use of long-haul wire circuits (trunks) between signal nodes and headquarters provide backup to radio and radio relay systems. The use of various multiplexing devices, make it possible to transmit more than one message over a single circuit. In combat, units should use existing commercial wire circuits when feasible. Wire communications are especially reliable and desirable in defensive operations where movement is limited and time is available for installation and maintenance.

1-7. The commander is responsible for the installation, operation, and maintenance of the unit's wire communications system. Commanders are responsible for installing and maintaining wire communications to subordinate, attached, supported, and reinforced units, and laterally to the unit on their right.

CABLE

1-8. A cable is two or more wires, combined together, that form a single assembly. The wires can either be running side-by-side and bonded, twisted, or braided. A cable is typically insulated either individually (each wire making the cable has its own insulation) or together (one insulation that covers the wires as a whole).

1-9. In electrical application, cables carry electric currents. Electrical cables used to connect two or more devices, enable transfer of electrical signals or power from one device to the other. Cables used for a wide range of purposes, and each must be tailored for that purpose.

FIBER OPTIC CABLE

1-10. Fiber optic cable is a non-metal type of cable and contains one or more optical fibers in a protective sheath that allows the transport of light particles between two devices and has a wide range of uses in fiber optic communications. Manufacturers make these fibers by drawing glass or plastic to a diameter slightly thinner than a strand of hair. Chapter 2 discusses fiber optic cable.

TACTICAL WIRE AND ASSOCIATED EQUIPMENT

1-11. Equipment and devices in this section are legacy equipment; however, they still have functional purposes. Some of this equipment is associated support items of equipment (ASIOE) for various WIN-T assemblages to include the joint network node, command post node, and single shelter switch. Their primary use is to provide interoperability with coalition forces. Tactical wire is ancillary equipment to associated equipment and devices covered in this section and allows analog connectivity for tactical analog voice networks, as well as point-to-point connection between tactical phones.

TACTICAL WIRE AND JUNCTION BOX

1-12. Tactical wire WF-16/U is four-wire system used during installation of tactical analog phones either to junction boxes or directly to telephone switches. It allows the capability for either two-wire or four-wire tactical phone configuration.

1-13. Tactical wire WF-16/U has four copper-cadmium alloy insulated stranded conductors in two pairs. One pair is olive drab and one pair is brown. The olive drab conductor has a ridge along the side for night identification. Conductors have the following characteristics—

- Copper-cadmium alloy stranded.
- Tensile strength of 200 pound.
- Weighs 62 pounds per 1.6 kilometers (1 mile).
- Attenuation (dB) per 1.6 kilometers (1 mile) 2.6 wet, 2.0 dry.
- Length 1.6 kilometers (1 mile).
- Four-wire, wire.

J-1077A/U

1-14. The J-1077A/U junction box (commonly referred to as a J-Box) connects to a telephone switch using a special purpose cable and allows 12 four-wire tactical phone connections or 26 two-wire tactical phone connections.

1-15. The J-1077A/U, see figure 1-1 on page 1-3, is a hard-wired (normal through) distribution box used to connect field wire. Traffic capacity is 12 four-wire lines or 26 two-wire lines. Two J-1077A/Us are required for use during field expedient patching.

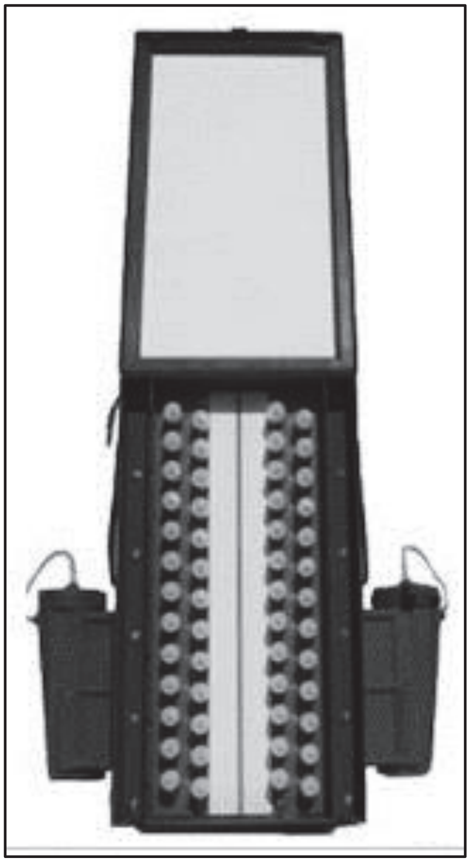

Figure 1-1. J-1077A/U

Field Telephones

1-16. Field telephone sets are portable, self-contained communications equipment designed for field use. These sets combine durable construction with portability. The selection of a specific field telephone depends on length and type of circuit and the type of switchboard used. These field telephones are also legacy equipment, but still have functional uses. These phones are ancillary to the J-1077A/U for interoperability with coalition forces and used by combat units as a means of communications for manning observation posts, listening posts, and entry control points.

TA-312/PT

1-17. Telephone set TA-312/PT (see figure 1-2, page 1-4) is a small, rugged, waterproof, portable field telephone designed primarily for operation in the field on a local battery system. However, the telephone also operates on a common battery system and common battery signaling system. For information on operator level and unit level maintenance refer to TM 11-5805-201-12.

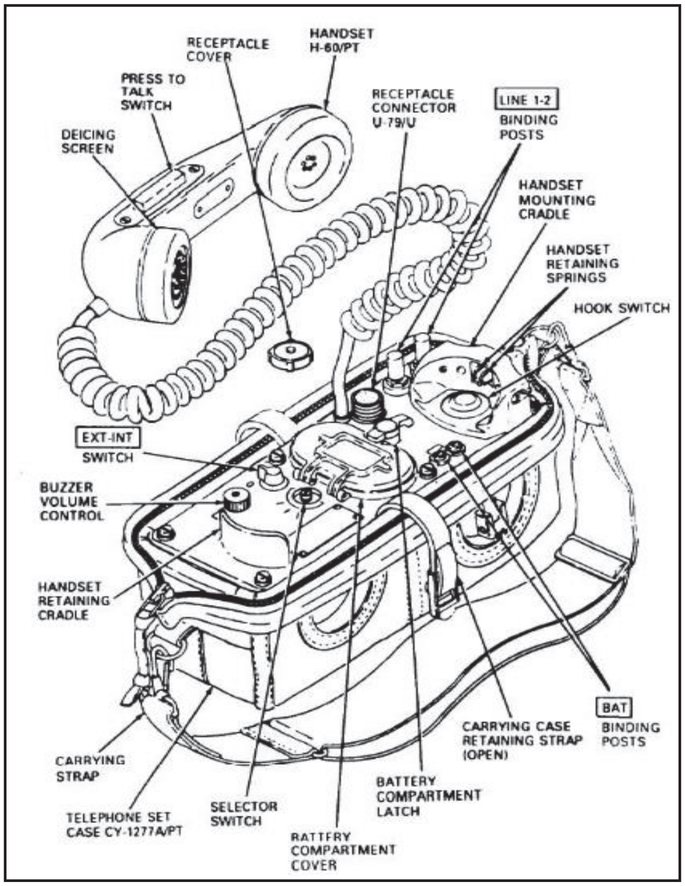

Figure 1-2. TA-312/PT

1-18. The telephone set TA-312/PT is no longer limited to use with manual switchboards. It can be attached to a tone-signaling adapter TA-955/PT which turns the telephone into a push-button, dial tone, two-wire, common battery subset capable of producing the standard dual tone signals used by military and commercial automatic-switching systems.

1-19. Telephone set TA-312/PT, may be installed on a tree or pole. Unfasten the carrying strap from the end farthest from the line terminals. Place the telephone set against the support at a convenient height. Wrap the carrying strap around the support and secure it to the ring in the case. Insert a piece of field wire through the lower loop on the back of the canvas case and tie it securely around the support.

> ***Note.*** TA-312 installed from aerial construction will have approximately 6 inches slack to provide drip loop.

1-20. The following are the steps for connecting wires to the TA-312/PT—

1. Remove about 1 inch of insulation from each wire of the pair to be connected (Field Wire WD-1/TT or WD-1A/TT). Scrape the stripped ends clear of insulation. Fold back the stripped wires about 1/2 inch from the end.
2. Push down on one of the line 1-2 binding posts, insert the bare end of one of the wires into the binding post slot, and release the pressure. Be sure to clamp the wire firmly. Repeat the procedure for the other wire and binding post.
3. Tie the wire to the ring on the carrying case, and make a ground loop tie at the base of tree or pole.
4. Operate the selector switch for the type of operation desired-local battery, common battery, or common battery signaling. Install two batteries (BA-30) in the battery compartment for local battery or common battery signaling.

5. When utilizing the telephone set as a desk set in a semi-permanent installation, it is acceptable to remove and store the canvas case for future use.

Note. Refer to TM 11-5805-201-12 for detailed information on TA-312 operation.

WARNING:

Soldiers may get a 90-volt AC shock if they touch bare wire when signaling.

Digital Nonsecure Voice Terminal TA-1042A/U

1-21. The TA-1042A/U digital nonsecure voice terminal (DNVT) is a ruggedized field telephone (see figure 1-3). It is operable as a tabletop device in both tactical and garrison environments, to include outdoors while strapped to a tree or pole. The DNVT has the durability to endure exposure of the elements during operation and transportation.

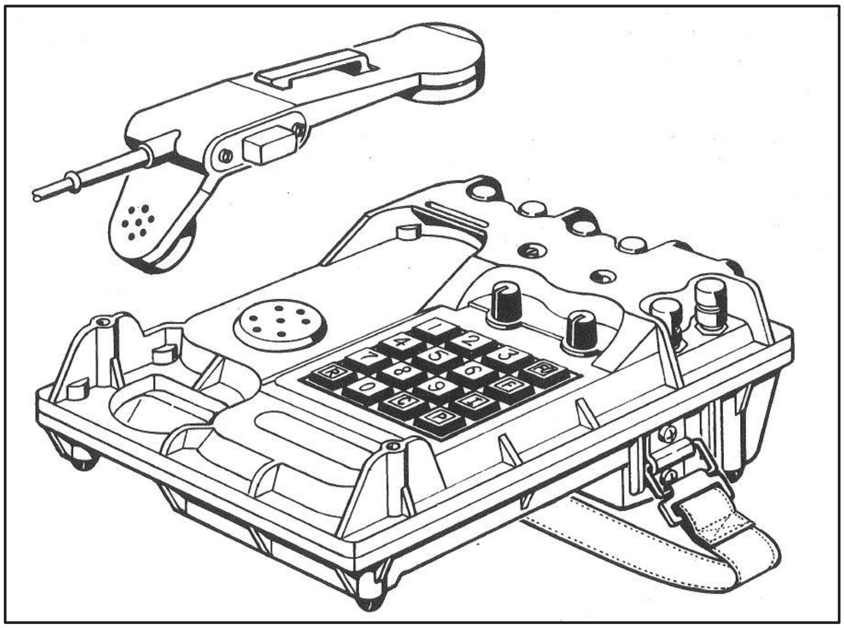

Figure 1-3. TA-1042A/U (DNVT)

1-22. The DNVT transmit and receives full duplex, conditioned diphase digital voice and loop signaling information at 16 or 32 Kbps rates. The DNVT is a nonsecure telephone with no encryption capability. It digitizes voice information using continuously variable slope delta (CVSD) modulation. Accomplish digital communication transmission, both to and from the DNVT, using a conditioned diphase (CDP) data transmission method. Accomplish CDP data transmission method by using of the digital data port (DDP). The DNVT operates in both common battery (CB) mode and local battery (LB) point-to-point mode, but not simultaneously. Figure 1-4 on page 1-6 displays a top view of the DNVT that shows all connection points used when installing the DNVT for both CB and LB modes.

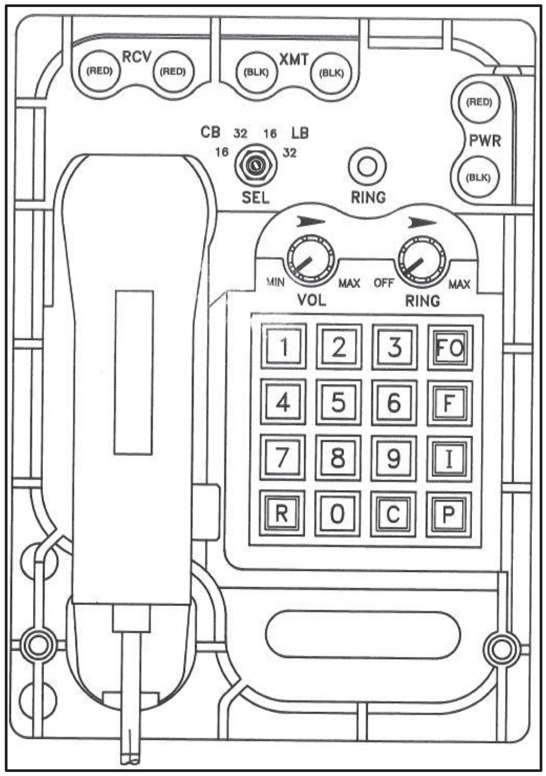

Figure 1-4. Top view of TA-1042A/U (DNVT)

1-23. The following are procedures to install the DNVT in CB mode—

1. Identify transmit field wires (WF-16/U). Remove insulation from and connect transmit field wire to the black spring loaded binding posts labeled XMT on top side of the DNVT.
2. Identify receive field wires (WF-16/U). Remove insulation from and connect receive field wires to the red spring loaded binding posts labeled RCV on top side of the DNVT.
3. Using a common straight blade screwdriver, turn select switch labeled SEL to position labeled CB (16 or 32) on top side of the DNVT.
4. Operator should lift the handset to verify receipt of dial tone. If no dial tone is heard but ring indicator illuminates the phone is properly installed but the tactical circuit switch is not on line. The ring indicator will go out within ten seconds after replacing the handset.

1-24. The following are procedures to install the DNVT in LB mode—

1. Identify transmit field wires (WF-16/U). Remove insulation from and connect transmit field wire to the black spring loaded binding posts labeled XMT on top side of the DNVT.
2. Identify receive field wires (WF-16/U). Remove insulation from and connect receive field wires to the red spring loaded binding posts labeled RCV on top side of the DNVT.
3. Using a common straight blade screwdriver, turn select switch labeled SEL to position labeled LB (16 or 32) on top side of the DNVT.
4. Connect an external power source (5.5-28 VDC, 75 milliamp) to the PWR binding posts. Positive lead of power source attaches to the red binding posts, negative lead of power source attaches to the black binding posts. If the local termination is a time division multiplexer (TDM) the local battery power is available by way of the loop modem card in the TDM. In this case the LB power is provided using the XMT/RCV connections.

TACTICAL AND NON-TACTICAL CABLES AND ACCESSORIES

1-25. The tactical cables discussed in this section are considered as legacy equipment; however, these cables are currently be used for network compatibility with various coalition forces and during operations where local laws prohibit the use of wireless connectivity, resulting in the requirement to establish physical connections over long distances. They are also ancillary equipment to various WIN-T assemblages. Establish both digital voice and data network communications using various non-tactical cables described in this section.

Special Purpose Electrical Cable Assemblies, Tactical

1-26. Army communication systems have special cable interfacing connections. These connections have become the standard for most signal entry panels found on the shelters that house the equipment. The following cable assemblies have connectors that provide a strong physical and locked interface with the signal entry panels.

CX-4566/G

1-27. Twenty-six pair cable assembly, special purpose, electrical (CX-4566/G) is a stranded conductor with 26 pairs of color-coded wires. It provides cable distribution for local telephone lines and circuits, interconnects communications shelters in conjunction with distribution boxes. It terminates in a universal connector at each end. The cable is sturdy enough for both ground and aerial use. It comes in 250-foot lengths on metal cable reel RC-435/U. CX-4566/G is also legacy equipment but is ancillary equipment, used for providing the required cable connection between applicable WIN-T assemblages and the J-1077A/U.

CX-11230A/G

1-28. Special purpose electrical cable assembly CX-11230A/G is an inter-area coaxial cable. It provides a four-wire cable transmission medium for wideband pulse-code modulation (PCM) and time division multiplexing (TDM) carrier systems. CX-11230A/G is available in 33 meters (100 feet) and 0.4 kilometers (1/4 mile) lengths. Use the 33 meter and 0.4 kilometer lengths in combination to obtain the required length of a transmission line. CX 11230()/G provides transmission line for 12-, 24-, and 48-channel TDM and PCM systems, as well as 96-channel XDM-PCM systems. The CX-11230A/G is a legacy item as well but provides cable connectivity between Army and coalition forces communications equipment.

Note: During freezing weather, handle tactical cable carefully as they may lose their flexibility in extreme cold, resulting in breaking. Refer to ATP 6-02.53 for maintenance improvement during extreme cold weather.

Installation of Special Purpose Electrical Cable Assemblies

1-29. A special purpose electrical cable is installed as aerial line, buried line, and surface line with ties, as described in the following—

- Install aerial cable normally on A-frames, trees, or poles, using basket hitch tie and weave tie. It must have a minimum clearance over main roads of 18 feet above the center of the road and 14 feet over the secondary road and in command areas.
- When construction requires buried cable, bury the cable 6 to 12 inches deep.
- Normally installations of twenty-six pair cable keeps it off the ground, but when used on the ground, take care to avoid any type of vehicle running over it.

Connecting and Disconnecting Special Purpose Electrical Cable Assemblies

1-30. Connect the twenty-six pair cable by joining the conductors together and then hand tightening the connection by turning both sleeves on the conductor; make a tension bridge after connection. Ensure the cable has the appropriate sag for each span between poles or trees. Six inches of sag is required for every twenty-five feet of span length. It is necessary to maintain 18 feet across all main traffic arteries and paved roads, and 14 feet over secondary roads and other roads where vehicles travel. Do not permit the sag tension to exceed 100 pounds.

1-31. Twenty-six pair cable is recovered/disconnected following these procedures—

- Remove all wires, tags, ties, junction boxes, and telephones.
- Lower aerial cable and remove buried road crossing.

- Install RC-435/U with empty reel and reel-in cable with first six feet of cable into the reel center storage area, place connector into storage compartment and secure the cable with storage straps.
- Station one team member by the reel with the crank, one team member to hold the end of the cable connector, and a third team member to guide the cable on the reel when recovering cable.

NON-TACTICAL CABLE

1-32. Electrical cable is two or more metallic core wires or fiber optic cores bound together, typically in a common protective jacket or sheath. The individual wires or fibers inside the jacket may contain materials that protect, insulate and separate individual strands or a set of strands (binder) identified by a specific color code for installation purposes. The electrical wire is usually copper because of its excellent conductivity, however aluminum also have good conductivity and is more cost effective. Manufacturers make fiber optic cores with glass, plastic clad silica or both depending on type, manufacturer, and application. The following cables are addressed in this section—

- Twisted pair cable.
- Unshielded twisted pair cable.
- Shielded twisted pair cable.
- Category (CAT) 5 cable.
- Coaxial cable.

Twisted Pair Cable

1-33. Twisted pair cable is a type of cabling currently used for telephone communications and most modern Ethernet networks. A pair of wires form a circuit that can transmit data. Twisting the pairs provides protection against crosstalk, the noise generated by adjacent wire pairs. When electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out. They also cancel out any outside magnetic fields. Twisting the wires enhances this cancellation effect. By using cancellation together with twisting the wires, cable designers effectively provide self-shielding for wire pairs within the network media.

1-34. Two types of twisted pair cables exist: unshielded twisted pair (UTP) and shielded twisted pair (STP).

Unshielded Twisted Pair Cable

1-35. UTP cable has no metal shield, used indoors, and comes in a variety of sizes. The most common kind of UTP is copper telephone wire. A variety of networks uses UTP cable daily. Figure 1-5 on page 1-6—UTP cable is a medium composed of pairs of wires. Each of the eight individual copper wires in the UTP cable has a covering of insulating material with each pair twisted around each other. Some twisted pair cable has two or more pairs of cable within a single jacket.

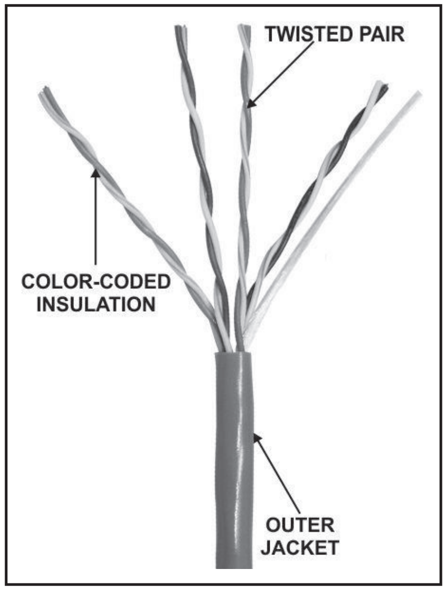

Figure 1-5. UTP cable

1-36. The acronym naming convention for UTP has changed to U/UTP, which designates the cable as having neither shielding around the cable, or the individual pairs, see table 1-2, on page 1-15, for more information.

Shielded Twisted Pair Cable

1-37. Shielded twisted pair cables have a metal insulation to prevent electromagnetic interference. Because the shielding is made of metal, it may also serve as a ground. However, usually a shielded or a screened twisted pair cable has a special grounding wire added called a drain wire. Apply this shielding to individual pairs, or to the collection of pairs (also called screening). Shielding provides an electric conductive barrier to attenuate electromagnetic waves external to the shield and provides a conduction path for ground.

1-38. Both UTP and STP come in stranded and solid wire varieties. The stranded wire is the most common and is very flexible for bending around corners. Solid wire cable has less attenuation and can span longer distances, but is not as flexible as stranded wire. You also cannot bend Solid wire repeatedly. Refer to figure 1-6 on page 1-10, for a picture of the STP cable.

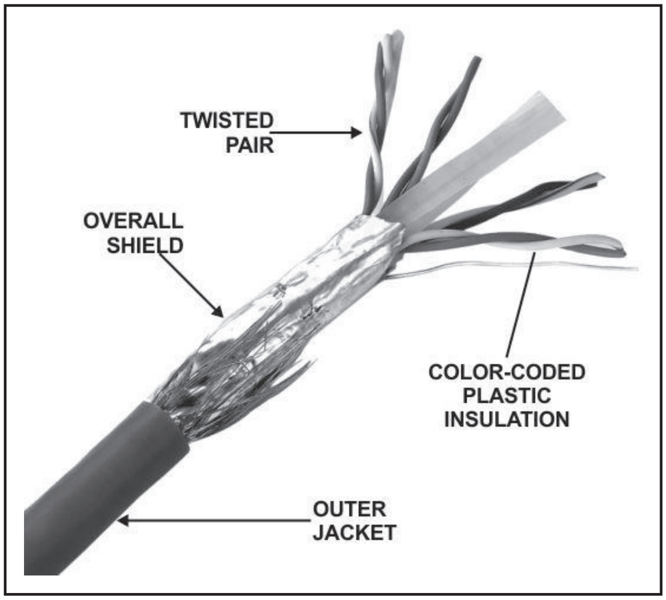

Figure 1-6. STP cable

1-39. Use shielded twisted pair cable with token ring or fiber distributed data interface (FDDI) networks. This type of shielding protects cable from external electromagnetic interference (EMI) from entering or exiting the cable and protects neighboring pairs from crosstalk.

Screened Twisted Pair

1-40. Screened twisted pair cabling offers an overall sheath shield across all of the pairs. Foil shielded twisted pair uses foil shielding instead of a braided screen. This type of shielding protects EMI from entering or exiting the cable.

Screened Shielded Twisted Pair

1-41. Screened Shielded Twisted Pair or Screened Foiled Twisted Pair cabling, offer shielding between the pair sets and an overall sheath shield. This type of shielding protects EMI from entering or exiting the cable and protects neighboring pairs from crosstalk.

1-42. Screened shielded twisted pair cable is individually shielded, like shielded twisted pair cabling, and has an outer metal shielding covering the entire group of shielded copper pairs. This type of cabling offers the best protection from interference from external sources, and eliminates alien crosstalk.

Shielded Foiled Twisted Pair

1-43. Shielded foil twisted pair is different from screened foiled twisted pair; shielded foiled twisted pair is a kind of cable which has foil and shield together. Usually used for outdoor cables for better protection against electrical signals and physical effects.

1-44. ISO/IEC 11801 is an attempt to standardize the various designations for shielded twisted pair cable internationally. Table 1-1 on page 1-11 identifies these designations.

Table 1-1. Cable naming

Chapter 16 Old Name	*Chapter 17 New Name*	*Chapter 18 Cable Screening*	*Pair Shielding*
UTP	U/UTP	None	None
STP	U/FTP	None	Foil
FTP	F/UTP	Foil	None
S-STP	S/FTP	Braiding	Foil
S-FTP	SF/UTP	Foil, Braiding	None
SFTP		Foil	Shield

UTP: Unshielded twisted pair
STP: Shielded twisted pair
FTP: Foiled twisted pair
S-STP: Screened shielded twisted pair
S-FTP: Screened foiled twisted pair
SFTP: Shield foiled twisted pair

U/UTP: Same as UTP
U/FTP: Unshielded foiled screened twisted pair
F/UTP: Foiled shield unscreened twisted pair
S/FTP: Braided screened foiled shield twisted pair
SF/UTP: Braided screened foiled shield unscreened twisted pair

Category Cable

1-45. Category cable (also known as Ethernet cable) are twisted pair cable types designed for high signal integrity. Some of these cables are shield, and some are not. Their category (CAT) type designates these cables; see table 1-2, on page 1-12.

Category 5

1-46. CAT 5 is often used for computer networks such as Ethernet for both 10BASE-T and 100BASE-T network standards and is used to carry many other signals such as voice services, token ring, and ATM (at up to 155Mbits/s over short distance but 100 Mbit/s normally). CAT 5 cable includes four twisted pairs in a single cable jacket, this use of balanced lines helps preserve a high signal-to-noise ratio despite interference from both external sources and other pairs (this latter form of interference is crosstalk). CAT 5 cable typically has three twists per inch of each twisted pair of 24 gauge copper wire within the cable.

1-47. Fabricating a CAT 5 Cable.

Skin off the cable jacket approximately 1inch or slightly more.

Untwist each pair, and straighten each wire between the fingers.

Place the wire in the order of one of the two orders such as straight thru or crossover.

At this point, recheck the wiring sequence with the diagram.

Optional: Make a mark on the wire at 1/2 inch from the end of the cable jacket.

Category 5e

1-48. CAT 5e supersedes CAT 5. CAT 5e specification improves upon the CAT 5 by tightening some crosstalk specifications and introducing new crosstalk specifications that were not present in the original CAT 5. Both CAT 5 and 5e has bandwidth of 100 MHz.

Category 6

1-49. CAT 6 cable is a standardized cable for Gigabit Ethernet and other network physical layers that is backward compatible with the CAT 5/5e and CAT 3 cable standards. The cable standard provides a bandwidth of up to 250 MHz and is suitable for 10BASE-T, 100BASE-TX (fast Ethernet), 1000BASE-T/1000BASE-TX (gigabit Ethernet) and 10GBASE-T (10-Gigabit Ethernet).

1-50. When used for 10/100/1000BASE-T, the maximum allowed length of a CAT 6 cable is 100 meters or 328 feet. This consists of 90 meters (300 ft.) of solid “horizontal” cabling between the patch panel and the wall jack, and 10 meters (33 ft.) of stranded patch cable between each jack and the attached device. Since stranded cable has higher attenuation than solid cable, exceeding 10 meters of patch cabling reduces the permissible length of horizontal cable.

1-51. When used for 10GBASE-T, CAT 6 cable's maximum length is 55 meters (180 ft.) in a favorable alien crosstalk environment, but only 37 meters (121 ft.) in a hostile alien crosstalk environment, such as when many cables are bundled together. However, because the effects of alien crosstalk environments on cables are difficult to determine before installation, it is highly recommended to test all CAT 6 cables used for 10GBASE-T once installed.

Category 6a

1-1. The most important point is a performance difference between ISO/IEC and EIA/TIA component specifications. At a frequency of 500 MHz, an ISO/IEC CAT 6A connector performs 3 dB better than a CAT 6A connector that conforms to the EIA/TIA specification; 3 dB equals 50% reduction of near-end crosstalk noise signal power.

1-2. CAT 6a, or Augmented CAT 6 was added to the Commercial Building Telecommunications Cabling Standard Addendum known as ANSI-TIA-EIA-568-B.2-10 that specifies a bandwidth of 500 MHz. and has improved alien crosstalk characteristics, allowing 10GBASE-T to be run for the same distance as previous protocols (see table 1-2).

Table 1-2. Cable category types

Chapter 19 Name	***Chapter 20 Cable Type***	***Bandwidth***	***Application***	***Notes***
Level 1	U/UTP	0.4 MHz	Telephone and Modem	Analog voice and low speed modems
Level 2	U/UTP	4 MHz	Old Terminal Systems, 4MBit/s	Digital voice
CAT 3	U/UTP, U/FTP S/STP	16 MHz	10Base-T and 100 Base-T4 10 MBit/s	TIA/EIA-568-B
CAT 4	UTP, ScTP, STP	20 MHz	16 MBit/s	Not commonly used
CAT 5	U/UTP, U/FTP, S/STP	100 MHz	100Base-TX and 1000Base-T 100 MBit/s	Common in Local Area Networks
CAT 5e	U/UTP, U/FTP. S/STP	100 MHz	100Base-TX and 1000Base-T 1GBit/s	Enhanced Cat 5
CAT 6	U/UTP, U/FTP, S/STP	250 MHz	10GBase-T, 10 GBit/s	
CAT 6a	U/FTP, S/STP	500 MHz	10GBase-T, 10 GBit/s	ISO/IEC 11801:2002 Amendment 2

CAT: Category
EIA: Electronic Industries Alliance
GBit/s: Gigabits per second
IEC: International Electrotechnical Commission
ISO: International Organization for Standardization
ScTP: Braided shield twisted pair (without foil)
S/STP: Braided shield twisted pair (with foil)
TIA: Telecommunications Industry Association
U/UTP: Unshielded twisted pair

COAXIAL CABLE

1-3. Coaxial cable has become a standard in communications, from analog video transmission to networking to extremely low noise audio cables. Different companies produce custom cable assemblies using any type of coaxial cable and multiple connectors, such as Bayonet Neil-Concelman (BNC), terminal node controller (TNC), phone plugs and jacks, and Radio Corporation of America (RCA) plugs and jacks. We can assemble coaxial cables with either crimp or solder terminations. Built to military specifications and classified according to radio guide utility (RG/U) numbers, these products support high frequency radio transmissions. After some time, these RG/U numbers fell into classifications according to impedance characteristics. The rapid growth of the computer technology brings about a greater need for coaxial cables for commercial use. Manufacturers of proprietary systems demand a variety of unique cable designs.

1-4. Cables in use for two-way communication**,** RF and microwave transmission, data transmission and instrumentation/control are typically 50-ohm coaxial cables. These cables comply with military specification (MIL-Spec) designs and uses their Radio Guide (RG) type number as references. The cables fall into a few categories: Transmission and computer cables based upon RG type designs, but not per the current MIL-Spec; MIL-C-17 cables that comply with the current MIL-Spec; and low-loss cables based loosely upon RG type designs. The RG number specifies the physical construction, materials, physical, mechanical and electrical requirements of the cable.

1-5. Today, the RG number has become a generic identifier, telling the user of its general construction and electrical properties, but not specific enough to compare attributes from one product to another. Products (and manufacturers) recognized as MIL-Spec approved are published in the qualified parts list. These products are compliant with a specific slash sheet, and tested according to the latest revision of MIL-C-17, currently revision G. Today the majority of cable applications do not require a MIL-Spec cable.

1-6. The typical coaxial cable construction is similar, but the materials that make up the jacket and dielectric core varies depending on application. An insulating material from the surrounding shield separates the inner conductor of a coaxial cable. This dielectric material maintains consistent electrical properties and minimizes signal loss. The result is a clear, trouble free transmission. See figure 1-7.

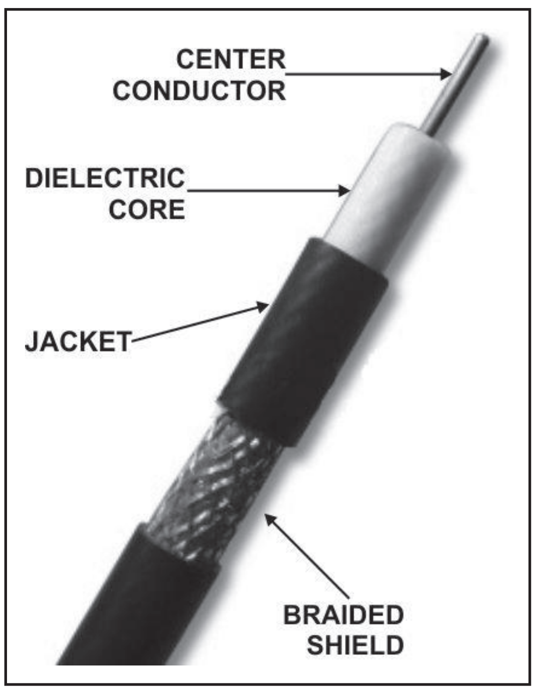

Figure 1-7. Coaxial cable

1-7. The use of coaxial cable is extensive with Army high frequency (HF) radio, satellite and microwave communication systems. Some government-off the shelf (GOTS) and commercial off- the shelf (COTS) ancillary devices that have non-return-to-zero interfaces, multiplexers and modulator-demodulator (modems) are part of systems such as the baseband shelters and Warfighter information network-tactical.

CABLE CONNECTORS

1-8. Army communication systems have special cable interfacing connections. These connections have become the standard for most signal entry panels found on the shelters that house the equipment. The following cable assemblies have connectors that provide a strong physical and locked interface with the signal entry panels.

1-9. There are many different connectors used with UTP and STP. Characterization of these connectors are by the pinout of the connector as well as the construction and size.

Modular Jack

1-10. Modular connector is the name given to a family of electrical connectors originally used in telephone wiring and now in use for many other purposes. Probably the most notable applications of modular connectors are for telephone jacks and Ethernet jacks, both of which are nearly always modular connectors.

1-11. The original use of the modular connectors were with the registered jack system, which precisely describes how to wire connectors for telecommunications. The registered jack (RJ) specifications define the wiring patterns of the jacks, not the physical dimensions or geometry of the connectors of either gender. Instead, ISO standard 8877 covers these latter aspects, first used in integrated services for digital network (ISDN) systems. TIA/EIA-568 is a standard for data circuits wired on modular connectors.

1-12. All registered jacks contain a number of potential contact positions and the actual number of contacts installed within these positions. RJ11, RJ14, and RJ25 all use the same six-position modular connector, thus are physically identical except for the different number of contacts (two, four and six respectively) allowing connections for 1, 2 or 3 phone lines respectively.

1-13. Cables sold as RJ11 often use 6P4C (six position, four conductor) RJ14 connectors, with four wires running to a central junction box. Two of its six possible contact positions connect tip and ring, and the other two conductors are then unused. 6P2C (six position, two conductor) and 6P6C (six position, six conductor) are also be found in stores.

1-14. The conductors other than the two central tip and ring conductors are in use for various things such as a second or third phone line, a ground for selective ringers, or low voltage power for a dial light.

Registered Jack

1-15. RJ is a standardized physical interface for connecting telecommunications equipment (commonly, a telephone jack) or computer networking equipment. The standard designs for these connectors and their wiring are RJ11 and RJ14, which uses a 6P2C modular plug and jack.

1-16. RJ-11 is a four or six wire connector used primarily to connect telephone equipment in the United States and to connect some types of LANs. Phone cable generally contains two pairs of wires, for two phone lines. The first pair is green and red and the second is black and yellow. An excellent “association method” to remember this is to consider two holidays-Christmas and Halloween. This set of colors for stranded wire (house wire) is standardized.

1-17. The wiring for the plug side of a RJ11 connector using stranded cable is as follows from left to right: place the black conductor in the far left slot; next is the red conductor, followed by the green conductor and last is the yellow conductor. For solid wires, the installation of cable to the RJ-11 is pair and pair two.

1-18. Install UTP cable using an RJ45 connector (see figure 1-8 on page 1-15). The RJ45 is an eight-wire connector used commonly to connect computers onto a local area network, especially Ethernets. UTP cable is more prone to electrical noise and interference than other types of networking media. The distance between signal boosts is shorter for UTP than it is for coaxial and fiber optic cables.

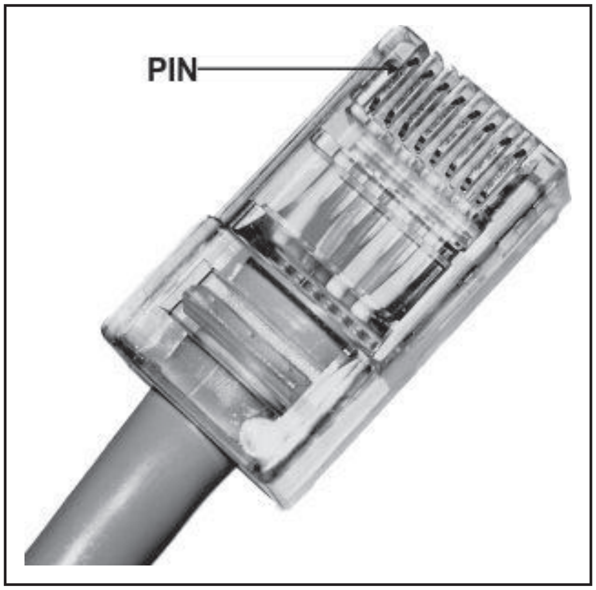

Figure 1-8. RJ45 connector

1-19. The RJ45 requires four pairs of wires. Each pair consists of a solid colored wire and a white wire with a stripe of the same color. The pairs are twisted together to maintain reliability in the cable. You should not twist the wire any more than 1cm.

1-20. While used for a variety of purposes, the most common use of RJ45 connector is for 10Base-T and 100Base-TX Ethernet connections. UTP has only two pairs of wires in the eight-pin RJ45 connector used to carry Ethernet signals. Both 10Base-T and 100Base-TX use the same pins, in which a crossover cable made for one also works with the other.

ANSI TIA/EIA T568

1-21. ANSI TIA/EIA T568 is the cable connection standard used for the majority of Ethernet cables and is one of the two most widely used standards. Wire the both ends of the cable using either the T568A or T568B standards. The standards differ in color sequence in pin positions 1, 2, 3 and 6.

Straight-Through Cable Configuration

1-22. When using a straight-through cable configuration, one of the two units must perform a crossover function. Figure 1-9 on page 1-16 is an example of a straight-through cable. The following connections typically require a straight-through cable connection—

- Computer to residential (gateway/router).
- Computer to normal port (hub/switch).
- Access point to normal port (hub/switch).
- Print server to normal port (hub/switch).
- Uplink port to normal port (hub/switch).

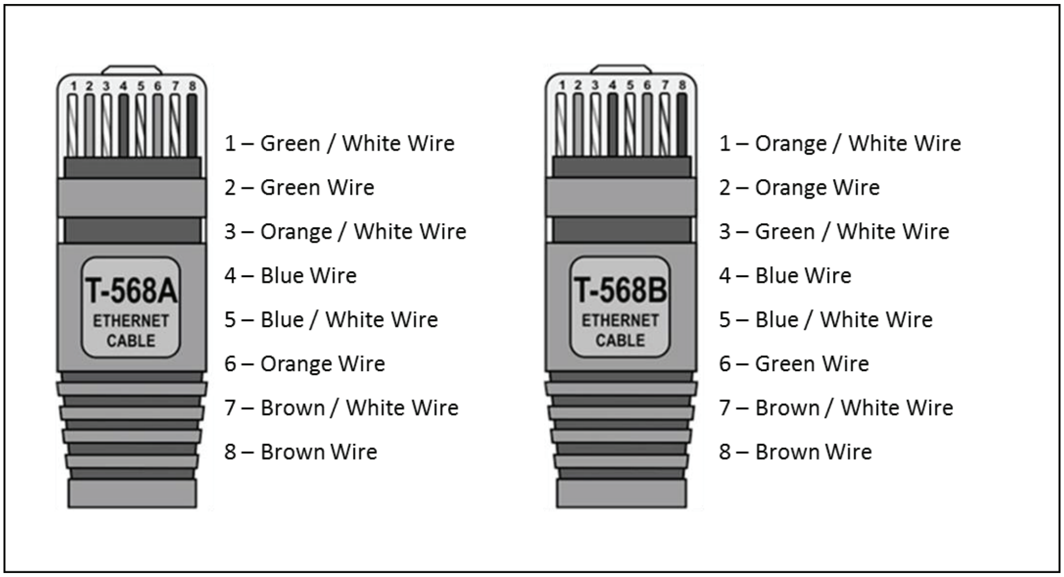

Figure 1-9. Straight-through cables

Crossover Cable Configuration

1-23. A crossover cable configuration consists of the same color code assignment as T568B except for pin numbers 1, 2, 3 and 6. The T568A color code is on one end and T568B is on the other. Use the crossover cable to connect two identical mediums together or two computers together as seen in figure 1-10, on page 1-17. The following connections typically require a crossover cable—

- Computer to computer.
- Computer to uplink port.
- Computer to print server.
- Uplink port to uplink port (hub/switch).
- Normal port to normal port (hub/switch).

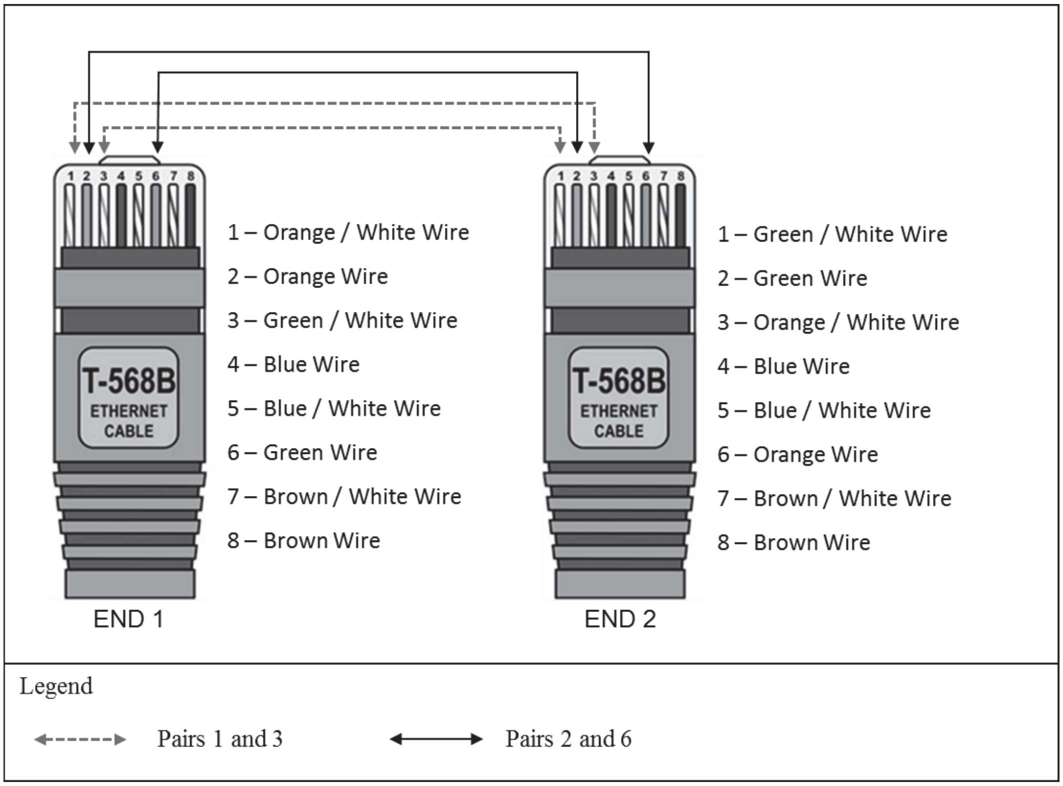

Figure 1-10. Crossover cable/T568B

Coaxial Cable Connectors

1-24. The identifying properties of coaxial connectors are either male (plugs) which have a center conductor probe or female (jacks) which have a center conductor receptacle. There is a variety of connectors to use for RF applications. Impedance, frequency range, power handling, physical size and a number of other parameters determine the best type for a given application. Figure 1-11 depicts the most common type of connector.

Figure 1-11. Coaxial connectors

1-25. Inner Conductor: Center conductors may be solid or stranded wire, or in some cases, a tube. Base the selection on the mechanical and electrical properties desired. Solid wires result in lowest cable attenuation. Stranding permits increased cable flexibility but also increases attenuation. Often, the use of bare, tinned, or silver plated copper wire is for center conductors. Other materials are copper weld, cadmium bronze, aluminum, nichrome, and karma.

1-26. Insulation: A common choice is a solid polyethylene insulator. Lower-loss cables use a polyethylene foam insulator. Also, use Solid Teflon as an insulator. Some coaxial lines use air (or some other gas) and have spacers to keep the inner conductor from touching the shield.

1-27. Outer Conductor**:** insulation and sheathing. The outer shield is earthed (grounded) and protects the inner shield from electromagnetic interference from outside sources.

1-28. De-energize the circuit under test before connecting the apparatus. Accomplish this by disconnecting both ends of the tested wire before connecting the continuity tester. This prevents false indications on the test set and prevent the possibility of damage to the test set.

Chapter 2

Fiber Optic Cable

This chapter provides an in-depth discussion on fiber optic cable. It discusses the theory of light wave communications and a comprehensive description of fiber optic cable, to include its characteristics and applications. This chapter also covers fiber optic cable connectors used for various tactical and non-tactical applications. Discussion on the use of equipment used for splicing, testing, and troubleshooting fiber optic cable (fiber splicing) is also covered.

THEORY OF LIGHTWAVE COMMUNICATIONS

2-1. Fiber Optic is the technique of transmitting information through thin, flexible glass or plastic fibers using light waves. The most common use of fiber optics is as a transmission line connecting two electronic devices or circuits. There are seven Advantages to using fiber optic: bandwidth, low attenuation, electromagnetic immunity, weight, size, security and safety. The four components of fiber optic communications are—

- A transmitter that converts electrical signal to optical signal.
- Optical fiber is the transmission medium for carrying the light.
- A receiver converts the light back into electrical signals.
- Connectors connect the fiber to the transmitter and receiver.

NATURE OF LIGHT

2-2. Light travels at a specific speed. The speed of light is the velocity of electromagnetic energy in free space. The speed of light is equal to 186,000 miles per second or 300,000 kilometers per second. Light travels almost the same speed in clear air as it does in space. It takes about one thousandth of a second for a light flash twenty miles away to reach the eyes.

2-3. Light travels slower in other media. The speed of light through glass is about 124,000 miles per second. In water, its speed is about 140,000 miles per second. Different light wavelengths (colors) travel at different speeds in the same media.

THE ELECTROMAGNETIC SPECTRUM

2-4. The electromagnetic spectrum consists of the entire range of radiation from 0 to 1023 hertz (frequency), or from 10-13 centimeters to infinity (wavelength). Light is electromagnetic radiation, because an electric and magnetic field accompanies photons. Many other types of electromagnetic radiation differ from light by frequency and wavelength. Microwaves and radio waves have lower frequencies and longer wavelengths than light. Gamma rays and x-rays have higher frequencies and shorter wavelengths than light. See figure 2-1, on page 2-2. For more information regarding the electromagnetic spectrum and spectrum management operations see ATP 6-02.70.

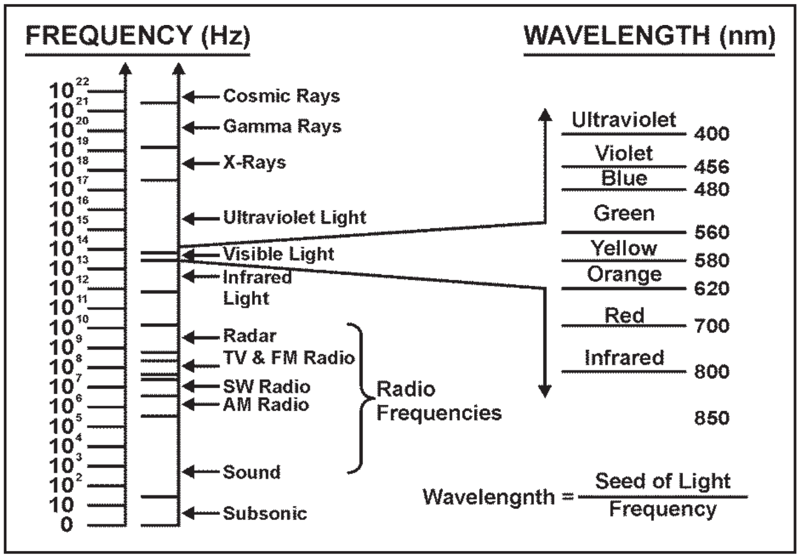

Figure 2-1. Electromagnetic spectrum

2-5. Optical radiation lies between microwaves and x-rays. It includes all wavelengths between 10 nanometers (nm) and 1 millimeter (mm). It includes ultraviolet, visible light, and infrared radiation. The visible spectrum is only a tiny piece of the electromagnetic spectrum. Fiber optic communications operate in the near infrared, at wavelengths just beyond the red fringe of the visible spectrum.

2-6. Optical fibers have three low loss windows in the near infrared at wavelengths of 850, 1300, and 1550 nm. This is part of the reason that fiber optic communication links have the potential for carrying vast amounts of information compared to the fastest wire or radio systems.

REFLECTION

2-7. There are two types of reflection: regular and diffuse. Regular reflection occurs when the surface is smooth and polished. Reflection of light is in one direction. Diffuse reflection occurs when the surface has irregularities or is rough in comparison to the wavelength of light. Reflection of light is in many directions.

REFRACTION

2-8. When light passes from one medium to another, it changes speed, which causes a deflection of the light. *Refraction* is the bending of light. A light ray refracts at the boundary between two media because the wavelength changes and the wave crests must match at the boundary. Deflection may also occur in a single medium of varying density.

2-9. White light is really a mixture of all the different colors. Each color contains a light wave of a different length. These divided light waves are the colors red, orange, yellow, green, blue and violet. A prism demonstrates this principle: White light entering a prism is composed of all colors. The prism refracts the light. Because each wavelength changes speed differently, each wavelength refracts differently. The light emerges from the prism divided into the colors of the visible spectrum. See figure 2-2, on page 2-3.

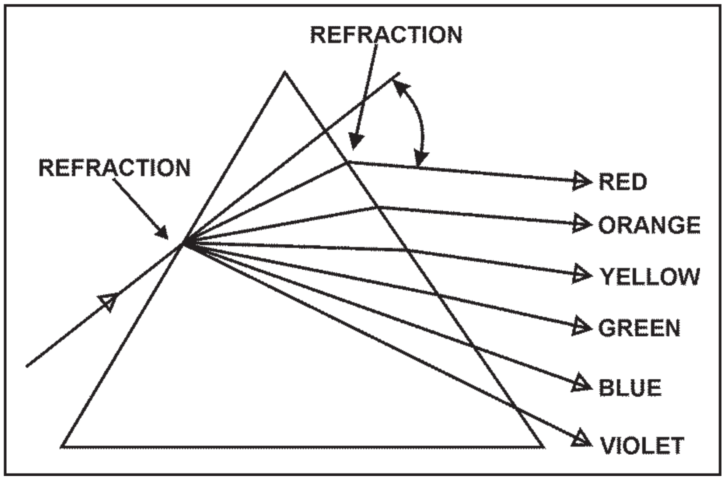

Figure 2-2. Refraction of light through a prism

2-10. In fiber optics, refraction defines the angle that light strikes the interface between two media, and the angle by which it refracts.

FIBER OPTIC CABLES

2-11. Fiber optic cables contain optical fibers (known as the core) that are long, thin strands (about the diameter of a human hair) of very pure plastic clad silica, glass or both. See figure 2-3. Arrangement of the core is in bundles called optical cables, allowing transmission of light signals over long distances. The performance standards for optical fiber fall under the ANSI-TIA-EIA-568-B.3. Fiber optic comes in three types: single-mode step index, multimode step index and multimode graded index. Single-mode fiber optic cable has a small core and only one pathway of light. Single-mode aligns the light toward the center of the core instead of simply bouncing it off the edge of the core as with multimode. Fiber optic cable is highly used with the Warfighter Information Network-Tactical (WIN-T), providing connectivity between various networking assemblages (Joint Network Nodes, Command Post Nodes, and Tactical Hub Nodes) and transport assemblages (High Capacity Line of Sight and Satellite Transport Terminals). See ATP 6-02.60 for more information on various uses of fiber optic cable with WIN-T.

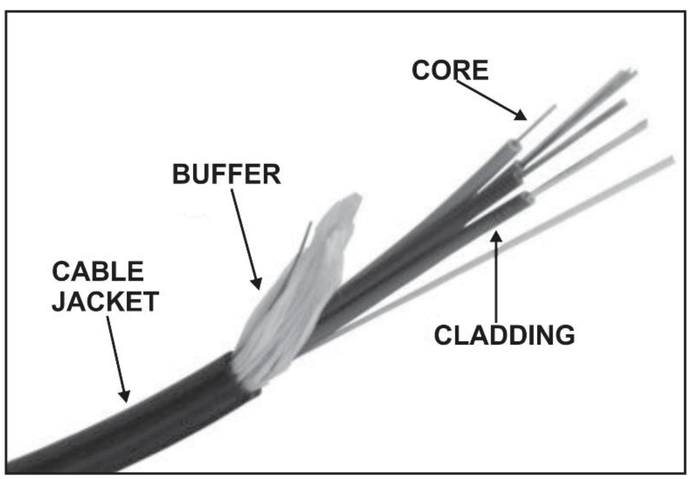

Figure 2-3. Fiber optic cable

2-12. The optical fiber works on the principle of total internal reflection. Once light begins to reflect down the fiber, it will continue to do so. The fiber contains two layers of glass (or plastic), one layer surrounding the other. The inner layer, the core, has a higher refractive index than the outer layer, the cladding. Light injected into the core and striking the core-to-cladding interface at greater than the critical angle reflects back into the core. Since the angles of incidence and reflection are equal, the reflected ray repeatedly strikes the interface at the same angle and then reflected. The ray continues reflecting down the length of the fiber.

FIBER OPTIC CABLE CONSTRUCTION

2-13. A typical optical fiber consists of three parts—

- Core.
- Cladding.
- Buffer.

2-14. The Core provides the optical transmission path. The core will always have a higher refractive index than the cladding. The diameter or the core may range from a few micrometers (µm), 2 to 12 µm for single-mode glass fibers, up to several hundred µm or more for multimode plastic fibers.

2-15. The Cladding surrounds the core and provides the reflective surface that allows light to propagate along the core to the distant end. Cladding consists of a solid section of transparent glass or plastic less dense than the core. Most common diameter for glass fiber cladding is 125 µm but can be over several hundred µm in diameter.

2-16. The relationship between the core and the cladding is important. Where the core meets, the cladding must be very smooth to achieve regular reflection, which prevents light from scattering. To minimize signal loss the core must be denser, and thus have a higher refractive index, than the cladding.

2-17. The Buffer, also called the coating, adds strength to the fiber cable. Mechanical strength of the fiber depends on the fiber material and the buffer coating.

2-18. A thin layer of acrylic usually coats fibers that is approximately 250 µm in diameter. Acrylic coating provides limited protection and color-coding. The cable manufacturer adds an additional buffer known as the *secondary buffer* to add strength and protection during installation and in operational environments.

2-19. There are two major types of buffering designs—

- Tight Tube.
- Loose Tube.

2-20. Tight Tube buffer is a soft plastic coating on the fiber. It provides better crush and impact resistance. In most cases, install a cable with tight tube buffer indoors.

2-21. Loose Tube buffer consists of one or more fibers in a hard plastic tube. The inside diameter of loose tube buffers are several times larger than the individual fibers. This allows the fibers to coil loosely in the tube. The tube sometimes has moisture-resistant compound installed. This construction allows cable to be pulled, twisted, and otherwise stressed with little strain on the fibers, which suits well for outdoor installation.

2-22. Additionally, fiber optic cables can have strength members that increase the tensile strength in fiber optic cables. All cables have at least one strength member; most cables have several. The strength member may consist of plastic or multi-filament strands of steel, copper, fiberglass and Kevlar. The strength member may be located in the center of the cable, around the fiber or parallel to the fiber.

2-23. The outer jacket of a fiber cable provides chemical resistance and abrasion protection for the cable. Common materials include polyethylene, polyurethane and polyvinyl chloride. Environmental conditions will mainly determine the types of outer jacket.

NUMERICAL APERTURE

2-24. The numerical aperture (NA) is the light-gathering ability of the fiber. It is advantageous for a fiber to accept and propagate as much light as possible. Because reflection can only occur when light strikes the cladding at an angle greater than the critical angle, we can form a cone, known as the acceptance cone, which defines which light reflects and which will not. Light injected at angles accepted by the acceptance cone will reflect; rays not meeting the acceptance cone specifications will not.

SINGLE-MODE STEP INDEX FIBER

2-25. Use single-mode fiber optic cable for high-speed transmissions over long distances. This allows a higher capacity to transmit information, because it preserves the light pulse over longer distances without the scattering caused by multiple modes, and it provides greater bandwidth than multimode. The typical single mode fiber has a core diameter of only 10um or less and a cladding diameter of 125um. Its smaller core, however, makes it more difficult to couple the light source, making the tolerances for single-mode connectors and splices also much more demanding. Figure 2-4 depicts the light refraction within a single-mode fiber strand.

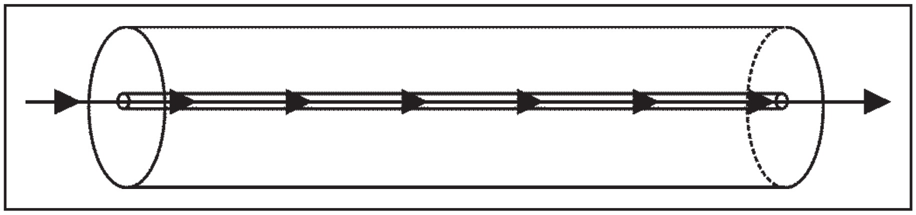

Figure 2-4. Single-mode fiber

MULTIMODE STEP INDEX FIBER

2-26. Multimode step index fiber is optical fiber designed to carry multiple light rays concurrently, each at a slightly different reflection angle within the optical fiber core. The core diameter can be anywhere from 50um to over 900um, which allows many modes of propagation. The light entering the fiber reflects at different angles using different paths. *Modal dispersion* is the spreading of light. This modal dispersion is the main limiting factor in the fibers operating speed or bandwidth. Generally, a larger core increases the dispersion, since it allows more paths for the light. Multimode step index fibers are more useful for carrying larger amounts of power very short distances than single-mode fibers. Figure 2-5 depicts the light refraction within a multimode fiber strand.

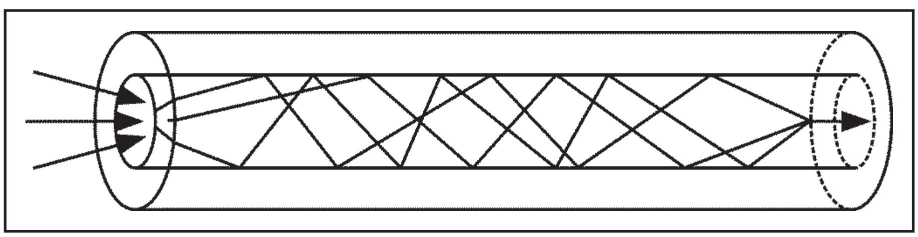

Figure 2-5. Multimode step index fiber

Note. The modal dispersion characteristics of the multimode step index fiber limits the speed signals can be sent through which constrains the bandwidth thus making it the least efficient.

MULTIMODE GRADED INDEX FIBER

2-27. The multimode graded index fiber has numerous concentric layers of glass that make up the core making the refractive properties the same throughout the cable. These properties causes light to travel faster as it continuously bends (refracts), unlike sharp reflection in the step index fiber. Modal dispersion, though still present, is much lower thus providing a higher bandwidth. Multimode graded index fiber, typically, has a core of 50 to 100 um and a cladding diameter of up to 140 um. The multimode graded index fiber has become very popular because of these properties. See figure 2-6 on page 2-6 for a depiction of light refraction properties.

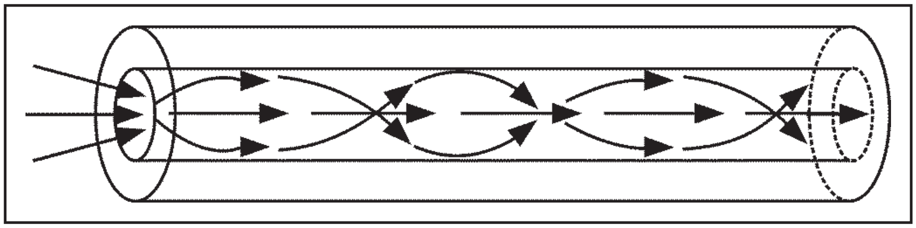

Figure 2-6. Multimode graded index fiber

FIBER OPTIC CABLE APPLICATIONS

2-28. From long haul telecommunications to WANs and LANs, fiber optic cables have many uses. Since the introduction of fiber optic cables and the many types of services associated with its properties to include multimedia services, video conferencing, videophone technology, and gigabyte Ethernet, they are rapidly replacing the older bulkier copper cable.

2-29. Though fiber optic cables are expensive to deploy, the advantages it holds outweigh its cost. These advantages include—providing an exponential amount of bandwidth, its low attenuation characteristics, having electromagnetic immunity, its small size and weight, providing a secure means for transmitting voice and data, and its nonconductive properties.

BANDWIDTH

2-30. Fiber optic cables can support bandwidths in the terahertz—trillions of hertz. The actual bandwidth of a fiber depends on the specific structure of the fiber and on the light transmitted through it. Optical multiplexing techniques using single mode fibers can produce an endless amount of practical bandwidth. Current technology has yet to find a way or the ability to exploit it. The high bandwidth not only makes fiber optic cable the preferred replacement for coaxial cable in long-haul transmission, it makes it a practical alternative to microwave and satellite communications.

LOW ATTENUATION

2-31. Signal transmission is attenuated (loses power) as it travels from one point to another, whether the transmission medium is through wire, space, or fiber optic cable. Fiber optic cables, however, provides lower attenuation than copper cables, especially at high frequencies. Unlike copper cables, attenuation is independent of the modulation speed in fibers. Increased signal speed does not mean increased attenuation. Attenuation ranges from 0.2 dB to 5 dB per kilometer for glass. The practical benefit of low attenuation is to permit long transmission distances without repeaters to amplify and reshape the signal. General transmission distances are 2 to 4 km for Light-Emitting Diode-based systems and 25 to 80 km for laser-based systems, although the use of optical amplifiers are applied to extend signal transmission upward to hundreds of kilometers.

ELECTROMAGNETIC IMMUNITY

2-32. Electromagnetic interference is unwanted energy given off by equipment. Wires, which can act like transmitting and receiving antennas, can be a main source of EMI. Because it is a dielectric, ordinary electromagnetic fields does not affect fiber optic cable. There is no inductive or capacitive coupling and no crosstalk. Given these properties, installation fiber optic cables in electrically noisy environments is a viable option and can be ran in the same conduit as power cables. You can also apply fiber optic cable without concern over ground loops. Electromagnetic interference immunity increases reliability by providing excellent bit-error rates without costly error-checking routines.

SMALL SIZE

2-33. Fiber optic cables are much smaller than copper cables. This advantage makes it easier to deploy in areas where space is at a premium such as overcrowded telephone conduits running under city streets or ducts under computer room floors. A single fiber has the same capacity as a 900 pair copper cable that is 27 times thicker than the fiber optic cable. In addition, the high bandwidth of each fiber means you may need fewer cables or conductors to carry very high data rates.

LIGHTWEIGHT

2-34. Glass weighs less than copper. A two-fiber cable, for example, is 20% to 50% lighter than a comparable four-pair CAT 5 cable. Weight savings can be significant, especially because the bandwidth and low dB loss of fibers allows a single fiber to replace many copper cables. Such savings can be especially beneficial in applications such as aircraft and cars.

SECURITY

2-35. Fiber optic cables are quite difficult to tap. Emissions from fiber optic cables do not radiate electromagnetic energy and incapable of being intercepted. Physically tapping the fiber takes great skill to go undetected. Thus, the fiber is the most secure medium available for carrying sensitive data.

SAFETY

2-36. The dielectric properties of fiber isolate it electrically. Use fiber optic cable in flammable environments and other hazardous applications where electrical codes and common sense prohibit the use of copper cables since it presents no spark hazard. Fiber does not attract or conduct lightning.

CX-13295/G TACTICAL FIBER OPTIC CABLE ASSEMBLY

2-37. The Tactical Fiber Optic Cable Assembly (TFOCA), figure 2-7, is extremely strong, lightweight, rugged, and tactically superior fiber optic cable that replaces existing CX-11230 coaxial cable. The design specifications of TFOCA allows its use for military tactical field and commercial applications. The TFOCA provides the physical connection between the fiber optic modem, repeaters or other equipment capable of electronic to optical conversion at each shelter assembly during operations. The fiber optic modem converts processed signals (mission traffic) from the interface equipment into an optical signal. The TFOCA transmits the multiplexed optical signal that contains high-speed digital data and maintenance order-wire signals. The fiber optic modem converts optical signals back into electrical signals at the far end shelter assemblies.

Figure 2-7. Tactical fiber optic cable

2-38. Manufacturers designed and developed TFOCA connectors for the world’s leading organizations in the Department of Defense, and industrial high reliability market segments. TFOCA connector systems, cable assemblies, harnesses, kits and specialty products is used throughout the world in some of the most critical applications. Various applications include—down-hole oil exploration platforms; Navy tactical battle systems; secure data lines for the United States Navy; water purification systems; and performance automotive.

2-39. The TFOCA comes in two lengths (300M and 1000M) and operates up to lengths of 8 kilometers (5 miles) with no repeaters and 45 kilometers (28 miles) with five repeaters. It is a glass fiber tube jacketed in polyurethane with connectors. The fiber wrapping and a plastic sheath protect the tubes. The tube terminates in a universal connector at each end. The TFOCA can be installed as the CX-11230(*)/G cable line. Some deviations exist because of the bending limitations of TFOCAs. Refer to Technical Manual (TM) 11-6020-200-10 Operator`s Manual for Fiber Optic Cable Assemblies CX-13295/G (300M) (NS) for more information.

FIBER OPTIC CABLE CONNECTORS

2-40. The fiber optic connector is a mechanical device mounted on the end of a fiber optic cable mating the cable to an information bearing light source. The connector directs and collects the light so the mating must be precise yet it can easily attach and detach from equipment. There are many connector types and they vary depending on the application. The following paragraphs discusses the more popular and widely used connectors.

FIX CONNECTORS

2-41. Single-mode and multimode fiber-optic cables use a fix connector (FC). FCs offer extremely precise positioning of the fiber-optic cable with respect to the transmitter's optical source emitter and the receiver's optical detector. FCs feature a position locatable notch and a threaded receptacle. FCs have metal housing and are nickel-plated construction. They have ceramic ferrules for 500 mating cycles rating. The insertion loss for matched Fix connectors is 0.25 dB. From a design perspective, recommendation to use a loss margin of 0.5 dB or the vendor recommendation for FCs. See figure 2-8 for an example of an FC connector.

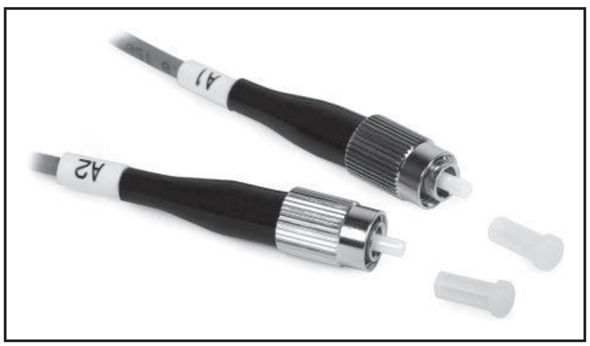

Figure 2-8. Fix connector

SUBSCRIBER CONNECTORS

2-42. Use a subscriber connector (SC) with single-mode and multimode fiber-optic cables. They offer low cost, simplicity, and durability. SCs provide for accurate alignment via their ceramic ferrules. SC connector is a push-on, pull-off connector with a locking tab. Typical matched SCs are rated for 1000 mating cycles and have an insertion loss of 0.25 dB. From a design perspective, recommendation to use a loss margin of 0.5 dB or the vendor recommendation for SCs. See figure 2-9 on page 2-9 for an example of a SC.

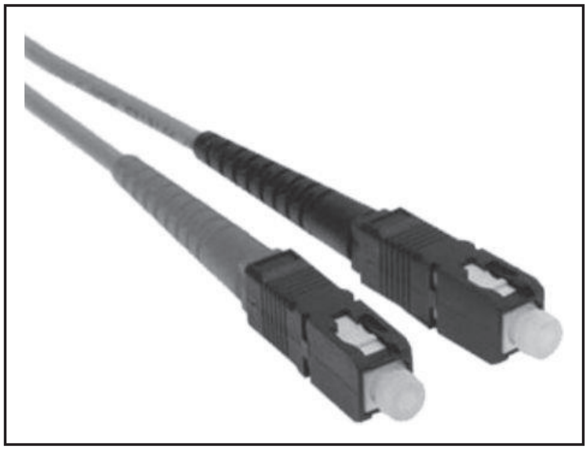

Figure 2-9. Subscriber connector

STRAIGHT TIP CONNECTORS

2-43. The straight tip (ST) connector is a keyed bayonet connector and used for both multimode and single-mode fiber-optic cables. It allows quick removal and insertion from a fiber optic cable. Method of location is also easy. ST connectors come in two versions: ST connector and ST connector -II. These are keyed and spring-loaded, push-in and twist types. STs Connectors have a metal housing and are nickel-plated construction. They have ceramic ferrules rated for 500 mating cycles. The typical insertion loss for matched straight tip connectors is 0.25 dB. From a design perspective, recommendation to use a loss margin of 0.5 dB or the vendor recommendation for ST connectors. See figure 2-10 for an example of a straight tip connector.

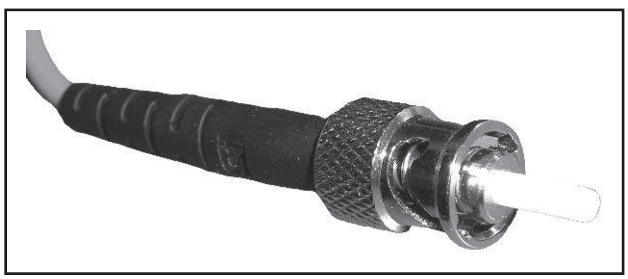

Figure 2-10. Straight tip connector

LITTLE CONNECTORS

2-44. Use a little connector (LC) with single-mode fiber-optic (SMF) and multimode fiber-optic (MMF) cables. LCs have a plastic housing construction that allows accurate alignment via their ceramic ferrules. LCs have a locking tab that has a 500 mating cycles rating. The typical insertion loss for matched LCs is 0.25 dB. From a design perspective, recommendation to use a loss margin of 0.5 dB or the vendor recommendation for LCs. See figure 2-11 on page 2-10 for an example of the little connector.

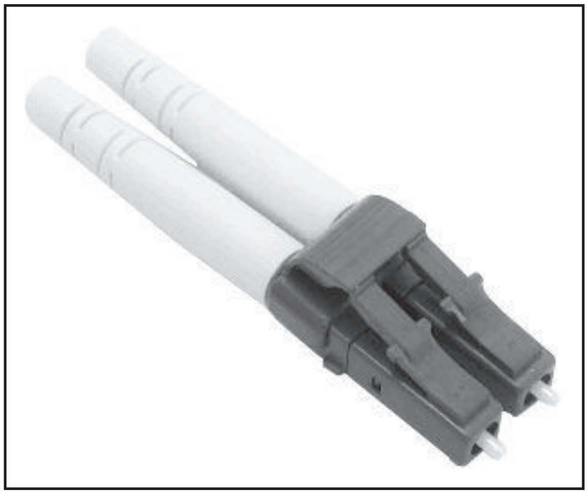

Figure 2-11. Little connector

MECHANICAL TRANSFER REGISTERED JACK CONNECTORS

2-45. Use a mechanical transfer-registered jack (MT-RJ) connector with single-mode and multimode fiber-optic cables. MT-RJ connectors a plastic housing construction and provide for accurate alignment via their metal guide pins and plastic ferrules. MT-RJ connectors have a 1000 mating cycles rating and the typical insertion loss for matched connectors is 0.25 dB for SMF and 0.35 dB for MMF. From a design perspective, recommendation to use a loss margin of 0.5 dB or the vendor recommendation for MT-RJ connectors. Figure 2-12, is an example of the MT-RJ connector.

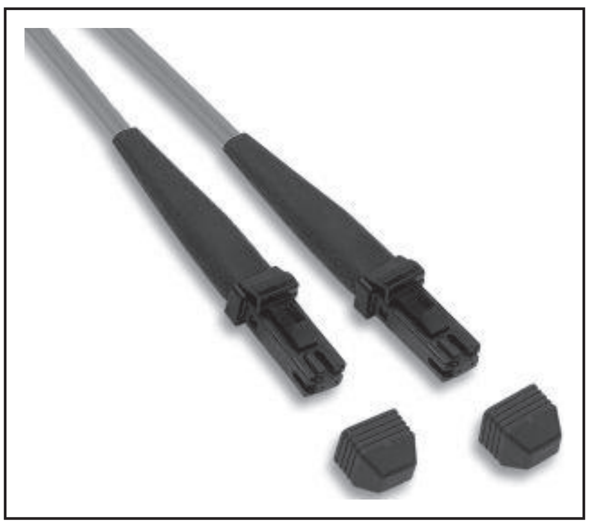

Figure 2-12. Mechanical transfer-registered jack connector

FIBER DISTRIBUTED DATA INTERFACE CONNECTORS

2-46. The fiber distributed data interface (FDDI) connector is a two-channel device using two ferrules and a side-latch mechanism. A rigid shroud protects the ferrules from accidental damage, while a floating interface ensures consistent mating without stubbing. Provided are different keying arrangements to key the connector to different fiber distributed data interface requirements. Fiber distributed data interface connectors are not restricted in their applications. The fiber distributed data interface has a push-pull design for easy connect and disconnect. It is a duplex connector with 2.5mm ferrule. Figure 2-13 on page 2-11 depicts the fiber distributed data interface connector.

Figure 2-13. Fiber distributed data interface connector

BICONIC CONNECTORS

2-47. The biconic connector is a high performance fiber optic connector that incorporates precision molding techniques to yield fractional dB insertion loss. These connectors are used for cable-to-cable, or cable-to-equipment single fiber connections, and can be installed on interconnect cable, buffered or unbuffered fiber.

2-48. The connector's loss per mated junction typically averages 0.5 dB with a maximum of 1.0 dB. Return loss of 30dB is more than adequate to meet the requirements for high bit rate single-mode transmission. Plugging and re-plugging is simple and some common applications include local area and premises networks, data processing systems, medical instrumentation, remote sensing, telemetry, and cable television. Figure 2-14 depicts the biconic connector.

Figure 2-14. Biconic connector

SUB-MINIATURE VERSION A CONNECTORS

2-49. The sub-miniature version A (SMA) uses a threaded plug and socket. It was the first connector for optical fibers to be standardized. In addition to their compact size, SMA connector has exceptional mechanical durability and holds only a single fiber. SMA connectors have a threaded coupling nut; the ferrule is traditionally made of steel, although ceramic versions are available. SMA connectors come in two varieties: the SMA -905 has a straight ferrule, whereas the SMA -906 has a stepped ferrule design. The 905 is a non-contact connector typically used in medical, industrial, and military applications. When mating two S SMA 906 together, the stepped ferrule design allows the use of an alignment sleeve and therefore the connection has lower insertion loss. The 905 does not have an alignment sleeve therefore; the insertion loss of the 905 is higher than that of the 906. See figure 2-15 on page 2-12.

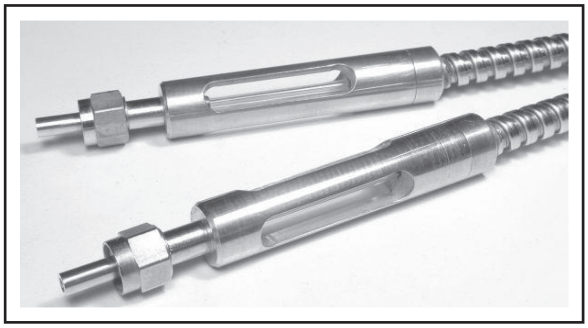

Figure 2-15. Sub-miniature version "A" connector

ESCON CONNECTORS

2-50. The enterprise systems connection (ESCON) connector, used in the International Business Machine (IBM) enterprise system controller, is similar to the fiber distributed data interface connector, but features a retractable shroud. See figure 2-16.

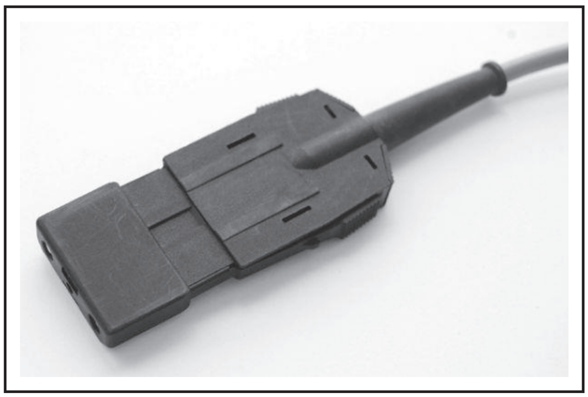

Figure 2-16. Enterprise systems connection connector

2-51. ESCON architecture is an interconnection design developed by IBM (and covered by several IBM patents) for various processors and devices such as switching units, converters, tape subsystems, storage control units, and other I/O devices.

2-52. ESCON architecture employs a new high-speed I/O protocol, a switched point-to-point topology, and a data rate of up to 17 MB/sec that combine to reduce the cost and complexity of connecting and sharing multiple devices.

TERMINATION TECHNIQUES

2-53. Follow the manufacturer's instructions when terminating connectors. If the instructions are not included in the package, contact the manufacturer. A generic assembly procedure assembles most connectors, but some require special attention to unique pieces or assembly steps.

2-54. Use of multimode connectors is common in field locations to terminate cable runs after pulling and to make jumpers for inter-rack connections. Multimode connectors normally have with losses of 0.5 dB or less.

2-55. Install single-mode connectors by splicing a factory made pigtail onto the fiber. The best choice is to obtain single-mode jumpers pre-made from the factory. Single-mode connectors and jumpers made in field locations often results in difficulty getting low-loss connections. This is because the tolerances on single-mode connectors are much tighter, and the polishing processes much more critical. It is difficult to make a single-mode connector with loss less than 1 dB.

Epoxy Mixes

2-56. There are many epoxy mixes available for bonding the fiber to the ferrule. Most require mixing two separate liquids or gels, then using a syringe to insert the mix into the connector body. Extrude the epoxy from the ferrule tip to form a bead to help protect the fiber tip. In addition, use epoxy to the Kevlar strands to help bond the cable to the connector. Epoxy mixes require a lengthy curing time if air cured, from 6-8 hours to overnight. More often, using a curing oven shortens the time to around 8-15 minutes for curing.

Hot Melt

2-57. This is a 3M trade name for a connector that already has the epoxy inside the connector. Prepare the cable, heat the connector in a special oven, and insert the fiber and let it cool. Use hot melts several times prior to disposal.

Crimp

2-58. These connectors use a crimp on the fiber to hold it in instead of using any epoxy. Very quick, but easy to crush the fiber. They usually cost much more. Two examples of this type of connector are the LC Crimp-on and the Crimplok.

Anaerobic

2-59. These connectors use a quick setting glue/epoxy mix with a curing agent (accelerator) mix. Once you spray the curing agent, you must work fast. A popular example of this type is the fast cure connectors, which comes in straight tip, sub connector, and fixed connector configurations.

Mechanical

2-60. Mechanical connectors' assembly does not require use of glue or epoxy mix. They also use no crimp; the assembly technique holds them together.

2-61. These connectors have a short fiber stub already epoxied into the ferrule and polished. A popular example of this type is the unicam. Cleave a fiber and insert it like a splice. It is very costly, and you must make a good cleave to get low loss. Even then, the loss will probably be higher than other connector types. This is because for each connector, there is connector and splice loss. A jumper results in two connectors and two splices adding to your loss.

POLISHING

2-62. Connectors must be polished for the following reasons:

- To remove any excess fiber protruding from the connector face.
- To remove excess epoxy from connector face.
- To provide a smooth surface for mating to adapters and bulkheads.
- To minimize loss from reflection and refraction. A smooth, mirror like finish on the connector face will allow the greatest quantity of light to pass to the connecting device.

2-63. As in termination, there are many techniques for polishing. Once again, follow the manufacturers' technique for the particular connector you are working with.

2-64. Inspect after the end is polished. Make sure connector end is free of scratches, chips, cracks, rough surfaces, dirt or debris or broken fibers. See figure 2-17 on page 2-14.

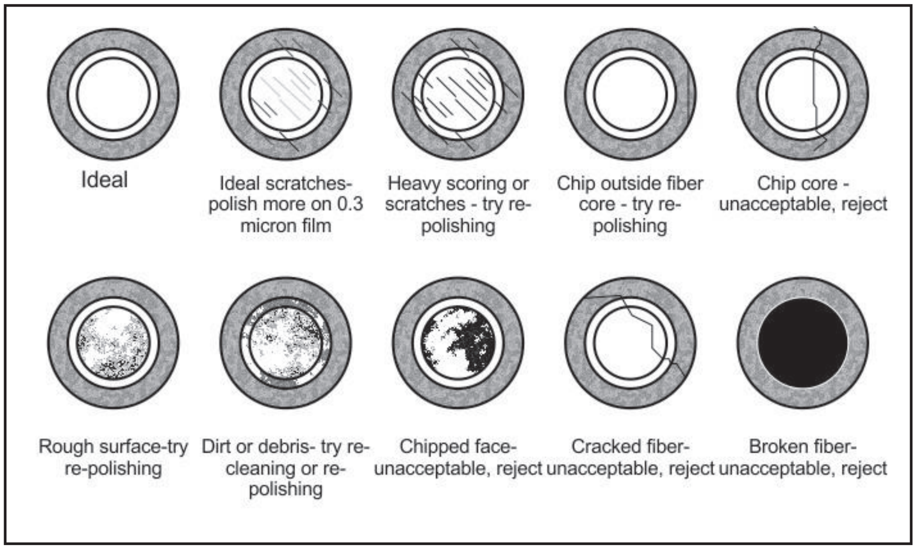

Figure 2-17. Fiber connector inspection

FIBER OPTIC SPLICING

2-65. Joining lengths of optical fiber is more complex than joining electrical wire or cable. Carefully cleave and splice the ends of the fibers together. Do this by either mechanically or by fusing them with heat.

FIBER OPTIC SPLICING EQUIPMENT

2-66. In fiber optic splicing, the right tools and materials are critical in accomplishing the task the proper way the first time. The cable knife is used to remove the sheath, the cable cleaner is used to remove the water resistant compound on the exposed fiber of a filled cable, the jacket stripper is used to remove the 3mm jacket or loose-tube buffer when splicing. There are two cleaving tools for fiber optic splicing, AT& T fitel CL-310-V1 cleaver and a precision fiber optic cleaving tool. The AT&T fitel CL-310-V1 cleaves silica fibers of 125-140 micrometer, cleave a fiber to a length measuring 2mm to 20mm (bare fiber) and it is used with 250 up to 900 micrometer buffered fibers. The precision fiber optic cleaving tool cleaves silica fibers to a length measuring from 5mm up to 20mm with 250 micrometer buffered fibers up to 900 micrometer buffered fibers.

2-67. The proper materials to use when splicing fiber optic are isopropyl alcohol and canned air. Use isopropyl alcohol with soft, lint-free cloth or tissue to clean bare fibers after buffer removal. Canned air is microscopically pure gas that removes grit and dust without scratching sensitive surfaces and used for cleaning bare fibers. Canned air is completely safe with all materials.

FIBER OPTIC SPLICING FACTORS

2-68. There are four factors for consideration before beginning a fiber optic splice—

- Location of splice.
- Number and size of cables.
- Method of splicing.
- Type of splice closure.

2-69. The location of the splice types will influence where the splice is going to be located, underground-manhole, buried-splice pit or pedestal enclosure and aerial. Number and size of cables deal with how many cables involved in the splice, how many fibers are in each cable and will a straight, butt, or branch splice be used.

2-70. There are two methods of splicing fiber optic cable, mechanical and fusion. The method of splice closure determines the type of closure used, also types of closures determines the amount of outer jackets removed to expose fiber for splicing. All measurements must be precise-optical fibers cannot be "pieced out" like copper conductors. It is imperative to avoid errors when cutting the cable or while removing the jacket.

2-71. Fiber splicing typically results in lower light loss and back reflection than termination making it the preferred method when the cable runs are too long for a single length of fiber or when joining two different types of cable together. This usually requires installing a continuous length of cable to avoid the requirement of fiber-to-fiber field splicing. Also, use splicing to restore fiber optic cables during accidental severing of cable. There are two major types of field methods to splicing optic fiber fusion splicing, and mechanical splicing.

Mechanical Splices

2-72. Mechanical splicing consists of placing two ends of fiber precisely aligned and held in place by a self-contained assembly, not a permanent bond. This method aligns the two fiber ends to a common centerline, aligning their cores so the light can pass from one fiber to another.

2-73. Use mechanical splicing with single-mode and multimode optical fiber. Its original use was in the military, but was restricted almost solely to emergency repairs by base maintenance personnel. Currently, the use of mechanical splicing is in just about any type of application where fiber cables require joining permanently.

2-74. It is important to know where mechanical splices and connectors are in a fiber to keep from confusing them with faults. Document each mechanical splice and connector in the installation and maintenance records. A mechanical splice has a similar signature to a connector; usually it has lower loss and reflection values. In distinguishing splices from bends measure at a higher wavelength. Bends will show a higher loss than splices.

Corelink Splice

2-75. The Corelink splice provides an average loss of .15db with an average installation time of 30 seconds (after fiber preparation). The splice accepts fibers with coatings of 250um to 900um.

2-76. To assemble a Corelink splice—

1. Strip and cleave each fiber, leaving an exposed glass length after cleaving of—
2. 8 - 9 mm (0.31 to 0.35") for 250 µm fibers.
3. 18 to 19 mm (0.71 to 0.75") for 900 µm fibers.
4. A good cleave is the most important step in achieving a good, low-loss splice.
5. Dab the ends of the fibers on isopropyl alcohol soaked lint-free wipe to clean the cleaved surfaces. Keep fibers clean to minimize the transport of foreign matter into the splice.

2-77. Corelink installation—

1. Open the package and remove the Corelink splice. Do not remove the Corelink splice until ready to use.
2. Remove the spreader keys from the key card supplies with the Corelink splice. Insert the keys into the key entry ports (the holes closest to the edge of the splice. The key handles should be parallel to the flat side and pointing away from the splice. Insert the keys all the way to their shoulders.
3. Turn both key handle tabs 90 degrees downward. The splice is now open.
4. Align the first fiber tip with the fiber entry port nearest the center of the end face. Insert the fiber slowly, making sure it travels smoothly through the channel into the center element. A 250 um fiber's coating will stop at the edge of the aluminum element, whereas a 900 um fiber's buffer will stop at the end of the wide part of the channel.

Note. If the fiber sticks or slides out of the channel during insertion pull it back slightly and continue to insert it until the fiber coating or buffer contacts the appropriate stop.

2-78. While applying gentle, inward pressure with the thumb and forefinger, gently rotate the key handle upwards 90 degrees (do not snap it closed). This locks the fiber in place. Inspect the fiber to make sure it remained in the channel during locking.

2-79. To install the second fiber, repeat steps 4 and 5 with the exception that the second fiber will not reach the stop, but will stop at the tip of the first fiber. Be sure to maintain gentle, inward pressure on the fiber while turning the key to ensure that the fibers butt against each other, and gently rotate the key when locking the second fiber to prevent the fiber tips from bouncing apart. Inspect the fiber to make sure it remained in the channel during locking. This completes the splice.

2-80. To tune the splice, unlock one of the fibers and pull it back slightly, rotate it 90 degrees to tune it, then push forward and relock it. Tuning is not usually necessary.

> ***Note.*** The spreader keys can be conveniently stored by taping them in or near the splice tray. The interior material of the Corelink splice contains index-matching gel. Exposure of the interior material to the skin or eyes, it may cause irritation. If contact occurs, wipe off the material and flush the area with water immediately.

ULTRA-SPLICE

2-81. The Ultra-splice is a high performance, easy to install tunable and reusable mechanical splice. One splice accepts any combination of buffer sizes from 250um-900um. Average loss is <0.2db with a fiber retention strength of >2 lbs.

2-82. Ultra-splice assembly procedures—

1. The splicing area should be clean, dry and well lighted. A clean, well organized splicing area will improve splicing efficiency and minimize the risk of contamination of the fibers or splices.
2. The Ultra-splice is delivered in the open position, ready to install 250-micron buffers. The blue tube is inserted for easy guiding of fibers with 250 and 500 micron buffers. Working with buffer sizes over 500 micron (for example 900 micron), remove the blue tube and open locking nut one-half turn counterclockwise.
3. Clean and cleave fiber ends to 7 - 9 mm. The ribs on the gray locking nut represent the exact cleave length.
4. Install one fiber end into the splice. You should be able to visually inspect the fiber location in the glass capillary. To secure it, simply twist the gray locking nut in the clockwise direction.
5. Proceed to install the second fiber. The fiber ends should contact each other in about the center of the glass capillary. To secure the other fiber end, twist gray locking nut closed (clock-wise direction).

2-83. Tuning splice for lowest loss. To tune the Ultra-splice—

1. Twist one end of the splices gray locking nut counterclockwise about half a turn.
2. Make adjustments by moving fiber slightly or turning it slowly while watching meter for lowest loss.
3. Re-lock the splice by turning the gray nut clockwise.

2-84. If you have difficulty inserting the fiber, check for the following problems—

- Cleave length is too long.
- Gray locking nut twisted out too far; unable to guide the fiber into the glass capillary.
- The gray locking nut not twisted out far enough for 900-micron buffer size.
- Must remove the blue tube for 900-micron buffers.

FIBERLOK SPLICE

2-85. Fiberlok splice provides permanent mechanical splices for single or multimode fiber, having a 125-micrometer cladding, made of a plastic body and cap with a metal element inside. The metal element's shape allows it to make contact at three points around the fiber longitudinally.

2-86. The Fiberlok splice has an insertion loss of <0.2db with a fiber retention strength of >0.75 lbs. Known for low reflection characteristics of -35db. Using V groove technology, it requires no epoxy. Splice time is approximately 30 seconds after preparing fiber ends. See figure 2-18 on page 2-17.

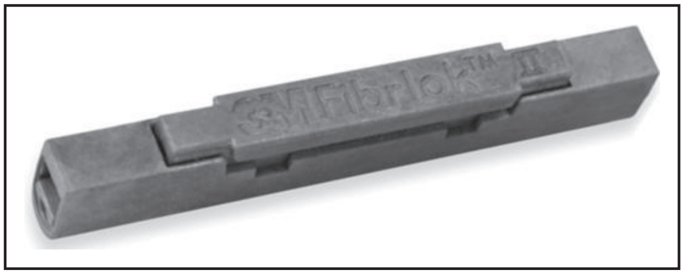

Figure 2-18. Fiberlok

2-87. Fiberlok splice procedures—

1. Keep Fiberlok splices clean. Do not remove splices from sealed cavity until ready to use.
2. Place Fiberlok splice into splice holding cradle in the assembly tool.
3. If using the Fiberlok 2501 assembly tool, be sure that the retention pad toggle arms are in the inward position for 250 µm fibers and in the outward position for splicing 900 µm fibers.
4. Strip and cleave first fiber to 12.5 mm +/- 0.5 mm (0.492 +/- 0.020 in). Clean fiber with alcohol and lint-free cloth after stripping it. Do not clean fiber after cleaving.
5. Taking care not to touch fiber end face, place fiber into foam retention pad.
6. Insert first fiber into the end port until coating bottoms out. If properly inserted, bare glass should not be visible outside of splice. If bare glass is visible, pull back slightly on fiber and continue insertion until resistance is met. If splicing 250 µm coated fiber to 900 µm buffered fiber, insert the 250 µm fiber first.
7. Strip and cleave second fiber to 12.5 mm +/- .5 mm (0.492 +/- 0.020 in).
8. Taking care not to touch fiber end face, place second fiber into the other foam retention pad.
9. Insert second fiber into the other end port of splice until it contacts the first fiber.
10. Push the first fiber back against the second until there are equal bowls of approximately 5 to 8 mm (0.2 to 0.3 inches) in both fibers.
11. Push down the Assembly Tool handle until splice cap snaps closed. Lift handle, remove the fibers from the foam retention pads, and remove completed splice from the tool. The splice should be secured in a splice tray to prevent damage to the splice. See figure 2-19.

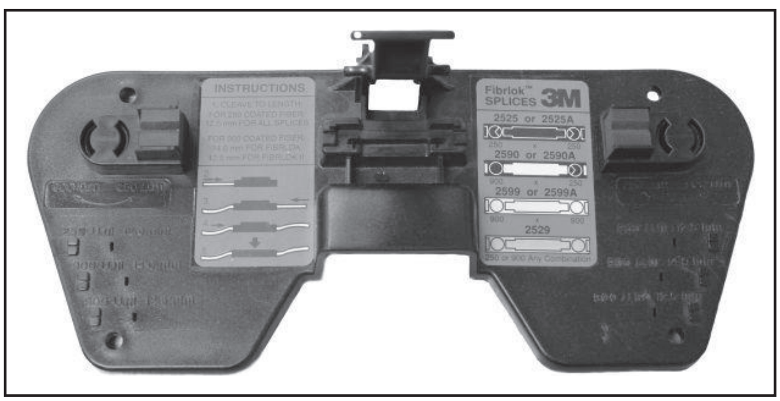

Figure 2-19. Assembly tool

FUSION SPLICING

2-88. Fusion splicing is the method of joining the fiber ends by using a fusion splicer. The process of performing a fusion splice involves applying a focused heat source that will fuse the two fibers together. If performed correctly, it will provide the lowest loss when compared to other splicing methods. Splice losses of < 0.02 dB are common, with more than 90% below 0.1 dB.

Fusion Splicer Characteristics

2-89. One of the main distinctions with fusion splicers is the mechanism used to align the fiber itself. The alignment of the fiber splice will play an important role in the quality of the splice.

Fixed V-Groove

2-90. Fixed V-groove splicers align the outside cladding of the fiber based solely on the fiber's position in a fixed v-groove. These systems are small, light, inexpensive, and lend to mass splicing applications.

Lens Profile Alignment System

2-91. Lens profile alignment system aligns the outer cladding of fiber using refracted light off the cladding glass layer. These systems offer low loss for new fibers.

Core-Alignment Utilizing the Profile Alignment System

2-92. Core-alignment using the profile alignment system aligns the inner core of fiber by utilizing camera and image processing of the core with moveable v-grooves. These systems have low loss and can provide a loss estimation before making the splice.

Core Aligning utilizing Core Detection System

2-93. Core aligning utilizing core detection system uses a brief arc discharged across the fiber ends causing the core to glow. A snapshot of the core position and the fiber aligned to match the cores of both fibers. The Advantages of this system are low loss, more accurate loss estimation, and the ability to perform core-alignment on Nano-structured fibers.

Core Aligning utilizing Local Injection Detection

2-94. The local injection detection system couples an optical signal into one fiber and the power level detected in the other fiber. The power level is at maximum at fiber alignment. Advantages of using local injection detection are the assurance of low signal loss and provision of loss measurements.

Types of Fusion Splicers

2-95. This section discusses the various types of fusion splicers that used for fiber splicing applications. Accessibility and portability are the two key considerations when determining which fusion splicer to use.

Compact Fusion Set II

2-96. The Compact Fusion Set II (CFS II) incorporates automatic fiber alignment with a manual splicer into a Compact Fusion Set. After preparing and clamping the fibers in the CFS II, the push of one button aligns and fuses the fibers. There are two perpendicular views of the fibers, captured by a camera, displayed at 100x magnification on a 4-inch display. This digital image is analyzed for cleave quality and fiber alignment by a microprocessor which controls the positioning and fusion of the fibers. Analysis of the image occurs after the splice and an estimated loss is determined and displayed. See figure 2-20, on page 2-19.

2-97. The CFS II is comprised of—

- Screen Intensity or Menu Keys–In normal mode, operating these keys controls the intensity of the liquid-crystal display (LCD) screen. When in program mode they allow the operator to move from one menu selection to another.
- Magnification Selection Key–This selects either the 25 times magnification single fiber view or the 100 times X and Y fiber views.
- Left Fiber Position Keys–These keys allow the operator to move the left fiber horizontally to butt the cleaved ends of the fibers in the arc zone when in the unit's manual mode.
- Heat Shrink Oven–The oven for shrinking heat shrink splice protectors.
- Clean Key–Used to gap the fibers and fires a cleaning arc in the manual mode.

- Fuse Key–This key fires the fusion arc and pushes the fibers together in the manual mode or begins the complete process in the automatic mode.
- Fiber Coating Clamps–The inside clamps on the right and left of the V-groove grip the fiber on the 250μm acrylate or 900μm outer coating.
- Light Tower Assembly–This removable assembly contains the bare fiber clamp as well as the light-emitting diode (LED) used to illuminate the fiber for display on the screen. Remove and secure the tower in the transit case during transport or storage.
- Fiber clamp–This clamp contacts the fiber while in the V-groove and maintains proper alignment during the fusion process.
- A hex head screw secures electrode assembly–Each electrode.
- Light Tower Retainer Pin–Remove the light tower by pulling this pin out.
- Power LED–LED that indicates the power is on. Indicates a low battery when flashing.
- Program key mode/select–This key allows the operator to enter the program mode and to select functions once in the mode.
- Right fiber position keys–These keys move the right fiber horizontally in the manual mode.
- DC charger input–The charger plugs into the fusion set at this point to charge the battery inside the splicer.
- V-Groove–Used to align fibers for fusing.

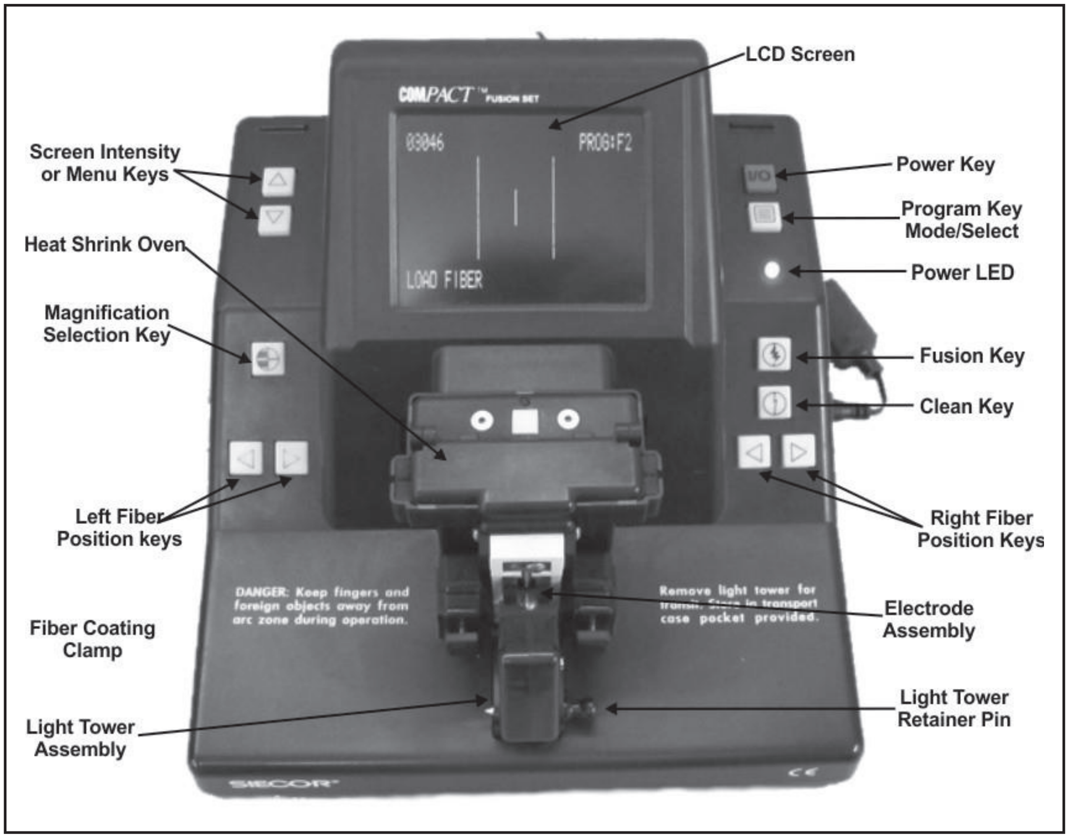

Figure 2-20. Compact fusion set II

Type-39 MicroCore Fusion Splicer

2-98. The Type-39 MicroCore fusion splicer is fully automatic, highly portable and self-contained instrument for creating quick and effortless low-loss optical fiber splices in any environment. The Type-39 MicroCore fusion splicer works with virtually all fiber types including single-mode and multimode.

The Type-39 MicroCore (figure 2-12) is comprised of—

- Brightness control key-Adjusts brightness of monitor.
- Up arrow key-Used to move cursor and enter numeric values.
- Left arrow key-Used to move cursor, enter numeric values and go back to the previous screen.
- Down arrow key-Used to move cursor and enter numeric values.
- Right arrow key-Used to move cursor, enter numeric values and select items.
- Square key-Used to access the menu screen and for manual re-arcing of a completed splice.
- Diamond key-Used to display key guidance.
- Power key/LED-Used to turn on and off the splicer. LED illuminates while the splicer is on.
- Set key-Starts the splicing operation.
- Reset key-Used to abort a splicing operation and initialization.
- Heat key (top)/LED-Starts the rear heat shrink oven. LED illuminates during heat cycle.
- Heat key (bottom)/LED - Starts the front heat shrink oven. LED illuminates during heat cycle.
- Heating plate-Heats fiber protection sleeve.
- Heat shrink oven clamps-Holds the fiber straight.

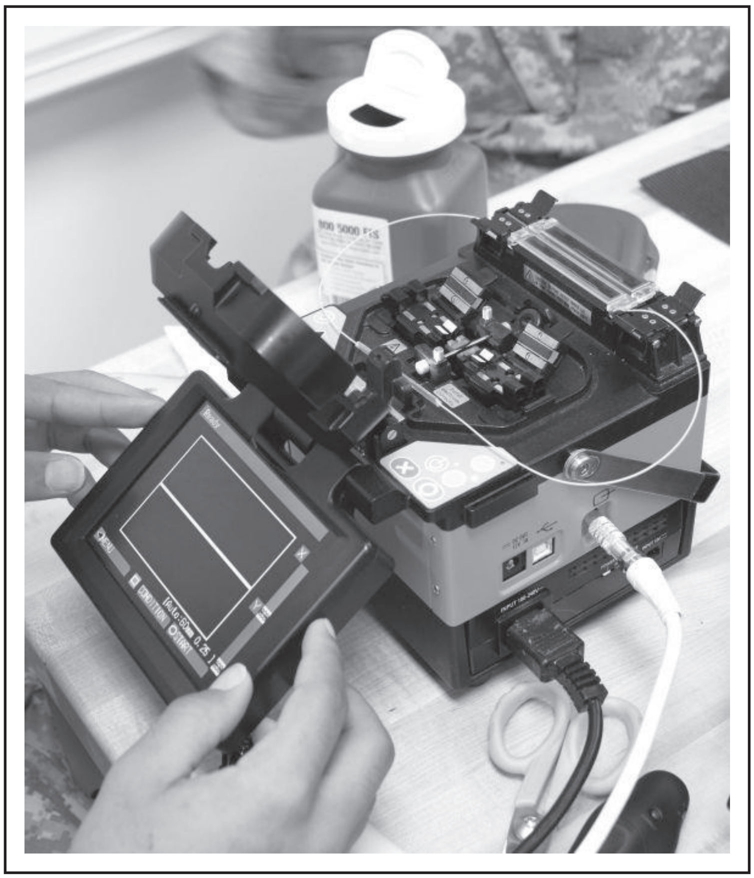

Figure 2-21. Type-39 MicroCore fusion splicer

Fusion Splicing Procedures

2-99. There are four fusion-splicing procedures; fiber preparation, perform arc test, fuse fiber, and protection of fused fiber. The following discusses these four procedures:

1. In fiber preparation remove the outer jacket, next, cut and secure the strength member, remove the buffer coating, clean the fiber and start cleaving the fiber. See figures 2-22, 2-23, and 2-24.

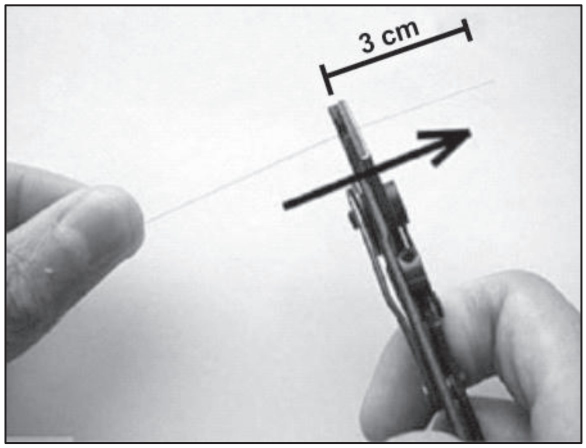

Figure 2-22. Strip

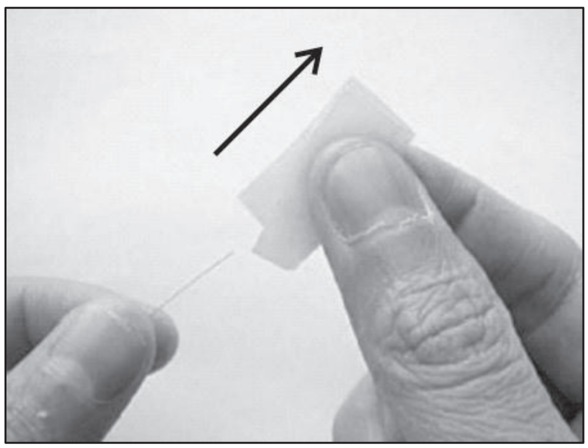

Figure 2-23. Clean

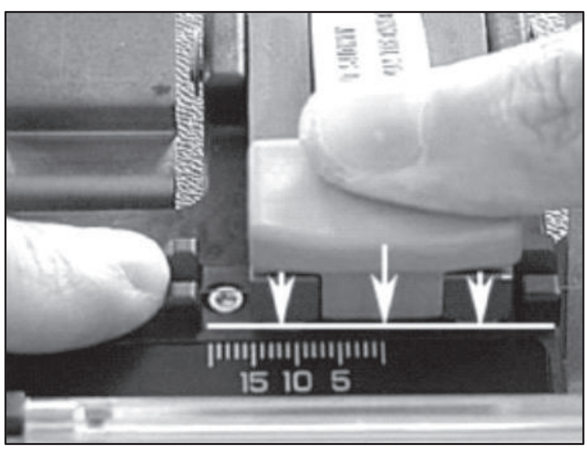

Figure 2-24. Cleave

2. While performing arc testing, set up splicer to environmental condition (barometric pressure, temperature, humidity, and input voltage); perform this last step before use.
3. Fuse the fiber ends together by placing in the fusion splicer. Fusion procedures are different depending on the fusion splicer being used.

4. Protection of the bare fused fiber is accomplished using a fusion splice sleeve which is a hollow plastic heat-shrinkable tube with a metal reinforcing rod. The fusion splice sleeve is installed over the fiber before the actual fusing operations. Once the fibers are spliced, the fusion splice sleeve is slipped over the splice junction and then placed in a heater to shrink the around the splice. The finished splice is then placed in a splice tray for greater security and protection.

FIBER OPTIC CABLE TESTING AND TROUBLESHOOTING

2-100. This section provides procedures on how to operate the optical power meter, to include system testing and calibration. It also discusses steps on how to use the optical time domain reflectometer.

OPTICAL POWER TEST SET

2-101. The optical power test set TS-4358/G is an optical power meter (OPM) and optical light source (OLS) that provides light in four operating wavelengths and measures fiber optic power levels for the same four operating wavelengths. A stabilized light source provides light measured by a separate power meter. Refer to TM 9-6650-906-12 for information on operator and unit maintenance for the TS-4358/G optical power test set. Figure 2-25 shows the components that make up the TS-4358/G.

Figure 2-25. Optical power meter and optical light source

2-102. Calibrate the test set for testing multimode fibers at 850 nm and 1300 nm. Calibration is for testing single mode fibers at 1310nm and 1550nm. The measurement range for the OPM is +3 dBm to -60 dBm.

2-103. The instructions for this test set do not apply for all test sets. Make sure you review the operating instructions for the particular equipment you are using before performing your tests.

Connecting Procedures

2-104. The procedures for connecting the OPM and stabilized laser source (SLS) for measurements follows—

1. Determine which type of connector is used for the fibers to test.
2. Determine the signal to be tested (single mode or multi-mode).
3. Select the setup to be used.
4. Remove the cap from the power meter's detector port.
5. Select a detector adapter.
6. Connect the detector adapter to the detector port.
7. Remove the cap from the light source output port.
8. Connect the chosen fiber jumper to the output port on the SLS.

9. Connect the other end of this fiber to the connector on the power meter for setting references. However, if extra patch cords are required in your test setup, include them for references.

Power Up and Calibration (CAL) Procedure

2-105. The following procedure is used to perform calibrations—

1. Remove the OPM and SLS from the test set carrying case. Make sure that the caps on the input and output ports are tightly in place.
2. Press the on/off key on the OPM.
3. Press and release the shift key, then press and hold down the OPM's calibrate key for 3 seconds or until-CAL appears across the display. The alignment lasts about 20 seconds.
4. Press the On/Off key on the SLS to turn it on.

Reference Setting for Loss Measurement

2-106. The following procedure is used for loss measurements with the OPM and SLS—

1. Select setup to be used.
2. Remove the cap from the power meter's detector port.
3. Select a detector adapter.
4. Connect the detector adapter to the detector port.
5. Connect the patchcord to the detector adapter of the OPM.
6. Remove the cap from the light source output port you will be using.
7. Connect the patchcord to the output port of the SLS.
8. Connect the two patchcords to the selected feed through connector.
9. If extra patchcords are required in your test setup, include them for references.
10. Turn the light source and power meter on.
11. Turn on the desired source Led by pressing either the MULTIMODE or SINGLEMODE key until the desired wavelength indicator is lit up.
12. Set the power meter to the same wavelength by pressing the λ SELECT key until the desired wavelength appears in the upper right corner of the display.
13. Store the dBm reading as a reference by pressing the REF key until the power meter reads the 0.0 dB loss and the reference appears in the upper portion of the display. It is a good idea to repeat this procedure for the other source LED on the same output port before disconnecting. This will save time later.
14. Turn the LED off and disconnect the set up at the feed through connector.

Note. Make sure to disconnect your set up at the feed through connector and not the light source end to ensure repeatability.

Standard Test Procedure

2-107. The standard testing procedure using the OPM and SLS is—

1. Make sure you have executed the reference setting procedure first.
2. Connect the units to the fiber to be tested. Make sure that the patchcord has not been disconnected from the light source. If the patchcord was disconnected and reconnected you will have to set new references.
3. To connect the units to a fiber for testing, connect the free ends of both fiber jumpers to separate feed through the hybrid connectors, depending on the selections made in the previous step. Connect the hybrid connectors to the ends of the fiber under test.
4. Turn on the desired LED in the SLS and read the loss measurement on the main 5 digits of the OPM display.
5. The referencing will have to be redone when changing from multimode measurements to single mode measurements and vice-versa.

FasTest Procedure

2-108. The SLS contains a function to test a fiber and acquire data automatically using the OPM. Your test light source activates the FasTest function; the OPM in turn auto-selects the wavelength of operation, acquires and stores loss measurement data. The following is the procedure for an automatic FasTest of fiber optic systems—

1. Connect the units to the fiber to be tested.
2. To connect the units to a fiber for testing, connect the free ends of both fiber jumpers to separate feed through the hybrid connectors, depending on the selections made in the previous step. Connect the hybrid connectors to the ends of the fiber under test.
3. At the SLS, select the output port by pressing the single mode or multi-mode key. Keep in mind that the multimode and singlemode ports are separate on the SLS.
4. Activate the FasTest function by pressing the FasTest key on your SLS. The operator of the OPM never needs to touch his unit during this test. Observing the power meter, notice the receiver wavelength, the stored reference value, and the calculated loss reading which is automatically stored in memory. Both wavelengths from the source will be referenced. The test source beeps and self-deactivates upon FasTest completion; the power meter will then indicate dashed lines since it receives.

Optical Time Domain Reflectometer

2-109. An optical time-domain reflectometer (OTDR) injects a series of optical pulses into the fiber under test. It also extracts, from the same end of the fiber, light scattered or reflected back from points along the fiber. The strength of the return pulses is measured and integrated as a function of time, and is plotted as a function of fiber length.

2-110. Use an OTDR to measure the length or distance of any optical fiber within the measurement range of the test set. Length measurements can be used to determine Length of cable (installed or on a reel), Distance to splices, cable faults, or any other situation where length or distance is needed. This handbook will discuss functions and procedures for using the FTB-200 OTDR, the most commonly used OTDR in the Army.

FTB-200

2-111. The FTB-200 OTDR provides a compact modular platform capable of measuring loss characteristics, displaying faults, splices and other fiber events in single-mode and multimode optical fibers. The FTB-200 accommodates two field-interchangeable modules and has integrated hardware options such as visual fault locator (VFL), fiber inspection probe and a power meter. See Figure 2-26 on page 2-25.

Figure 2-26. FTB-200

2-112. The FTB-200 features Universal Serial Bus (USB) ports for saving data stored or transferring data to other systems. Use an Ethernet port that to connect the FTB-200 to a network or a Compact Flash card reader for added data storage. It is made of a rugged lightweight construction and includes a LCD touch screen resistant to shock, water, dust, and common chemicals.

Controls and Functions

2-113. The following are the controls and the respective functions for the FTB-200 that are operated from the front panel controls and functions:

- On/off-Turns the system on or off.
- Suspend-hold down button a few seconds until the unit beeps once will place it into suspended mode.
- Shutdown-hold down button until the unit beeps twice to shut down.
- Lock/start acquisition/F1 button-used for various application.
- Mute/move markers/F2 button-used for various application.
- Report/next or trace/F3 button-used for various applications.
- First shortcut button-starts the associated application.
- Second shortcut button-starts the associated application or built-in power meter application.
- Start fiber probe application button-Starts the fiber probe operations.
- Switch task button-switched to different tasks.

2-114. Top panel control has a two-slot platform used to insert test modules. Right panel controls and functions are—

- 8-Pin Connector-used to connect the fiber inspection scope.
- USB host port (type A connector)-used to connect such devices as USB memory drives, keyboards, and mouse drives.
- USB client (secondary) port (type B connector)-used to connect a USB cable for data transfer between your unit and a computer.
- RJ-45 Port-used to connect your unit to an Ethernet network.
- Left panel control and functions has a card reader used for bluetooth wireless and compact flash cards.

> **CAUTION**
>
> Do not install or terminate fibers while a light source is active.
>
> Never look directly into a live fiber and protect your eyes at all times.
>
> Use of controls, adjustments and procedures for operation and maintenance other than those specified in user guide may result in hazardous radiation exposure.
>
> Do not stare into the fiber connector or at any mirror-like surface that could reflect radiation emitted from the fiber connector.
>
> Do not stare at the non-terminated end of any test fiber installed in the fiber connector.

Note. The laser class of your unit depends on the modules that you use. Refer to the user guide or the online help of the different modules for exact information.

Operating Modes

2-115. The FTB-200 has the following operating modes:

- Auto mode-lets you select acquisition parameters automatically.
- Fault finder mode-save valuable time when you need to find the end of a fiber without setting any parameters.
- Template trace mode-compares each acquisition with a designated template trace for complete cable testing and documentation.
- Advanced mode-offers multiple setup and measurement capabilities for increased flexibility.

Length Measurement

2-116. Use the FTB-200 to measure the length or distance of any optical fiber within the measurement range of the test set. Use length measurements to determine the length of cable installed or on a reel, distance to splices, cable faults, or any other situation where there is a requirement for length or distance. When performing measurement, length or loss, the technician must know where to measure from and to.

2-117. Take measurements from leading edge to leading edge. The leading edge is where a reflective pulse, or a peak, starts up or a non-reflective pulse, or a dip, starts down from the normal backscatter line. The end of a pulse is where it either levels back off into the normal backscatter level or drops off into the noise level.

2-118. The FTB-200 measures fiber length rather than cable length. Keep this in mind when measuring loose-tube buffered fiber cable as the fibers will actually be longer than the confining buffer tube by about 1%. This is normally not a problem on relatively short sections of cable, but on extremely long cable runs, the difference could be considerable.

Chapter 3
Outside Plant Operations

Outside plant operations consist of the installation and maintenance of all physical cabling and supporting infrastructure (such as conduit, cabinets, tower or poles), and any associated hardware (such as repeaters) located between a demarcation point in a switching facility and a demarcation point in another switching center or customer premises wiring. A demarcation point is the point at which the public switched telephone network ends and connects with another switching center or the customers on-premises wiring. The customer premises wiring is customer-owned telecommunication transmission or distribution lines.

CONSTRUCTION ORDERS

3-1. In the Army, cable installer and maintainers are typically responsible for outside plant operations, to include installation, maintenance, and repair of aerial wire and cable runs, the burying of cable and wire, and underground wire and cable runs. See FM 6-02 for more responsibilities and capabilities of tactical installation and networking units. Reference throughout this publication regarding individuals performing cable and wiring tasks will be called construction teams.

3-2. The construction orders given to construction teams, organized and equipped from reconnaissance information, prescribe the number of circuits to install, the priority of each installation, the time to complete the circuit, and the actions to take upon installation. Much of this information is included in line route maps.

3-3. When the circuit requirements have been determined, give consideration to the type of construction required. This can be aerial, surface, or buried construction, or a combination of all three.

3-4. An aerial line generally provides the most satisfactory type of service. Aerial construction is easier to maintain and provides better quality circuits than surface construction. However, aerial construction has some disadvantages; it requires more time for installation, is vulnerable to enemy action, and is subject to the effects of storms and weather.

3-5. Wire lines laid on the ground require a minimum of time and material for installation. However, they are extremely vulnerable to foot troops and vehicles. Surface lines laid rapidly, and not properly installed, usually require immediate and continuous maintenance. Carefully installed surface wire lines provide reliable circuits suitable for most combat operations.

3-6. Buried wire lines are rare in forward areas. However, it may be necessary at times to bury wire lines to protect the lines from troops and vehicles. In addition, buried wire lines are more stable electrically than aerial or surface lines. Buried wire lines have the following disadvantages—

- More time is required for installation.
- They are more difficult to maintain and recover.
- General damage to the wire during recovery and is not reusable.
- Rarely affected by temperature and weather.

Note. Nuclear detonation affects all construction.

SELECTION OF ROUTES FOR WIRE LINES

3-7. Select the route for wire lines based on map study supplemented by ground reconnaissance. Use topographical maps and aerial photographs to select several possible routes. Plan several routes from a map survey and make the final selection after ground reconnaissance.

RECONNAISSANCE

3-8. During reconnaissance of the available routes, note the following—

- Number of aerial crossings.
- Number of buried crossings.
- Number of railroad crossings.
- Number of streams or river crossings.
- Type of terrain.
- Type of construction best adapted to available wire-laying equipment.
- Distances in miles.
- Concealment for wire parties during construction and maintenance.

3-9. Select and clearly mark on a map the exact route to lay the wire. Select a route that meets the requirements of the situation and is the least difficult for construction and maintenance of wire lines. Electrically test the wire before placing it in use.

PLANNING AND ROUTING OF WIRE LINES

3-10. The construction of wire lines requires prior planning. When planning, consider the following: availability of material, number and type of circuits required, number of lines required, length of the line, time permitted for the installation and type of terrain. This section details selection of routes for wire, techniques of installing wire lines, types of constructions, A-frame construction, constructing wire line in challenging areas, constructing wire line under unusual conditions, installing a tension bridge, wire records and concluding with safety.

3-11. The proper planning of telephone lines includes the type of line and the general route to follow. Consider the relative transmission characteristics of telephone cable when laid on the ground, buried, or installed on aerial supports. Generally, aerial lines give longer transmission ranges and provide more physical protection than surface lines. However, buried lines provide more protection than aerial lines. The time element may limit the use of aerial construction initially, in which case you can lay the line hastily on the ground.

3-12. Laying telephone lines rapidly on the ground, without regard for servicing, requires immediate and continuous maintenance. On the other hand, surface lines laid carefully, with due consideration to ties, crossings, and other means of protection, provide reliable circuits suitable for most combat requirements. Lay the lines with only a minimum of servicing initially to ensure continuous communication. Proper policing should be accomplished immediately afterwards. Avoid line construction among buildings, since such lines are difficult to install and maintain and may invite sabotage.

3-13. Use cross-country routes when practical to minimize interruptions from friendly traffic, aerial bombardment, and, in some cases, artillery fire. If the situation warrants, consider the use of trenches. The routes should provide cover from enemy observation and fire.

LINE ROUTE MAP

3-14. A line route map is a map, a map substitute, or an overlay, which shows the actual or proposed routes of wire lines. Use the line route map to show the actual physical location of wire circuits to installation personnel and to higher headquarters. The line route map contains as few lines, symbols, and notations as are necessary for clarity. It shows the routes of wire lines and test stations, the number of circuits along a route, and the type of wire construction. An organizational line route map is normally prepared from information obtained from teams performing the actual construction. Maintain and keep up-to-date wire construction information for reference data in future organizational movements and maintenance.

SECURITY

3-15. Do not carry complete line route maps and circuit diagrams into forward areas. Issue only such extracts of maps or diagrams that permit the proper performance of the specific mission to individual construction and maintenance teams. Such extracts do not show unit designations.

OUTDOOR CABLE AND WIRE MARKING

3-16. The Operations order and engineering installation package (EIP) provide the method for marking and identifying wire lines and circuits. Designate circuits by individual circuit numbers, switchboard designators, or a combination of the two, for example, 101-36 is a combination of the two, figure 3-1.

3-17. The circuit number is 101, and the code designation of the installing organization is 36, as in figure 3-1. (The circuit designation remains the same from the point of origin to the termination of the circuit.) Number wire lines consecutively, and no two lines are given the same number.

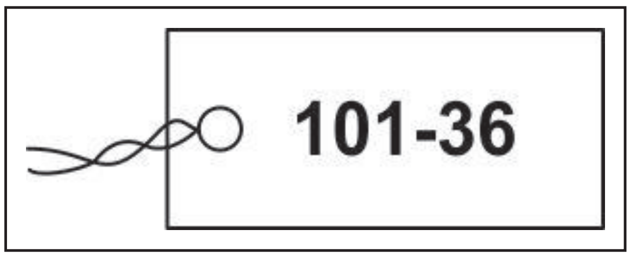

Figure 3-1. Example of tag marking

3-18. Tagging of wire lines is necessary because tags often provide the only method of distinguishing one line from another. Tagging simplifies the turning over of wire systems to relieving units, makes line tracing easier (especially in darkness), and simplifies maintenance. If tags, normally issued as a field item, are not available, use improvised substitute tags. Adequate labeling of lines is every unit's responsibility. During wire-laying, lines are tagged at the following points—

- Crossings at roads, trails, trolley and railroad tracks, railroad junctions, and bridges.
- Communications centers (inside and outside).
- Telephones, repeaters, switchboards, and test terminal points.
- At every cable hock connection (when restorer is present).
- Both sides of buried or aerial crossings.
- Cable laying or construction techniques changes.
- Where the wire-laying or construction techniques change from—
- Surface to underground.
- Surface to aerial.
- A point at which a wire line branches off the main route.
- Frequent intervals where several lines lie along the same route.
- Possible future trouble spots along a route.
- Both sides of a tension bridge.

3-19. Mark cables at both ends with two separate permanent identifications (labels). Do not remove these labels—

- The first marker (label) "TO" is placed within 12 inches of the connector and will indicate the bay, equipment shelf, terminal block, or position as defined in the CRL.
- The second marker (label) "FROM" is placed within 2 inches of the first marker and has the connection information of the opposite end of the cable as defined in the EIP.

- Place cables and labels so they are easy to read.
- The oblong-shaped tag should be made of moisture proof and waterproof material. Securely attach tags to the line. At points where there are many lines with tags (such as test terminal points) arrange tags in oblique or staggered rows. This prevents one tag from covering another.

3-20. Marking cables is necessary to identify them during installation and to aid in troubleshooting after the installation is complete. Identifying cables is also necessary for future planning and system upgrades.

SURFACE LINE CONSTRUCTION

3-21. During combat, telephone lines lain hastily on the ground are called surface lines. Protect these from traffic at command posts, at road and railroad crossings, and at other places where they cross traffic lanes.

3-22. Lay surface lines loosely, with plenty of well-distributed slack (approximately 20 percent) along the line. Slack allows the line to lay flat and simplifies maintenance and construction changes. Tie surface lines to trees, as displayed in figure 3-2, or posts to prevent passing troops and vehicles from pulling the cable into traffic lanes. Make all ties at ground level. Keep surface lines off roads and road shoulders. The principle advantages of surface lines are that less time and fewer personnel are required for installation, and, when laid loosely, surface lines are less vulnerable to artillery fire.

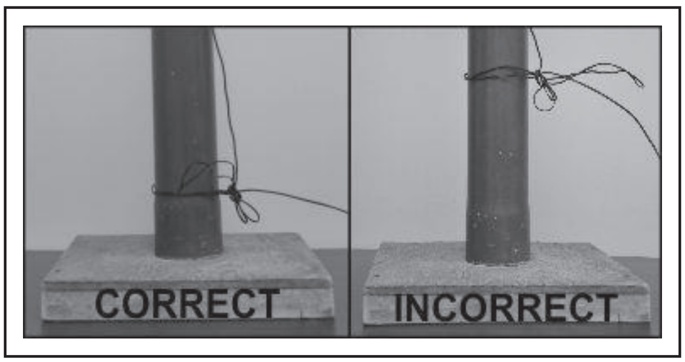

Figure 3-2. Tying surface lines on trees or posts

3-23. The main disadvantages are that surface lines may become unserviceable in wet weather and may often be broken by passing troops and vehicles. When laying surface lines along a road, keep the wires well off the traffic lanes.

3-24. Lay wire lines hastily if the need for urgency dictates. Complete the installation by conducting a thorough policing of each circuit. Tie the wire lines to some fixed object at the beginning and at terminating points of the line. Leave sufficient slack at these points to provide lead-in wire to reach the switchboard at the command post or terminal strips in the construction center. Test wire lines before and after splicing a new reel onto the line. Perform an operational test after connecting a line to the terminal equipment.

CABLE AND WIRE AERIAL INSTALLATION

3-25. Install aerial cable systems during outside plant operations. Use this technique to allow vehicle and personnel traffic to continue using roadways or path while ensuring protection of the cable and wire. This technique can also be used as an option to surface or burial installation in none traffic areas such as locations with a lot of forestry, locations with surfaces that have surfaces that can't be trenched for cable burial without heavy machinery, locations where cable burial is prohibited, or locations where buildings are in close proximity. Aerial cable installation is also the feasible choice when installing set poles in the location of outside plant operations.

3-26. Wire lines should be aerial at command posts, congested troop areas, along roadways, at points on the road that divert from the road, and main or secondary road crossings. Use a white streamer spaced across the span to mark aerial crossings constructed across rivers, streams, and valleys that are in the flight pattern or air routes for helicopters. Aerial spans within the approach and departure corridors of heliports will be similarly marked.

3-27. Tie wire lines securely at both ends of the aerial span in aerial construction. The type of tie used depends on the span length and local climate. Make ties at the top and bottom of the support, as shown in Figure 2-10 on page 2-13. Sag in the line is an important factor in the construction of aerial lines. Six inches of sag is required for every 25 feet of span length. When placing sag in the lines, it is necessary to maintain a minimum road clearance of 18 feet across all main traffic arteries and paved roads. Maintain a clearance of 14 feet over secondary roads and at other points where vehicles travel.

3-28. In aerial construction, when using power distribution poles for supports, tie the wire lines 4 to 6 feet below the power lines, depending on the voltage of the lines. These clearances are required to prevent inductive hum on the line and as a safety precaution for the construction crew.

3-29. Tie wire lines at least 2 feet below the open wire conductors to the poles of open wire lines. This clearance minimizes the possibility of inductive interference or contact between the wire and open wire circuits. Never tie the wire to the crossarm brace.

Note. Consider all electric light and power wires to be carrying dangerous voltage. Do not tie wire lines to transformer cases, electric light brackets, or power crossarms. Be extremely careful when working near power lines. Observe all safety precautions, and follow safe construction practices.

POLE LINE SURVEY

3-30. The construction of wire lines requires prior planning. When planning, consider the following: availability of material, number and type of circuits required, number of lines required, length of the line, time permitted for the installation and type of terrain.

3-31. A pre-survey of the cable route, figure 3-3, is very important in planning for an aerial cable project. The purpose of a pre-survey is to determine if any work may be required along the proposed route before cable placement begins. Each section of the route must be properly prepared before cable installation begins.

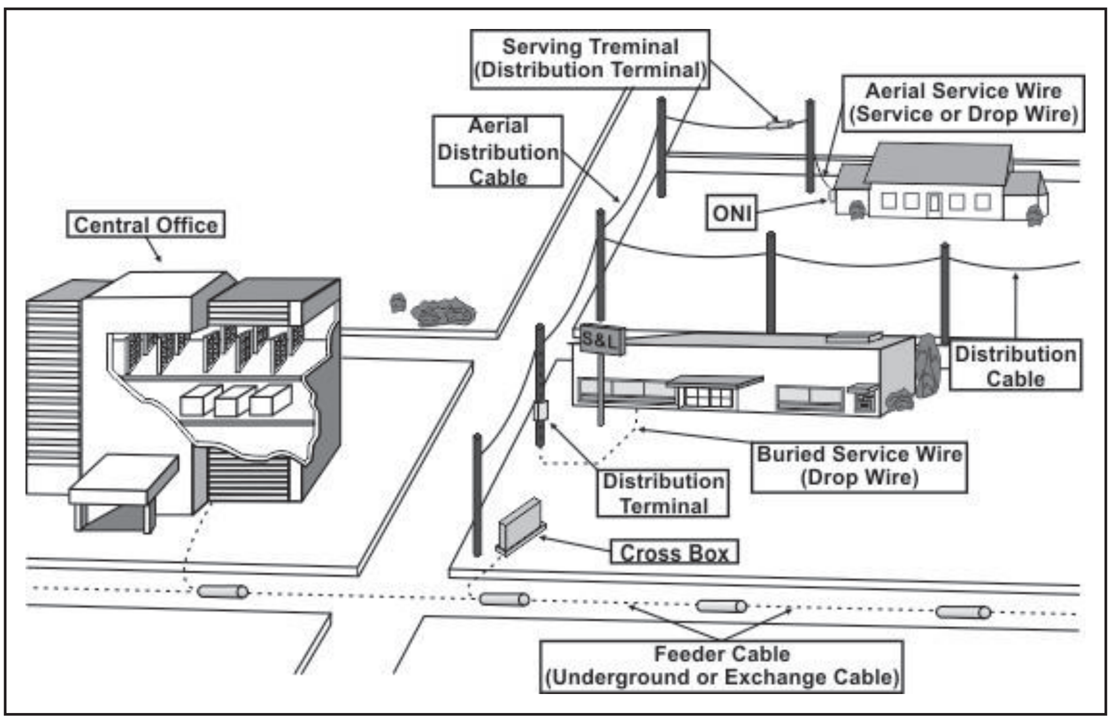

Figure 3-3. Cable routes

3-32. One of the objectives of the pre-survey is to determine where to place each reel of cable. In addition, considering slack locations and cable storage requirements is important, along with splice locations. The pre-survey will verify construction methods, special tools required, or possibly require a revision of preliminary splice locations.

3-33. Investigate the characteristics of the ground along the route. Ensure to note trees or other obstructions that could hinder placing operation. Take into account clearance issues over areas such as roadways and driveways into account before cable placement begins.

3-34. The method of cable placement and the tools necessary for placement are dependent upon vehicle accessibility to the cable route. In areas where a vehicle cannot go, pull the cable in. In other areas with easy vehicle accessibility, lash the cable as it comes off the vehicle's reel.

3-35. Establish the general route the cable will take from the survey. Pole stakes should carry the line number in a consecutive order along the route. Use this information to create the route.

AERIAL CABLE SUSPENSION ACCESSORIES

3-36. The methods described are for guideline use only, as it is impossible to cover all the various conditions that may arise during an installation. Support aerial cables on poles via a suspension strand. This is usually a steel cable that spans from one pole to another with the primary function to add tension strength for cables.

3-37. Use aerial cables mostly where the distribution at each service location is small and may be accomplished by means of drop or block wiring. The advantages of aerial cable systems are that the cost is less than underground installation, and perhaps even less costly if existing pole lines are present. A disadvantage of installing aerial cables is that cables are more susceptible to damage than either underground or buried installations. In addition, the appearance of aerial installation may be objectionable. Do not install aerial cables in areas where it would present a hazard to aircraft operation or frequent changes in direction would require extensive guying; which would increase the cost of the system.

SUSPENSION STRANDS

3-38. The purpose of the suspension strand is to support the multi-paired cable. The proper size can be determined if the following items are known—

- Cable weight (pounds per foot).
- Type of cable sheath and conductors (including polyethylene-aluminum, steel-aluminum, and fiber optic).
- Length of the longest placed span (distance between the poles).

Storm loading area, determined by the climate in which you are working (heavy, medium, light).

3-39. There are five sizes of suspension strand. They are—

- 4M (4,000 lbs), 1/4- inch diameter.
- 6M (6,000 lbs), 5/16-inch diameter.
- 10M (10,000 lbs), 3/8-inch diameter.
- 16M (16,000 lbs), 7/16-inch diameter.
- 25M (25,000 lbs), 1/2-inch diameter.

SUSPENSION STRAND HARDWARE

Cable Suspension Bolts

3-40. The machine bolt, double arming bolt, and the crossover bolt are the cable suspension bolts used.

3-41. Cable suspension bolts are used to—

- Attach suspension clamps to a pole.
- Attach guys to poles.
- Attach a guy and the strand to a terminating or dead end pole.

Cable Suspension Clamps

3-42. The two types of suspension clamps used are the straight suspension and the corner suspension.

3-43. Each clamp has a specific use —

- Use straight suspension clamps to support suspension strand.
- Use the corner suspension clamps where the pull is greater.

Strandvise

3-44. The strandvise can be used to terminate guy strand.

3-45. Splice strand together using the automatic locking strand clamp connector, shown in figure 3-4.

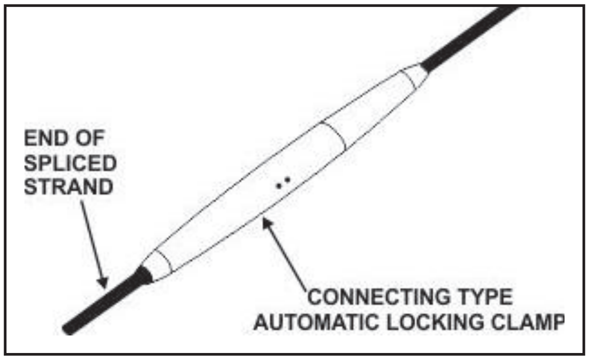

Figure 3-4. Clamp connector

Guy Grips

3-46. Use guy grips when appropriate to secure and terminate the strand to other hardware. Ensure that you use the appropriate size with the strand that you have installed.

INSTALLING SUSPENSION STRANDS

3-47. When installing suspension strand, always place the longest continuous length that you can. The factors governing the best length of strand to pull are—

- The number of corners and the amount of pull at each.
- Changes in grade.
- Interference with trees.
- Interference with wire or cables.

3-48. Pay out the strand in the same way as tactical cables. Tighten suspension strand to the proper tension using chain hoists and a tension-measuring device, and secured to the pole using the proper hardware. See figure 3-5, page 3-8.

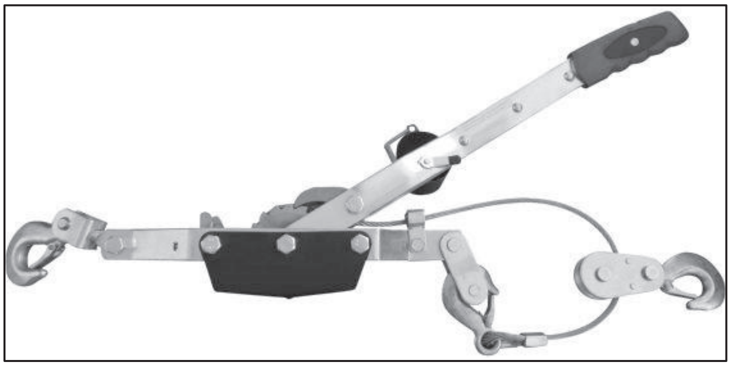

Figure 3-5. Tension measuring device

Procedures for Lashing Cable

3-49. A cable-lashing machine is a manually operated device that wraps lashing wire around the cable and the suspension strand while being drawn along the suspension. Based upon the size of the cable you will need use different sizes of lashing machines.

3-50. Install the cable on the suspension strand approximately 4 feet in front of the lashing machine. This allows the cable guidance into the lashing machine and prevents the cable from binding or undue strain upon the cable or lashing machine. It also allows the personnel to pull the machine along the suspension strand.

3-51. Secure the cable to the suspension strand using—

- Cable lashing clamp-used to secure lashing wire.
- Use cable support and spacers to maintain the desired separation between the strand and cable.

Measure the distance for each from the center of the pole out.

- Ten inches for the cable support and spacer.
- Twelve inches for the cable lashing clamp.
- Fifteen inches for the initial two wraps of lashing wire toward the pole on the strand only.

VS-3 Splice System

3-52. PICABOND connectors, shown in figure 3-6, these connectors are an economical and reliable means of splicing multi-conductor telephone cable. The bodies are tin-plated phosphor bronze and tin-plated brass with bonded polyester insulation.

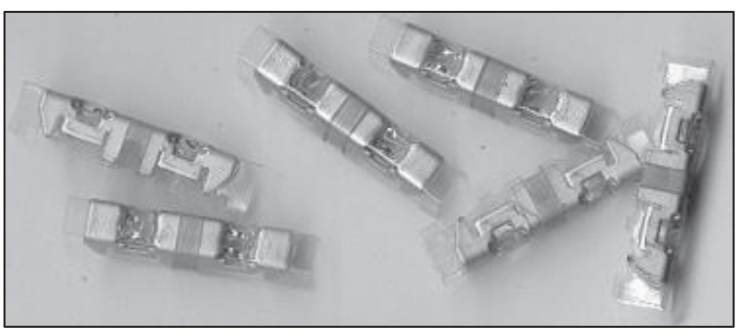

Figure 3-6. PICABOND connectors

3-53. Color-coding of the insulation denotes wire size and weather-resistant type. Any solid core wire, 28 to 19 American wire gage [0.32 - 0.9 mm], with pulp, paper or plastic insulation can be spliced. Lightweight and compact PICABOND splices reduce the space required over other splicing techniques by up to 33 percent.

3-54. The VS-3 PICABOND crimping tool, figure 3-7, is used to create a secure weather resistant connection when installing the PICABOND splices.

Figure 3-7. VS-3 PICABOND crimping tool

Note. Consider all electric light and power wires to be carrying dangerous voltage. Do not tie wire lines to transformer cases, electric light brackets, or power crossarms. Be extremely careful when working near power lines. Observe all safety precautions, and follow safe construction practices.

PROCEDURES FOR CONSTRUCTING AND INSTALLING AERIAL SUPPORT

3-55. There are three types of aerial supports that can be constructed to support cable lines—

- Lance pole construction.
- Setting poles
- A-frame

3-56. The type used depends on the materials available to make the supports, the tools and equipment available, and the type of terrain installing the support on. An A-frame is a type of fixture that a Soldier can construct to support aerial cable. The A-frame construction is more flexible than the hasty pole construction due to the ability to install on all types of terrain. The methods for construction and installation of the A-frames vary according to the number of personnel and amount of equipment available. In an ideal situation, conduct construction work in one continuous operation, normally construct the A-frames before beginning the actual installation of the cable.

Note. Do not use A-frames for primary road crossing due to insufficient height when constructed as outlined in this section.

3-57. Wire and cable lines should be aerial at command posts, congested troop areas, along roadways, at points on the road that divert from the road, and main or secondary road crossings. Use a white streamer spaced across the span to mark aerial crossings constructed across rivers, streams, and valleys that are in the flight pattern or air routes for helicopters. Aerial spans within the approach and departure corridors of heliports will be similarly marked.

3-58. Tie wire and cable lines securely at both ends of the aerial span in aerial construction. The type of tie used depends on the span length and local climate. Make ties at the top and bottom of the support, as shown in figure 3-8 on page 3-10. Sag in the line is an important factor in the construction of aerial lines. Six inches of sag is required for every 25 feet of span length. When placing sag in the lines, it is necessary to maintain a minimum road clearance of 18 feet across all main traffic arteries and paved roads. Maintain a clearance of 14 feet over secondary roads and at other points where vehicles travel. The Installing Cable and Wire Ties section will further discuss wire and cable ties.

Figure 3-8. Method of tying wire lines at bottom and top support

3-59. In aerial construction, when using power distribution poles for supports, tie the wire lines 4 to 6 feet below the power lines, depending on the voltage of the lines. These clearances are required to prevent inductive hum on the line and as a safety precaution for the construction crew.

3-60. Tie wire lines at least 2 feet below the open wire conductors to the poles of open wire lines. This clearance minimizes the possibility of inductive interference or contact between the wire and open wire circuits. Never tie the wire to the crossarm brace.

INSTALLING LANCE POLES

3-61. When poles, trees, or other supports are not available, lance poles provides a convenient method of supporting aerial lines. These wooden poles, which are 14 feet long, 2 inches in diameter, and tapered from the bottom to top with a sharpened or conical point at the bottom. Attached to the top of the pole is an insulator pin.

3-62. A wire line crossing over main traffic arteries and paved roads requires an 18-foot clearance. Since the lance pole is only 14 feet, obtain the additional length by lashing two poles together. When additional strength is required, lash two lance poles together at the base. Lash the poles with wire, overlapping the poles at least 5 feet. This type of construction can support up to 10 wire lines for short spans such as road crossings.

Guy each lance pole used to support aerial wire lines. Each pole has two guy wires at right angles to the direction of the line. Each tenth pole is four-wire guyed, with two guys on each side of the line at a 45-degree angle from the line at the 1 to 1 ratio. The length of each span varies according to the storm loading in that particular area. The normal span length is 100 feet.

3-63. Securely guy an aerial span supported by lance poles. To erect and guy an aerial span, proceed as follows—

1. Lash the lance poles together and lay the poles on the ground parallel to the road.
2. Tie the wire line to the insulator on the lance pole (use clove hitch tie).
3. Tie one end of each guy wire near the top of the lance pole (wire is suitable for guy wires).
4. Raise the lance poles and line into position.
5. Tie the guy wires at a 45-degree angle from the line to a secure object such as a post, tree, or stake at a 1 to 1 ratio.
6. Tie the wire line to a stake at the bottom of the lance pole.
7. Tag the line approximately 6 inches above the stake at the bottom of the lance pole, going up the wire line.

INSTALLING SETTING POLES

3-64. Use poles to support overhead lines. Poles can be made of metal, concrete, or composites like fiberglass, but the most common used are wood poles. The standard pole in the United States is about 40 ft. (12 m) long and is buried about 6 ft. (2 m) in the ground. The Army typically uses 30 ft. (9.1 m) with 5 ft. (1.5) meters in the ground.

3-65. The installation of a pole follows these steps—

1. Locate the spot for the pole to be set and mark it at the exact center of the hole to be made.
2. Determine the size and depth of the hole needed for your pole.

Note. The diameter of the hole should be a minimum of eight inches larger than the pole's diameter.

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3. Use a tractor with appropriate auger to drill the hole, or dig the hole manually.
4. Measure the hole’s depth to ensure it is correct.
5. Measure the pole from the bottom end and attach a 3/8-inch log chain to the pole a foot lower than the reach of the loader, if your loader reaches 14 feet, hook the chain at 13 feet.
6. Hook the chain to the bucket of the loader and begin raising the pole slowly while one or more people hold the bottom end of the pole down, causing the pole to tilt from horizontal to vertical as the bucket lifts.
7. Move the now-vertical pole to the hole slowly while the people hold the bottom end, ensuring the pole remains vertical.
8. Lower the pole into the hole, as centered as possible.
9. Shovel a foot of loose dirt into the bottom of the hole, and then use a 2-by-4 board to tamp and pack the loose dirt just added.
10. Add another layer of loose dirt and tamp it solid. Continue this procedure, while keeping the pole perfectly straight; fill the hole until packed with dirt.
11. Heap any extra dirt around the bottom of the pole in case the fill dirt settles.

Note. Manually raise a pole by placing a two-by-four inside the hole at the opposite end of the side that the pole faces to form a back brace.

BUILDING AND INSTALLING THE A-FRAMES

3-66. This section provides instructions on how to build both terminal and intermediate A-frames used for cable and wire aerial spans. This section will also provide instructions on when and how to install the two types of A-frames along with general standards and consider guidance during installation.

Building A-Frames

3-67. An A-frame, figure 3-9, requires two supports (2 by 4 boards, lance poles, tree limbs, or any other material) 22 feet long, a bolt (1/2 to 5/8 inch), 5 to 6 inches long with washer, and one drive hook. Typically, A-frame legs are 22 feet long, and bolted about two feet from one end. Construct the frame as follows—

1. Cut the supports in 20-foot lengths.
2. Drill a hole 2 feet from one end of each support.
3. Lay one support on top of the other so than the holes match.
4. Insert the bolt through the holes and tighten the nut on the bolt.
5. Drive the drive hook 6 inches from the top of one of the supports. If more than five cables are to be supported, drive another drive hook into the other support, so that one-half of the cables can be hung on each side of the frame.
6. When in upright position, the support resembles an A, hence the name A-frame.
7. The distance between A-frames should not exceed 125 feet for less than 10 cables and 100 feet for 10 cables or more.

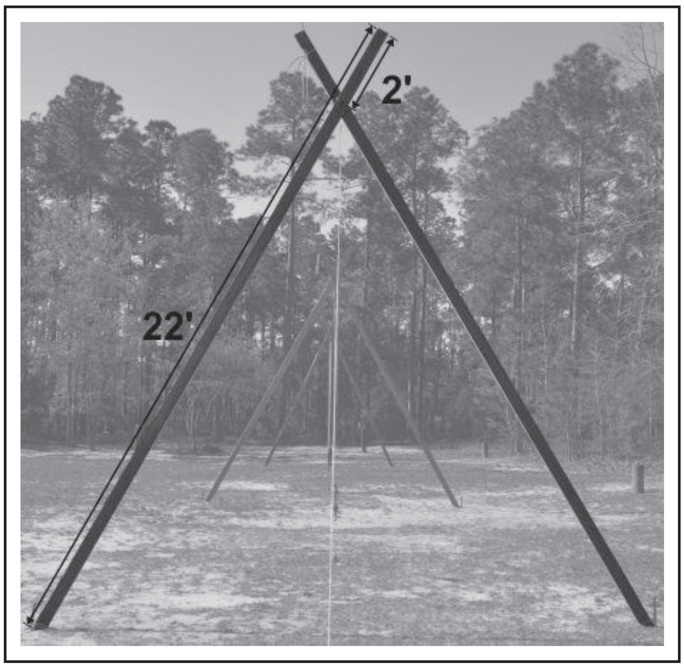

Figure 3-9. Construction of A-frames

Installing A-Frames

3-68. This section will discuss the material required to build and A-frame. It will also cover the installation of the two types of A-frames (intermediate and terminal) along with when to use each A-frame type.

Material Required to Install A-Frames

3-69. The amount of supplies required to install the A-frames depend on the length of the cable line. Each mile of A-frame construction requires the following supplies—

- Sixty-six A-frames.
- 4 kilometers (2.5 miles) of field wire or two rolls or spools of marline twine.
- One hundred stakes.
- Fifty preformed cable grips.
- In addition, construction of a cable line of any length requires one 2 1/2-ton truck, one 3/4-ton truck, one reel unit, and one cable reel DR-15-B, RC-453B/G, RC-435/U, or RC-453/U.

Installing Intermediate A-Frames

3-70. Use the intermediate A-frame (see figure 3-10) between terminal A-frames, and its center support can be 50 feet. Use the terminal A-frame for changes of construction, change of direction, and for termination of the cable line. The intermediate A-frame is installed as a single A-frame in the following manner—

1. From the last secured tie, take cable, pull it perpendicular to the ground, and stand on it. Have another person pull the sag out of the cable all the way to the next mark. Lay the head of the A-frame on the mark with the leg parallel to the cable with the legs facing the running end. Tie the cable on the drive hook of the A-frame using a weave tie or preformed grips if using CX-11230 A/G. Spread the A-frame legs approximately 20 feet.
2. Cut a piece of marline twine or field wire about 50 feet long for guy wire.
3. Loop the marline cord or wire around the apex at the bolt of the A-frame, so that approximately 25 feet extends on each side of the A-frame.
4. Raise the A-frame by having one-person hold the running end of the cable while standing 25 to 30 feet away from the A-frame. One person stands behind each leg of the A-frame, placing his foot at the base to keep it stationary when erecting. One person raises the head of the A-frame about waist height, and each person standing behind the A-frame legs walks the A-frame up while the person holding the cable pulls the tension tight. One person aligns the A-frame by standing far enough on the running end to see the crossing point in the A-frame and existing construction. Align crossover point of the A-frame with existing construction.
5. Drive an anchor stake (slightly tilted) behind each leg to keep it from sliding. Cut about 6 inches of marline cord or field wire, tie a clove hitch on the leg of the A-frame, and secure anchor stake to A-frame legs.
6. Drive a guy stake 17 feet from marker stake in the line of lead on each side of the A-frame.
7. Tie the ends of the guy line to each guy stake and secure with square knot.
8. Erect all intermediate A-frames in the same manner.

Figure 3-10. Intermediate A-frames

Installing Terminal A-Frames

3-71. A-frame construction should always originate and terminate with terminal A-frames as displayed in figure 3-11 on page 3-14. Use terminal A-frames at change of direction or every fifth A-frame. Terminal A-frames consists of two A-frames in an interlocking position forming a tee-pee appearance. It is to secure the cable to the terminal A-frame with a basket hitch and a weave tie on the intermediate A-frame. Finally, Terminal A-frames are required to support the weight and strain of the dead-end cables. Terminal A-frames are installed as follows—

1. Mark off distance to install the A-frame from last support tie. If the last support is not the same height as the A-frame, walk off the difference of height of last support and set marker stake. Place the head of the first A-frame at the marker stake parallel to the cable or alongside the cable at the marked off distance.
2. Tie the cable on the A-frame using a basket hitch tie or preformed grip and form a 10-inch safety loop or one hand span with the cable on the drive hook. Spread legs approximately 20 feet apart. Keep A-frame in line with previous construction.
3. Raise A-frame by having one-person hold the running end of the cable while standing 25 to 30 feet away from the A-frame. One person stands behind each leg of the A-frame, placing his foot at the base to keep it stationary when erecting it. One person pushes the A-frame upright, while the one holding the cable pulls the tension tight. One person aligns the A-frame with previous construction.
4. Place legs of A-frame 20 feet apart.
5. Drive an anchor stake behind each leg to keep it from sliding.
6. Place the second A-frame under the first A-frame, in line with marker set and drive a stake behind each leg, slightly tilted, and tie stake to A-frame with marline cord or field wire.
7. Wrap a piece of wire or marline cord around each leg, 3 feet from ground, using a clove hitch on first leg and a full revolution on the other legs. Pull the wire tight and finish with a square knot.

Note. Install several cables by tying together with marline cord, tape, or field wire.

Figure 3-11. Terminal A-frame

Installing a Tension Bridge

3-72. The team tying the cables to the support should also install tension bridges at connecting points of the cable sections. Tension bridges relieve the strain on the connectors and provide slack to permit access to the cable sections for testing purposes. See figure 3-12 on page 3-15. Construct a tension bridge as follows—

Note. When possible install tension bridges at ground level for testing purposes.

1. Cut a 6-foot piece of marline twine or field wire.
2. Loop the cable at the connectors. Make the loop approximately 10 by 20-inches wide.
3. Begin a basket hitch tie with a clove hitch tie with the twine or field wire, one foot from the center of the loop. Complete the basket hitch tie in the center of the loop. Tie a half square knot at opposite connector.
4. Install a basket hitch tie on the other cable in the same manner and tie the two ends in a square knot. Use the remainder of the twine or wire to support the loop.
5. Lock the dust covers.
6. Tie the dust covers to the connectors.

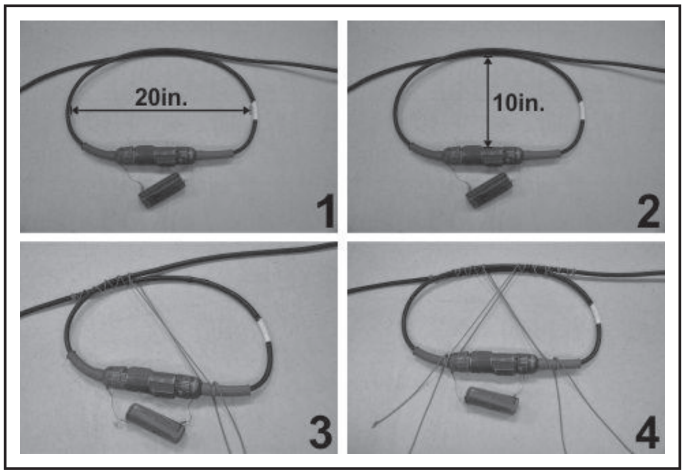

Figure 3-12. Tension bridge steps

Surveying the Line

3-73. Build the A-frames, and then align and erect the A-frames. The survey team performs the alignment; provide them with marker stakes, hammers to drive the stakes, three range rods, and a 150-foot measuring tape. The alignment is performed as follows—

1. Drive the first marker stake at the exact location of the first A-frame.
2. Measure the distance for the first span (125 feet for less than 10 cables; 100 feet for 10 cables or more). At this point, drive the second marker stake. Measure the distance for the third span, and line the stakes, as shown in figure 3-13. (Line the stakes with care, since an A-frame out of line will collapse under the weight of the cable).
3. Continue the lining procedure until the line survey is complete and all marker stakes are in place.

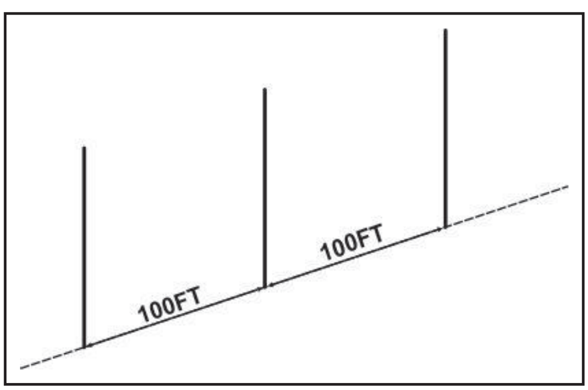

Figure 3-13. Lining marker stakes

POLE CLIMBING AND EQUIPMENT

3-74. This section explains climbing equipment, wearing climbing equipment, pole climbing, safety aspects of pole climbing equipment, and conclude with the essential use of pole climbing equipment.

3-75. Personnel needing to climb poles without pole steps or ladders use climbing equipment as shown in figure 3-14. The climbing equipment permits the personnel's hands to be free for performing work while aloft.

Figure 3-14. Climbing equipment

WEARING CLIMBING EQUIPMENT

3-76. On a correctly fitted body belt, the D-rings are just behind the projecting portions of the wearer's hipbones. Wear the body belt over the hips with buckle to the left side. It should be loose, but tight enough to prevent slipping, see Figures C-24, on page C-36 and Figure C-25, on pager C-38. Right-handed wearers snap both ends of the safety strap to the left-hand D-rings; left-handed wearers snap the ends to the right-hand rings. Snap the double end of the strap to the D-ring with the keeper toward the rear and keep it hooked at all times. Snap the other end of the strap on the D-ring, with the keeper toward the front and above the snap hook of the double end. Before climbing a pole, always adjust the length of the safety strap. To do this, engage the gaffs of the climbers near the base of the pole. Pass the safety strap around the pole and fasten the strap to the D-ring. Carefully lean back until the safety strap supports the full bodyweight. Adjustment is correct when the palms of the hands rest on the far side of the pole without any over-lapping of the fingers. The Soldier's shirt must be tucked into climbing belt and not impose a hindrance.

Note. The wearer must remove all jewelry and sharp objects from their pockets.

3-77. Figure 3-15 on page 3-17 shows the front and rear view of the climbing equipment.

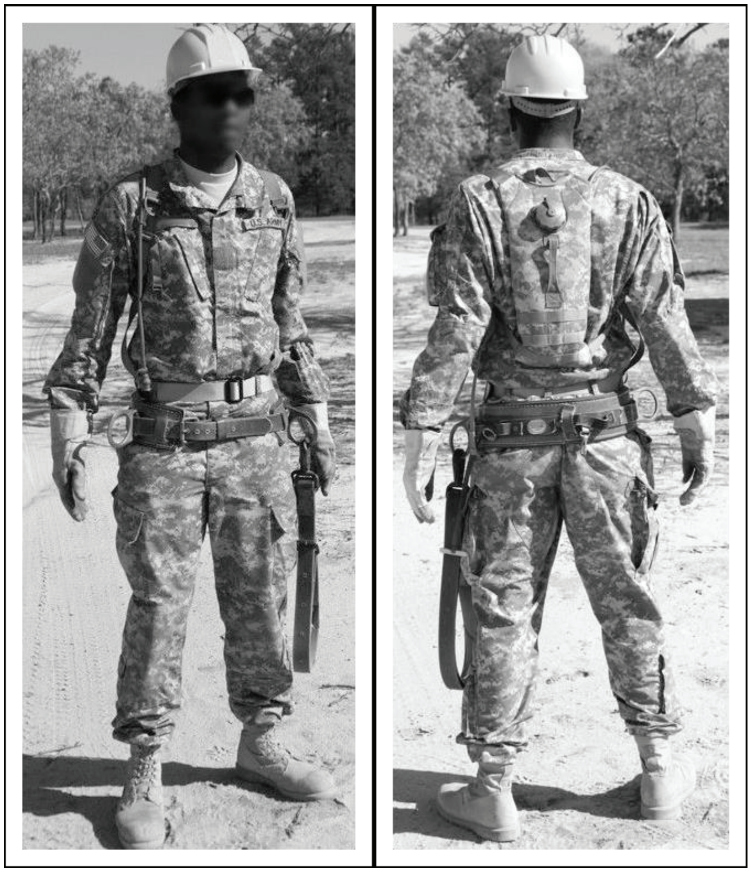

Figure 3-15. Proper wear of climbing equipment, front and rear view

3-78. Precautions instructions—

- While aloft on a pole, always use the safety strap to minimize the danger of falling and to allow you to work with minimum fatigue. Be careful not to drop tools or other equipment.
- Beginners should practice fastening and unfastening the safety strap close to the ground until they perform this step speedily, safely, and precisely.

LINEMAN'S BELT

3-79. The lineman's belt permits wiremen's hands freedom for performing work safely and permits wiremen's hands freedom while climbing. Lineman's belt LC-23 consists of a leather or fiber belt or a leather or fiber safety strap. Both belt and safety strap are adjustable for size of pole and waist size of climber. The belt has two D-rings used to attach the keepers of the safety strap. There are several loops sewn into the belt that provide a place to insert tools. Safety straps have keepers on each end. The double end keeper is the end of the safety strap that has the loop whereas the single end keeper is on the opposite end. The climber will never remove the double end keeper from the D-ring of safety belt.

3-80. Keep the leather clean, soft, and pliable by using either saddle soap, neat's-foot oil, or lather from a neutral soap (such as castile). This removes embedded dirt and perspiration that deteriorates the leather. Wipe the leather dry. Do not use mineral oil or grease and do not stand near an open flame while wearing leather equipment. Clean and dress the leather parts frequently with neat's-foot oil, if they become wet or in contact with paint. Always remove paint as soon as possible.

3-81. Inspect belt for cracks in at least three points. Inspect for pliability and obvious defects including holes for buckle adjustments as follows—

1. To check leather safety straps, bend the straps with the smooth side (grain side) out over a round object not less than 3/4 inch in diameter. Make the test in at least three places (near both ends and in the middle of the strap). Slight cracks normally appear on the surface.
2. To check leather body belts, bend the belts at any point that requires little effort, such as under the leather tool loop and tongue strap. Do not bend belts over too small an object, because this can cause damaging cracks. Always keep the grain side of the belt on top when bending the leather.

Note. If large cracks appear in the leather, discard the straps because they are not safe.

CLIMBERS LC-240/U

3-82. Climbers LC-240/U are adjustable, lightweight, metal climbers. The length is adjustable from 14 3/4 to 19 1/2 inches for different leg sizes. Climbers LC-240/U consists of two leg irons, 2-inch and 3-inch interchangeable gaffs, leather fastening straps, and climber pads. Use the 2-inch gaffs for climbing poles without steps.

3-83. To adjust the leg irons, unscrew the two leg-iron screws and move the slide assembly on the leg iron to the desired length. Replace and tighten the two leg screws in the nearest screw holes. To remove the gaffs, unscrew the two gaff retaining screws. Slide the gaff downward toward the stirrup and lift the gaff out of the retaining slot. Reverse these two steps to replace the gaffs.

POLE CLIMBING AND SAFEGUARDS

3-84. The following paragraphs explain safeguards, procedures, and techniques of pole climbing. Poles that have been in service for long periods might be defective, and could break under the weight of a lineman climbing or working aloft. Always inspect and test the pole before climbing. Rig temporary supports if you suspect a pole is defective. Test all poles before climbing.

3-85. Test the soundness of a pole by gently rocking the pole back and forth in a direction at right angles to the lines. Do not rock the pole if there is a chance that the pole will cause damage if it should fall. Use pole pikes for rocking. A defective pole will crack or break. Alternatively, jab the butt at a point 6 to 9 inches below the ground line with a screwdriver or pick to perform a soundness test on a pole. This test reveals rotten wood if the pole has begun to decay at that point.

3-86. When working near power lines, always leave 6 to 8 feet of clearance between any part of your body and the power line. There is danger of electrocution or serious injury from shock! Always assume that any metallic portion of the power line is alive with dangerous voltage. Do not rock a telephone pole to make a soundness test if there is a possibility that the swaying telephone wires will contact the power line. Insure to clear area around base of pole before climbing.

Preliminary Instructions

3-87. The following instructions are for right-handed wireman. A left-handed wireman performs the operations with the opposite hand and leg. When climbing a pole, keep the arms slightly bent with the hips away from the pole. Place the hands on the far side of the pole but do not have the hands overlap. Placing the hands on the sides of the pole causes unnecessary strain on the arms. Keep the body away from the pole. If the hips are too close to the pole, the legs will not angle inward. This could cause loss of footing. Make sure the hips are not too far out to prevent too much strain on the arms due to supporting a large portion of the climber's weight. If the knees touch the pole, the feet will cut out; keep the toes pointing in an upward direction.

Ascending

3-88. Before climbing, circle the pole and inspect it for soundness; also note the location of wide weather cracks and soft or hard spots in the wood. Look for any cables, crossarms, or other obstructions that may interfere with climbing. If the pole leans, face the direction in which the pole is leaning and climb on the high side.

3-89. Kick pole to knock sand/mud off boots, position hands on steps should be palms always down, steps are positioned about 18 inches apart. Position feet on steps and use foot instep only. Fasten safety strap (safety on). Adjust belt so that you are sitting on belt, and belt is not above your hips. Grasp the pole and raise the left foot about 10 inches from the pole and then position foot onto the face of the pole at a point about 8 inches from the ground, as in figure 3-16.

3-90. Lift the weight of the body on the foot by straightening the leg. While the weight of the body is on the one leg, keep the knee straight and away from the pole. Raise the other leg and corresponding arm as displayed in figure 3-16.

3-91. A sharp upward and outward motion of the leg disengages the gaff (see figure 3-16). When taking the next step, raise the left leg and left arm (or right leg and right arm) together. The body should not sway excessively. Reengage the free gaff firmly and continue climbing to the desired height. While ascending, always look up and avoid any possible obstructions. Whether ascending or descending, the gaffs should travel in a path on the face of the pole (approximately 4 1/2 inches apart). This may vary slightly, depending on the size of the climber.

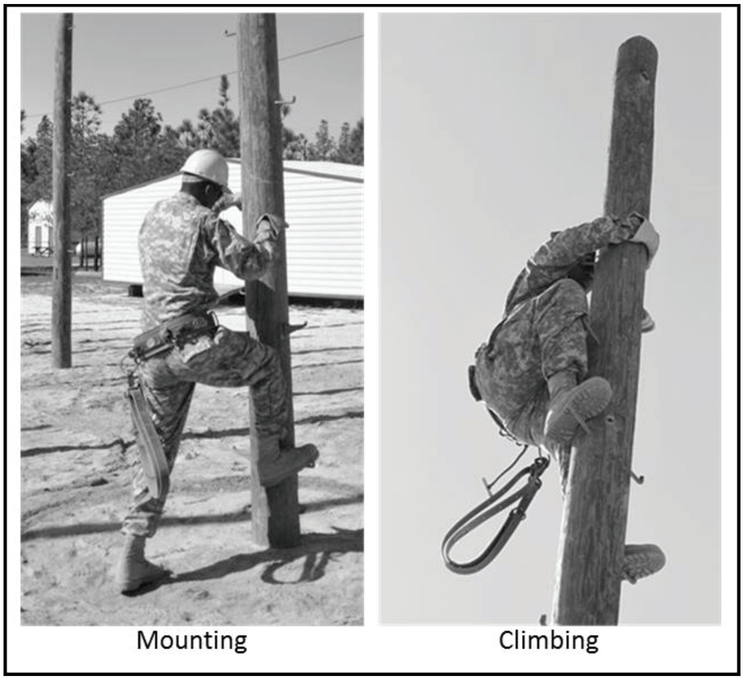

Figure 3-16. Climbing process

Fastening the Safety Strap

3-92. To fasten the safety strap at the top of the pole, proceed as follows (as shown in figure 3-17 on page 3-20)—

1. Shift the weight to the left foot and engage the right gaff at a slightly higher level than the left gaff.
2. Place the right hand around the pole. With the thumb of the left hand, open the keeper on the snap-hook and shift the end of the safety strap around the pole to the right hand.
3. Transfer the snap-hook and strap to the right hand, while balancing the body with the left hand.
4. Loosely support the strap on the pole and with the right hand pull the strap around the right-hand D-ring while keeping the left hand on the safety strap. Snap the hook on the D-ring with the heel of the right hand.
5. Lean back, carefully placing the full weight of the body on the safety strap adjusts body position and feet to take up a comfortable working position. Lean to the left and to the right to test full adjustment of the safety strap.

Note. It is essential to ensure proper engagement of the snap hook. Do not assume from the snapping noise of the keeper, that the D-ring engages the snap-hook.

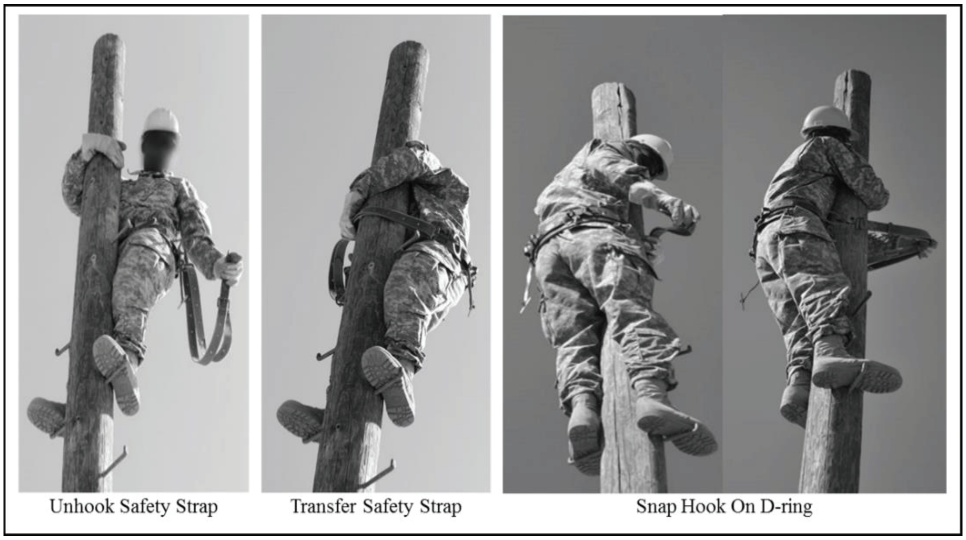

Figure 3-17. Unhooking safety strap

3-93. Figure 3-18 displays correct positions while working on poles.

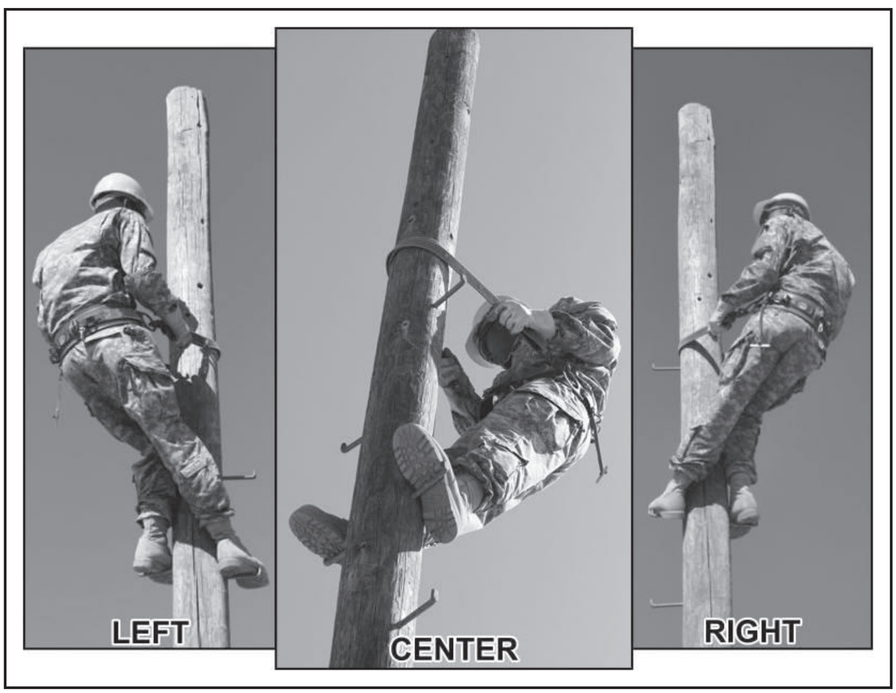

Figure 3-18. Work position posture

Working Aloft

3-94. When working aloft on a pole, never place the safety strap within 12 inches of the top of the pole or above the top cross arm. To reach the outer right insulator, hook the safety strap below the cross arm. Place the right foot slightly lower and to the side of the pole. Straighten the right knee. Adjust the length of the safety strap to allow the climber to work farther out from the pole. If this is the case, adjust the safety strap before ascending.

3-95. When circling a pole to the right, position the right foot slightly lower and to the right side of the pole. (Take small steps.) Stiffen the knee and shift the body to the right, move the left foot close to and slightly higher than the right foot. A slight twist of the hips equalizes the length of the safety strap. Continue in this manner to reach the desired position. To circle left, reverse the above procedure. (Practice circling the pole close to the ground to gain confidence and efficiency).

Unfastening Safety the Strap

3-96. To unfasten the strap, reverse the procedure described previously. Move the right gaff up and reengage it at a slightly higher level than the left gaff. Grasp the pole with the left hand. With the right elbow up, the hand twisted, and the thumb held downward, press the keeper and disengage the snap-hook from the right-hand D-ring. Pass the strap around the pole to the left hand, balancing the body with the right hand. Snap the hook to the left-hand D-ring with a single downward movement.

Descending

3-97. Descend the pole as follows—

1. Lean back then look down between legs to determine which foot to step down with first.
2. Take a small step up with the right foot, unsnap the safety strap, and reconnect it to the left D-ring.
3. Stiffen the right leg, keep the toes pointing upward, take a long downward and inward step 12 to 18 inches, and drive the gaff into the pole. The right knee should now be approximately opposite the left heel.
4. Take a downward step with the left leg.
5. Move the right arm with the right leg and move the left arm with the left leg when ascending or descending.
6. Continue to descend, looking down to avoid any obstructions or defects on the pole.

Pole Climbing Steps

3-98. Ascend the pole as follows—

1. Kick pole to knock sand/mud off boots.
2. Position hands on steps, palms always down, steps are about 18 inches apart.
3. Position your feet on step and use the instep of the foot.
4. Look up and down while climbing.
5. Fasten safety strap (safety on).
6. Adjust belt so that you are sitting on the belt and belt in not above your hips.

3-99. These are the working positions while pole climbing with steps—

1. Left working position.
2. Right working position.
3. Center working position.

3-100. Place the double-end keeper on the “D” ring nearest the body with the “open” part of the keeper facing to the rear of your body. Place the single-end keeper on the “D” ring outside of the double-end keeper with the opening of the keeper facing to the front of your body. While pole climbing with steps, shirt must be tucked into climbing belt and not impose a hindrance. Soldier must remove all jewelry and sharp objects from their pocket.

3-101. Steps for inspection and preparation of pole before climbing are—

1. Inspect area around pole.
2. Locate high side of pole.
3. Inspect pole for damage, cracks, and check base at least 8 inches below ground level for rot.
4. Create and clear a safety circle.
5. Adjust safety strap.

3-102. Steps for descending pole are—

1. Unfasten safety strap (safety off).
2. Lean back; look down between legs to determine which foot to step down with first.
3. Descend pole.

Note. Look down while descending.

INSTALLING CABLE AND WIRE TIES

3-103. Wire ties hold wire in place and relieve strain on a line preventing a disconnection or malfunction. Securely tie the wire to a convenient tree, standard pole, or before connecting it to the binding posts. In addition, tie lines in at various points on a tree or pole. This section details several wire ties: drip loop, clove hitch tie, aerial loop-knot tie, square knot, ground loop knot, basket hitch tie and weave tie.

DRIP LOOP

3-104. Place a drip loop, displayed in figure 3-19, in a lead-in wire with the line tied above the terminal equipment. The drip loop drains the water down the lead-in wire to the bottom of the loop, preventing water from entering the equipment.

Figure 3-19. Drip loop

CLOVE HITCH TIE

3-105. Use a clove hitch tie to secure cables and fasten cables to objects having either an unobstructed top such as stakes, fence posts, preinstalled stub poles, and different types of cables. There are two types of clove hitch ties, clove hitch unobstructed and clove hitch obstructed.

3-106. Use clove hitch unobstructed when required to place a clove hitch over an object, and able to place the loops over the top of the object without an impediment. A clove hitch obstructed (also called closed and clove) is used when required to place a clove hitch over an object and you are not able to place the loops over the top of the pole/stake because you have an impediment.

3-107. To make this a clove hitch tie, as depicted in figure 3-20—

1. Form two loops in the wire.
2. Place the right-hand loop on top of the left-hand loop without turning either loop.
3. Place both loops over the object tying to and tighten the loop.

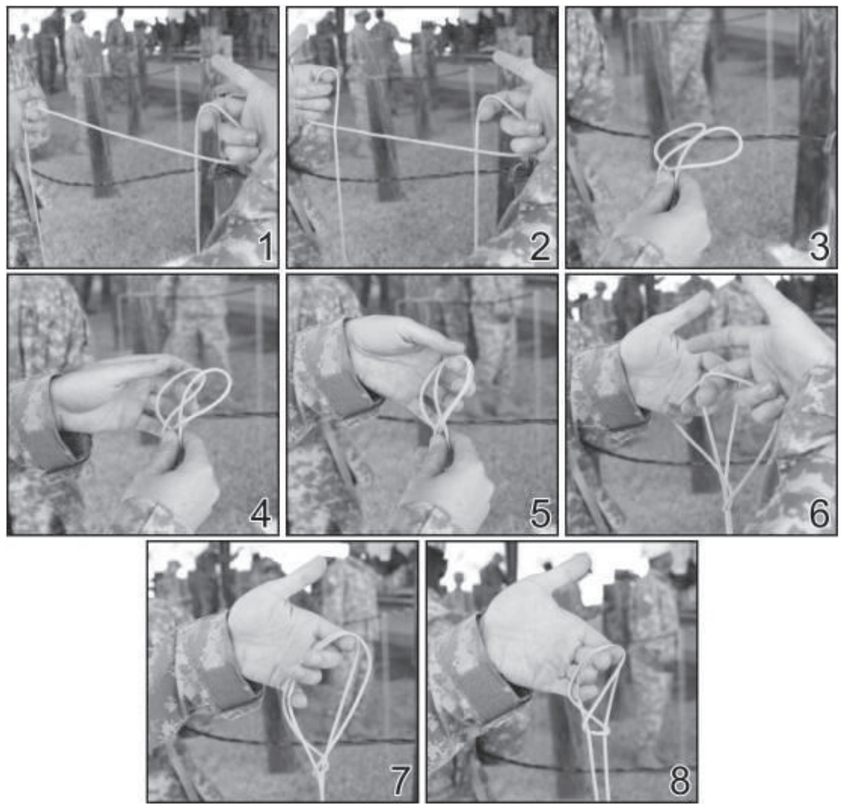

Figure 3-20. Clove hitch tie steps

AERIAL LOOP-KNOT TIE

3-108. Use an aerial loop-knot tie for short temporary aerial spans. See figure 3-21, on page 3-24. Do not use it for long or permanent aerial spans, because the weight of the wire causes the knot to bind, thereby causing damage to the insulation. Do not use it in places where passing personnel, vehicles, or animals can un-tie it accidentally. To make the loop-knot tie—

1. Place the wire between you and the object to which you are tying.
2. Pull enough slack to form a bight (a loop formed by the wire) around the object, plus an additional 3 feet. (Form a longer bight to eliminate climbing of wire to untie the loop during wire recovered later, if needed).
3. Place the bight around the object from the direction of the running end (that part of the line that leads to the wire-laying equipment). If a greater strain is on the running end, place the bight around the object in the opposite direction.
4. Hold the running end, the standing part (that part of the line that has been installed), and the bight in one hand. With the other hand, reach over the running end with the palm down, grasp the bight, and twist to form a loop. (With the palm down, make the twist in only one direction.)

5. Reach down through the loop, grasp the bight, enclosing the standing end and the running end, and pull up to form a double bight.
6. Tighten the knot securely against the object. To unfasten the tie, pull on the lower single loop.
7. Make a ground loop-knot tie (see ground loop-knot tie section) in the same manner as the aerial loop-knot tie, except place the hand under the loop. (With the palm up, twist the loop in only one direction.) Pull the double bight down through the loop, and tighten the knot. The double bight should be down, and the single loop should be up, making it easier to untie.

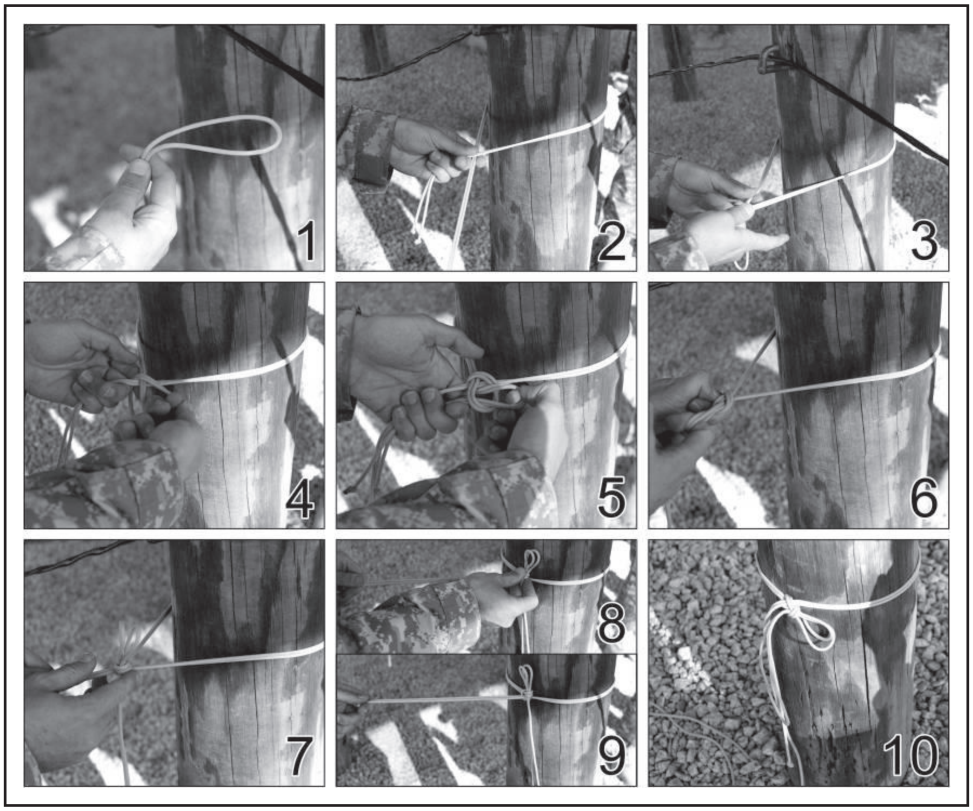

Figure 3-21. Aerial loop-knot tie steps

Square Knot and Ground Loop Tie Knot

3-109. The square knot and ground loop-knot tie, in figure 3-22, on page 3-25, is more secure than the simple loop-knot tie. Use the square knot to terminate ties, and secure the tie in such a manner it will not loosen. To make the square knot and ground loop-knot tie knot—

1. Pull in slack and pass a bight around the object in the direction of the running end. Pull in an additional three feet.
2. Bring the bight over the standing part and running end, and then between the object and the wire.
3. Draw the knot tightly against the object.
4. Bring the bight over the running part to form a closed loop opening.
5. Reach through this opening and pull about 6 inches of wire through the opening to form a double bight.
6. Tighten the tie by holding the double bight in one hand and pulling the running end with the other. To unfasten, pull the lower loop and untie the knot from the object.

Figure 3-22. Square knot and ground loop tie knot

3-110. Make this tie more secure by completing the square knot and eliminating the loop. To make the square knot tie—

1. Proceed as with the square knot and loop tie, but pull the end of the bight through the opening.
2. Tighten the tie by holding the end of the bight in one hand and pulling the running end with the other.

BASKET HITCH TIE

3-111. Use the basket hitch tie in figure 3-23, on page 3-26, to tie wire under conditions of extreme heat, long spans, heavy winds, or icing. Aerial support of multiple pairs of cable and wires requires the use of a basket hitch tie. Fiber optic cables require special attention to prevent damage from bending and pulling during aerial construction. To make a basket hitch tie—

1. Cut a 12-foot length of wire or marline cord.
2. Make a clove hitch around the supported wires. (Wrapping the tie wire around the wire or cable that needs supporting forms the clove hitch). The clove hitch may slip, to prevent this, wrap several turns of the friction tape around the cable before making the weaves.
3. Weave the tie wire around the wires or cable, placing the tie alternately on the inside of one cross and on the outside of the next cross. Tying the wires this way insures the even distribution of the gripping action for the entire length of the tie. Usually, seven crossovers hold the supported wire.
4. Hold the two ends of the tie wire together and make 1 1/2 turns around the support.
5. Separate the two ends. Bring one end over and one end under the standing part of the tie wire.
6. Tie the two ends together with a square knot and cut off excess wire.

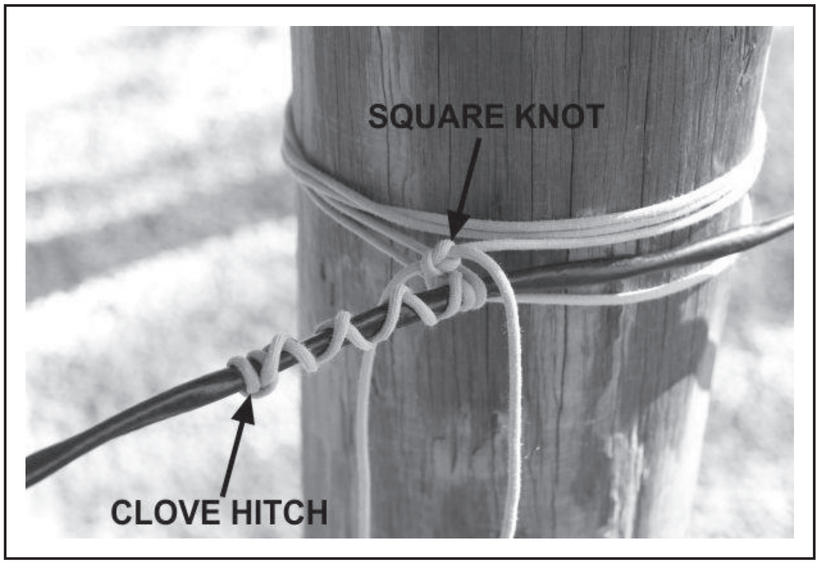

Figure 3-23. Basket hitch tie

3-112. Use two basket hitch ties to support points of aerial span construction with a safety loop. Loop the line around the support so the wire line or cable does not rub against the support. Make the ties as explained in the previous paragraph.

3-113. It is possible to make the basket hitch on the ground before climbing the support for the line. After securing the line to one support, stand at the base of the next support and pull the line tight to the center of the next support at ground level. Measure back towards the first support a distance of 2 feet and start the basket hitch tie at this point. This allows the necessary amount of sag in the line when the span is completed. (Sag is the vertical distance between the lowest point on the line and a straight line between the two points of suspension).

Weave Tie

3-114. The weave tie in figure 3-24, on page 3-27, is a variation of the basket hitch tie used to support multiple-pair cable and aerial wire lines for semi-permanent installations. Use the weave tie to support aerial multi-pair cable on intermediate poles or support only and all aerial-to aerial applications used for semi-permanent installation. Use the weave tie to attach wire to ground supports, such as stakes or trees. To make the weave tie—

1. Select two 12-foot pieces of wire to make the weave tie.
2. Fasten the tie wire to the support with a clove hitch.
3. Separate the twisted conductors at each end of the tie wires. (About 18 inches to complete the tie)
4. Pull the wire up against the clove hitch.
5. Weave the tie wire along the wire at least 8 inches in both directions (Increase the length of the weave for long spans)
6. Terminate the tie-wire ends in square knots.
7. Trim the excess wire from the square knot.
8. Tape the wire to prevent the tie from slipping.

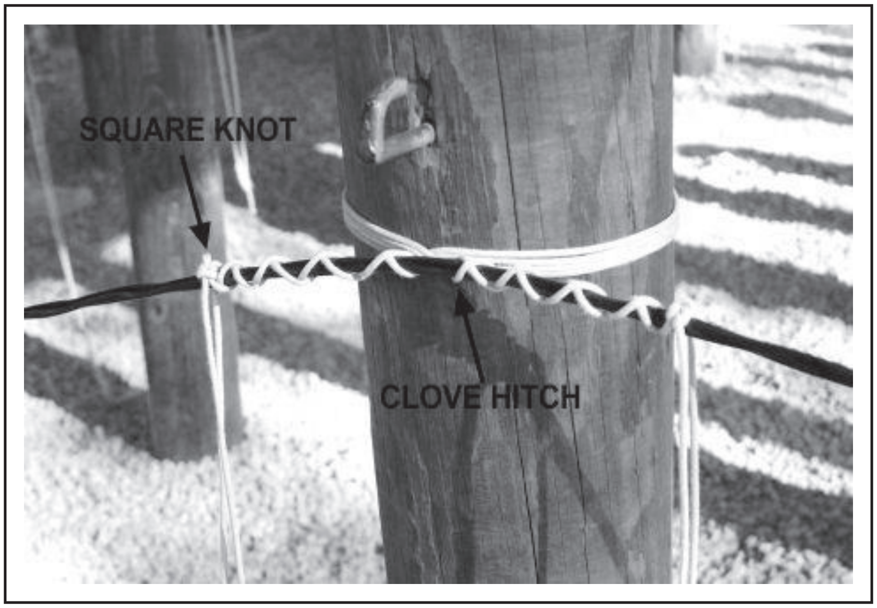

Figure 3-24. Weave tie

SPLICING

3-115. A splice should have the same tensile strength, relative conductivity, abrasion and weather protection, and insulation resistance as the un-spliced portion of the wire. A bad splice causes transmission loss, noise, and impairs the circuit quality.

3-116. Splicing Wire WF-16/U expedient method—

1. Cut conductor flush.
2. Cut the end of the conductors 6 inches.
3. Split the conductors at each end.
4. Remove 3 inches of insulation from each conductor on both sides.
5. Connect each conductor using square knot.
6. Tape each knot with friction tape.
7. Press the wire loops against the knot and wrap with electrical tape.

UNDERGROUND CABLE SYSTEMS INSTALLATION

3-117. Underground cables are any cable placed in a fixed underground conduit system. Underground cable systems find their greatest use in routes containing main feeder cables and branch feeder routes. The use of an underground cable should be considered when—

- Full size cables are required.
- Placing more than two cables on a pole line or buried.
- The possibility of damage to aerial or buried cable exists.

3-118. Underground cables offer many advantages. These include—

- Less susceptible to damage.
- High degree of salvage possible.
- Usage with any size and weight of cable.
- Optimal physical arrangement for splicing.

3-119. The main disadvantage for underground cables is the cost of installation. The cost is considerably higher than aerial or buried cables. However, there is little difference in cost when large cables are involved.

MANHOLE INSTALLATION

3-120. Manholes form the first part of an underground cable system. Manholes are usually made of concrete. Capping the chimney on a manhole are a manhole frame and cover. This arrangement is the most common type of manhole.

3-121. The second component of the underground cable system is the conduit. Conduit can be construct from various types of material. Plastic, fiber, and fiber-cement conduit are available only in single duct form, but are arranged in any multiple required.

3-122. In general, position manholes and conduit in relation to the earth. Ensure to grade in a manner to provide drainage of moisture into the manholes. It is important to bail or pump out manholes filled with enough water to hinder or prohibit work, the water.

Placing Guards and Warning Devices

3-123. Since most manholes are located under streets, highways, and alleys, those working at manhole locations are subject to traffic hazard, unless manholes are adequately guarded. Ensure to use barricades, manhole guards, flags, men working signs and other suitable devices.

3-124. When guarding manholes it is better to use more than may appear necessary. Obey all regulations concerning traffic control, warning signs and guards.

3-125. Place warning devices to indicate the presence of open manholes. Place warning devices before opening manholes. In roads, place the warning devices in the lane in which the manhole is located. On heavily traveled highways, place a barricade about 300 feet from the manhole to warn drivers.

3-126. Place additional warning devices on the approach to provide ample warning of danger ahead for manholes hidden from view by a hill or curve. The number of warning devices will depend on local conditions. Place succeeding warning devices about 300 feet apart.

3-127. After replacing the manhole cover, remove all warning devices. Keep warning flags clean and replace them when needed. Display lanterns when conditions apply, as in between sunset and sunrise.

Removing Manhole Covers

3-128. After placing your warning devices and manhole guard, you are ready to remove the manhole cover. Manhole covers are heavy and require at least two people to handle them. Use manhole hooks to remove them. If you encounter a frozen manhole cover, you can thaw the ice with hot water. Never try to chip the ice with a tool or use open flame because of the buildup of dangerous gases in the manhole, of which many are explosive.

3-129. Because gases accumulate in manholes, you must be able to test for these gases before you enter the manholes. These gases are poisonous and explosive. Always test the manhole for gas. Do not enter the manhole until test results indicate a satisfactory atmosphere.

3-130. Use an approved portable gas detector that detects carbon monoxide, poisonous/combustible gases and the lack of oxygen. Ventilate the manhole continuously, using an artificial ventilation method. Continue to test the manhole for gas at frequent intervals to ensure a safe working atmosphere.

Water Removal

3-131. There are two types of water pumps to remove water—

- Centrifugal: gas powered and has to be primed before using.
- Submersible: Can be AC, DC or hydraulic powered. Lower the whole pump in the manhole to pump out water.

Ventilation Procedures

3-132. Proper ventilation of manholes and cable vaults is required to maintain satisfactory atmosphere necessary for safe working conditions. The three methods of ventilating manholes are artificial/ forced, natural and advanced ventilation.

3-133. Use artificial or forced ventilation when there is a heavy concentration of gas or when the manhole contains a light concentration of gas, but insufficient air currents to permit the natural ventilation method.

3-134. Use natural ventilation when sufficient air currents exist near the manhole, a light concentration of gas is contained in the manhole and ventilating equipment is not available. This method requires hanging a blanket or strip of muslin (approximately 2 feet wide) from the top of the manhole guardrails. The cloth must extend down into the manhole and hang so the air currents flows into the manhole.

3-135. Use the advanced ventilation method when you will be working in several manholes in the same conduit run. In such cases, open several manholes along the run and leave them open for a period sufficient to expel the bad air.

SELECTION OF DUCTS

3-136. Make the selection of ducts in advance of work operations as shown on the detail plans. Select ducts for new cables, as they are required.

3-137. When selecting the duct for any particular cable, do not assign a duct the occupancy of which may block other vacant ducts or racking positions on the manhole wall. Bear in mind that, in some cases, a good assignment in one manhole may prove bad in the next manhole.

3-138. The largest manholes and heaviest cable runs are often nearest the central office. For this reason, select ducts in these sections first to maintain the best cable conditions in the heaviest runs. Designate conduits by size of cable.

SPLICE POINTS

3-139. Always leave enough overlap of cable to ensure that there is plenty of cable to splice or install into terminals or other associated hardware.

INSPECTION AND MAINTENANCE OF CABLE

3-140. All strategic cable inspection and maintenance consists of the following steps—

1. Check the cable sheath for cracks or breaks.
2. Check lashing wire for looseness.
3. Examine splice closures.
4. Check nuts and bolts.
5. Check racking in manholes.
6. Examine grounds.
7. Check pressure valves in pressurized cables.
8. Check duct seal around cable.

TERMINAL

3-141. Use terminals as an interface between the main cable and the users' equipment with house wire and the cable connected to modular connector blocks inside the terminal.

3-142. Remove terminals for repair and maintenance as required. Look for any foreign object or broken parts in the terminal when performing maintenance. Check for loose wire, bent or damaged terminals, damage to the cable, pairs in the wrong place, and bad Ground.

Cross Connect Box

3-143. A cross connect box is an enclosure that is usually found at intersections, beside the road, or at other convenient locations that will bring the cable up out of the ground or down from the air. It allows the ability to make cross connects to smaller cables that serve other sub-cables or facilities.

Service Entrance Panel

3-144. The service entrance panel is the panel within a building where the main cable terminates and provides lightning protection to both the cable and the customer terminal equipment. Cross connection, capabilities are provided to send the signal either to a station (such as telephone, fax, or computer) or to a satellite.

BURIED CABLE

3-145. This section will discuss some advantages and uses of buried cable, as well as considerations when installing buried cable. This section will cover the primary equipment that the Army uses to physically locate buried cable and detect faults without having to extract the buried cable. Using the Dynatel 2273-advanced cable and fault locator accomplishes both tasks. This section will also provide instructions on how to employ the Dynatel 2273 advanced cable and fault locator.

BURIED CABLE

3-146. Buried cables are cables buried directly in the ground. Buried cables find their greatest use in long runs where distribution is extremely limited. They are also main feeder and branch feeder cables where only one or two cables are required.

3-147. Use buried cables in distribution plant to avoid physical hazard or damage. They also provide better appearance and used when the cost of underground cables and conduit cannot be justified.

3-148. Buried cables have many advantages. One of the main advantages is that splicing locations can be anywhere, manholes, permanent splice pits, or even trench or plow run. In addition, installers can splice branch cables to them at any location.

3-149. Buried cables are more susceptible to physical and electrical damage than underground cable and can cost more, depending upon site and amount of cable installed. Short runs may cost twice as much per foot as long runs and the physical location may not permit use of a trenching machine or a cable plow.

3-150. The methods of trenching buried cable depends on soil conditions, the lay of the ground, the route of the cable, and the equipment available. Installers usually conduct maintenance of buried cable at splice points. If damage is extensive then replace the cable without removing the old cable.

DYNATEL 2273-ADVANCED CABLE AND FAULT LOCATOR

3-151. The Dynatel 2273-advanced cable and fault locator consists of a transmitter and a receiver, Figure 3-25 on page 3-31, for locating buried cables. It also measures and pinpoints sheath faults in buried cables and conductor faults in aerial cables. The transmitter provides four frequencies to accommodate varying factors such as distance, cable type, or soil conditions. If desired, transmit all four frequencies immediately. The transmitter also provides a separate tone function for identifying cables and pairs. The receiver provides four locating modes to accomplish fast or difficult tracing and to pinpoint or verify a conductor. The receiver detects 50 or 60 Hz AC power signals and also measures the signal current in a cable and displays its magnitude. Installers can also display the depth of buried cables or sondes.

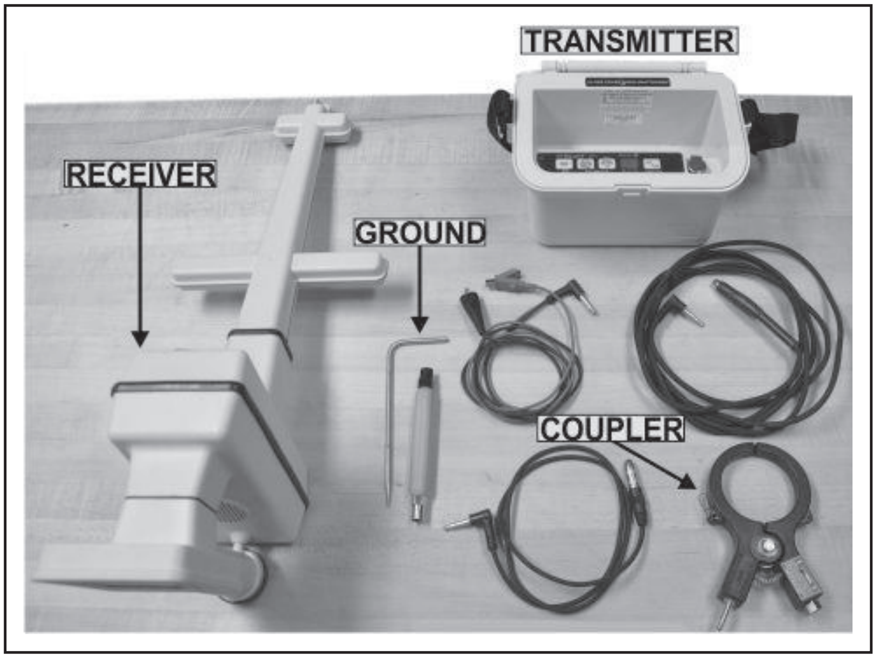

Figure 3-25. Dynatel 2273 advanced cable and fault locator

Transmitter Description

3-152. The transmitter, figure 3-26, provides a frequency source for cable testing and location. The transmitter also includes a built in ohm meter for cable testing. A LCD provides the operator with status information of the transmitter as well as setup. The transmitter is controlled via four button selectors on the front panel:

Figure 3-26. Dynatel transmitter

- Use the "off" button (far left button) to turn the system off and to perform the battery test.
- Use the next two selectors to turn the transmitter on and select the mode of operations.

- The second button is used to select one of three functions:
  - Activate ohms mode by pressing the button once and is represented by the omega symbol. Use this mode to take the ohm (resistance) measurements on a cable.
  - Pressing the button twice activates the fault mode. The numbers 577 and 33K will flash alternatively, representing that the transmitter is producing 577 Hz and 33 kHz simultaneously.
  - Pressing the button a third time, will activate the tone mode. The numbers 577 and 200k will flash. This represents the receiver producing 577 Hz and 200 kHz simultaneously.

3-153. The third button is the trace button. This button activates the cable location mode. Pressing this button repeatedly will cycle through all four transmit frequencies of 577 Hz, 8 kHz, 33 kHz, and 200 kHz displayed on the LCD. When ALL displays on the LCD, all four frequencies transmitted simultaneously.

3-154. The last button is the output level button, pressing this button allows for the selection of output levels for the transmitter. The following output levels selections are available: ½ watt, 3-watt and 5-watt. The default or normal output of the transmitter is ½ watt. No flag above the output icon on the LCD indicates that the transmitter is in normal output. Pressing the output button will select 3-watts, which is the high output mode. A flag above the output icon on the LCD indicates that the transmitter is in high output mode.

3-155. Connecting the transmitter to an external power source will allow for 5-watt operations. A flashing flag above the output icon on the LCD indicates the 5-watt operation.

Receiver Description

3-156. Use the receiver, figure 3-27, to detect the transmitted signal from the transmitter or for detecting frequencies present on a cable in use. Also, use the receiver to locate the position of a fault on a buried cable. Configure the receiver using the input buttons on the front panel.

Figure 3-27. Dynatel receiver

3-157. The system configuration displays on the large LCD. The selector descriptions are as follows:

- The power button turns unit off and on.
- The speaker button adjusts the volume of the receiver. Configure the receiver for the volume to be off, low, med, high, and expander (Xpand). Use the Xpand mode to pinpoint a target cable or pipe.

- Control contrast of the screen with the arrows located above and below the contrast.
- The two gain buttons adjusts the sensitivity of the receiver up or down to maintain a satisfactory signal level.
- The locate/ok button sets the receiver to trace mode for locating cable or pipe. Also, use the locate/ok button to acknowledge setup entries.
- The menu button displays the setup screen for configuration of the unit.
- The backlight button toggles the backlight through low, high, and off.
- The four yellow soft keys on the receiver vary in function; their function displays on the LCD above the key. The functions will change, depending on the operation mode of the receiver.

3-158. The receiver also has an external access panel, figure 3-28. The access panel contains an external jack port to connect cables from external devices such as the earth frame, a second dyna-coupler, or toning coil. A serial port is available to connect the receiver to a personal computer via a straight serial cable. The third connection is an earphone jack that fits a standard 1/8 inch mini-jack mono earphone plug.

Figure 3-28. Dynatel receiver access panel

Transmitter Battery Test

3-159. To test the Batteries, press and hold off button. Listen to the tone and watch the display. A solid tone and 'OK' indicates the batteries are good; a beeping tone and 'LO' indicates the batteries are low; and no tone and '- -' indicates the batteries need to be replaced.

Note. The battery test indicates battery condition for normal output levels. When selecting the high output selection, if the unit resets use the normal output level or replace the batteries.

Reciever Battery Test

3-160. Whenever turning the unit on, test the Receiver batteries for two seconds. You can extend the time interval by pressing and holding the power button. During the battery test, a bar graph displays and should extend to the right of the battery level mark, otherwise replace the batteries. When the batteries are low, the battery test indicator will flash.

DANGER!

Voltage greater than 240 volts will damage equipment and cause personal injury and death. Make all direct test connections before turning on the Transmitter, then activate the Transmitter in the Ohms mode and check the display for voltage readings. Follow standard procedures for reducing the voltage.

WARNING!

Potential for electrical shock exists when handling connecting cables while the Transmitter is in the TRACE, FAULT or TONE modes. Turn the Transmitter off before handling connecting cables.

Transmitter Direct Connect Method Setup

3-161. The following steps discuss how to setup the Dynatel 2273 using the transmitter direct connect method:

1. Plug the direct connect cable into the output jack of the transmitter. Connect the black clip to the ground rod. Place the ground rod in the earth perpendicular to the suspected cable/pipe path (see figure 3-29).

Figure 3-29. Direct connect ground rod connection

2. Remove the ground bonding and attach the red clip to the shield of the cable, pipe, or target conductor. See figure 3-30 on page 3-35.

Note. If locating power cables, attach the red clip to the transformer cabinet, or the meter box.

Figure 3-30. Direct connect cable connection

3. Turn the transmitter on by pressing Ohms button. The continuity of the circuit will be measured. The results are displayed in ohms on the display and as a tone.
   - If the continuity of the circuit is very good, the reading on the display is less than 3K Ω. and a solid tone sounds from the transmitter. All frequencies can locate. Always use the lowest frequency available. Lower frequencies are less likely to bleed over to other cables in the same area, and are very good for tracing over long distances.
   - If the circuit reads more than 3K Ω. but less than 1OK Ω, indicated by a beeping tone from the transmitter, it will be necessary to use a higher frequency than 577 Hz to locate the cable/pipe.
   - If the circuit reads more than lOK Ω., it will be necessary to use a radio frequency (RF) signal of 33 KHz.
   - If there is no tone and the transmitter indicates that there is an open circuit, OL in the display, this could be an indication of a poor ground, or an open-ended cable or pipe. Use 200 kHz at a high level. If it is an open-ended cable or pipe, the receiver's response will decrease suddenly at the site of the clear or severed end.

Note. In the ohms mode, the transmitter can detect voltage as well as ohms. If the transmitter detects a low voltage, the display will alternate between displaying ohms and volts. When displaying ohms, the flag over the Ω symbol will be visible. When displaying volts, the flag over the V will be visible. When the voltage magnitude is sufficient to impair the accuracy of the ohms measurement, only voltage displays. If the voltage is alternating current, a sine wave will be visible on the display. If the transmitter detects a high AC voltage, a rapid beeping tone sounds.

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4. Press the Trace button repeatedly until the desired frequency appears on the display.
5. Press Output button to select high output level for longer tracing distances or deep pipe or cable.

Transmitter Dyna-Coupler Method Setup

3-162. The following steps discuss how to setup the Dynatel 2273 using the transmitter dyna-coupler method—

1. Connect the dyna-coupler to the transmitter output jack using the coupler cable.
2. Clamp the dyna-coupler around the cable or pipe, below any bonds, just before it enters the earth. The jaws of the coupler must fully close, see figure 3-31 on page 3-36.

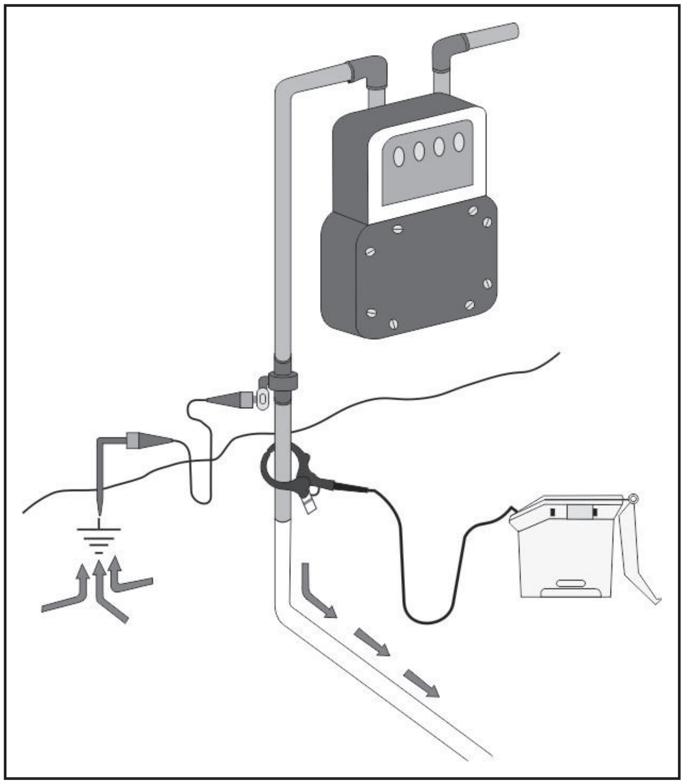

Figure 3-31. Dyna-coupler connection

3. Press Trace to turn on the transmitter. Press again to select 8 KHz, 33 KHz or 200 KHz.

Note. When using a Dyna-Coupler, always select high output level by pressing the output key on the transmitter.

Transmitter Induction Method Setup

4-1. If you cannot make a direct connection, or use the Dynatel dyna-coupler clamp to apply a locating signal on the target, use the induction method. This method uses the internal coil of the transmitter to generate a magnetic field. This is the least preferred method of applying a signal on a target conductor because other non-target conductors in the area can easily pick it up. However, it is the preferred method of applying a signal to multiple cables or pipes in the same trench. The following steps discuss how to setup the Dynatel 2273 using the transmitter induction method:

1. Verify the battery level of the transmitter and remove any cables from the output jack.
2. Position the transmitter over the target facility with the hinge of the transmitter over and in line with the cable/pipe path, see figure 3-32.

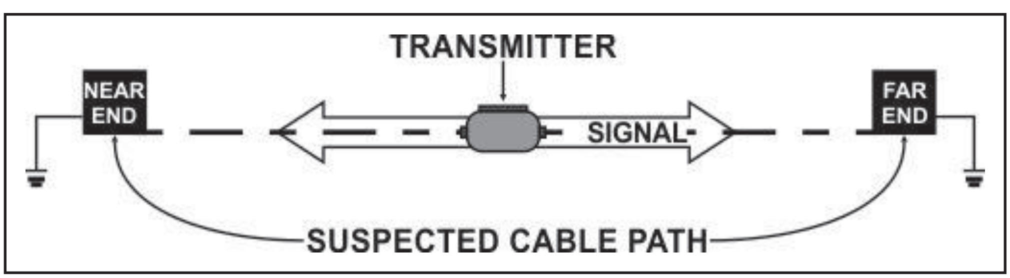

Figure 3-32. Dynatel induction method

3. Align the Induction Direction arrows on the transmitter with the target conductor.
4. Turn on the transmitter by pressing the Trace key.
5. Press Trace again to select 33 KHz or 200 KHz.
6. Select High Output level for the best signal-to-noise ratio.
7. Trace the signal path with the receiver using the Induction Peak mode.
8. The induction mode of the receiver is a mode in which the upper antenna of the receiver is tuned to minimize distortion from the magnetic field of the transmitter.

Note. The receiver must be at least 25 feet away from the transmitter to begin tracing the target path.

Receiver Direct Peak Mode (Dir Pk)

3-163. Use the yellow soft key selectors on the receiver to place the receiver in the direct peak mode. Select mode and directional peak (Dir Pk).

3-164. In Dir Pk mode, use four peak antennas to analyze the magnetic field pattern. The bar graph displayed on the LCD indicates signal strength and the directional arrows sense the edges of the magnetic field. The left and right arrows will indicate the direction to the nearest cable in-line with the receiver handle.

3-165. As the antenna crosses the cable or pipe, the receiver speaker volume increases to a maximum, the bar graph fills from both sides toward the middle, and the numeric signal strength increases. As the antenna moves off the target path, the speaker volume decreases and the bar graph opens. Use the bar graph and the numeric signal indicator to locate the exact target path, see figure 3-33.

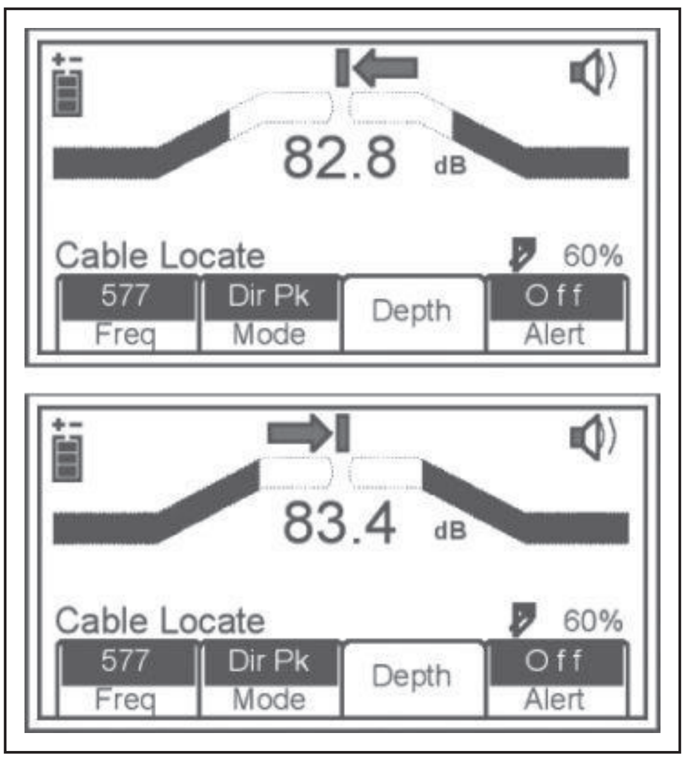

Figure 3-33. Directional peak, off target

3-166. Once the target path has been located, the arrows at the top of the screen will indicate the location of the target path in relationship to the receiver. See figure 3-34 on page 3-38.

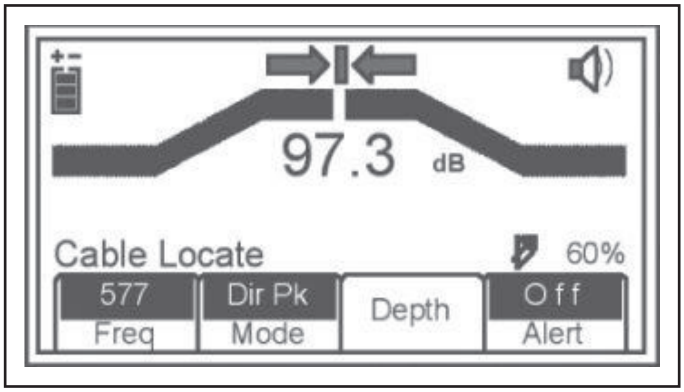

Figure 3-34. Directional peak, over target

Note. When field distortion, due to congestion, is affecting the receiver, the left and right arrows may not coincide with the bar graph. Use the maximum numerical signal strength to target the cable or pipe.

Receiver Directional Null Mode (DirNull)

3-167. Use the yellow soft keys on the receiver to place the receiver into the directional null mode (DirNull) by selecting mode and DirNull.

3-168. In DirNull mode, as the operator approaches the cable or pipe, the numerical signal will increase then fall sharply as the receiver crosses the target cable or pipe. The bar graph fills from both sides toward the middle and the receiver speaker volume decreases. As the antenna moves off the target path, the bar graph opens, the signal strength increases, and the speaker volume increases. Gain adjust is automatic in DirNull mode.

3-169. The center of the DirNull screen provides a compass view of the target path. An arrow will point toward the location of the cable or pipe in 45-degree steps. A solid line will appear over the cable or pipe, indicating its orientation to the receiver handle. See figure 3-35 on page 3-39.

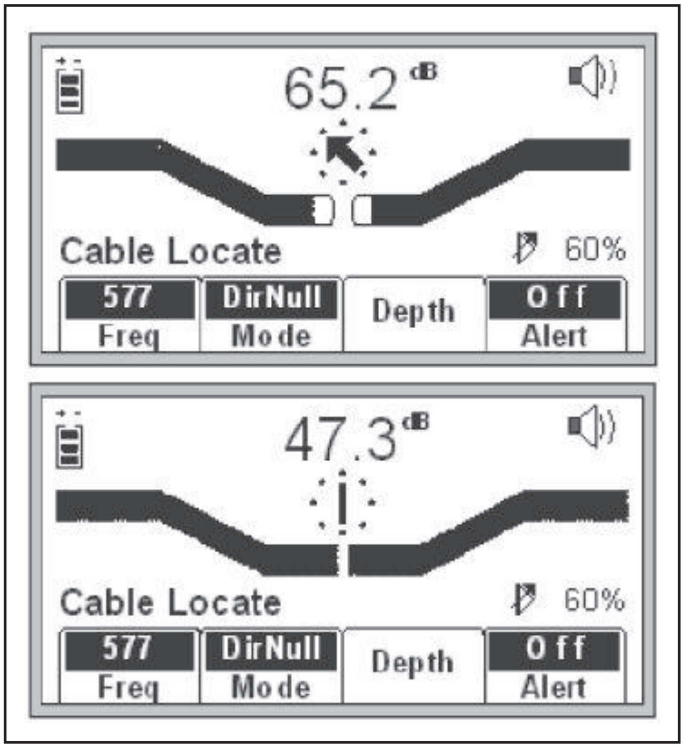

Figure 3-35. Directional null

Note. Before marking target path, always use directional peak or special peak mode to verify location.

Receiver Special Peak Mode (Spl Pk)

3-170. Use the yellow soft keys on the receiver to place the receiver into the special peak mode (Spl Pk) by selecting mode and Spl Pk.

3-171. Special Peak Mode turns on only the peak antenna closest to the ground. Use Special Peak Mode in applications such as very deep cable, or if the signal is too weak for normal or directional peak tracing.

Receiver Inductive Peak Mode (Ind Pk)

3-172. Use the yellow soft keys on the receiver to place the receiver into the inductive peak mode (IndPk) by selecting mode and IndPk.

3-173. If you cannot make a direct connection, or use the dyna-coupler clamp to apply a locating signal on the target, use the induction method. This method uses the internal coil of the transmitter to generate a magnetic field.

3-174. The induction mode of the receiver is a mode in which the upper antenna of the receiver that is tuned to minimize distortion from the magnetic field of the transmitter.

Reciever Peak with Expanded Mode

3-175. Use the yellow soft key selectors on the receiver to place the receiver in the direct peak mode. Select mode and directional peak (Dir Pk). Press the speaker button to select High-Expanded.

3-176. The third ring of the speaker icon will appear dotted or broken and 'xpnd' will appear below the speaker icon, the receiver is in "Expanded" mode. Use this mode for pinpointing a target cable or pipe. The area of response of the receiver narrows, allowing the locator to detect very small signal changes.

Depth and Current Estimates

3-177. To get a depth and current estimate, locate the cable or pipe that requires measurement. Lower the tip of the receiver to the ground and press the yellow soft key marked Depth. The depth to the target cable or pipe displays on the LCD. The bold current reading is a relative current measurement. Compare this reading to the current reading that alternately flashes with the frequency on the transmitter. The milliamp reading is an actual current measurement. See figure 3-36.

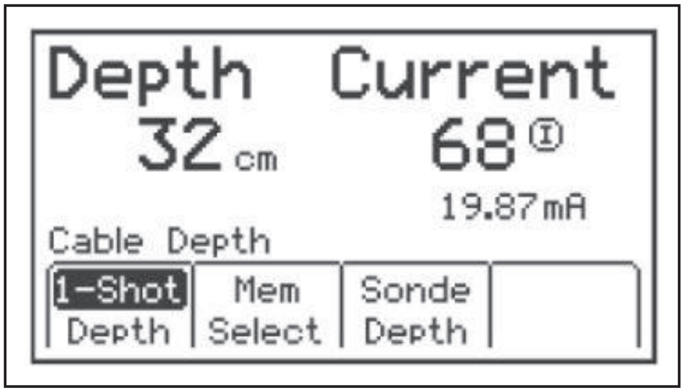

Figure 3-36. Depth and current estimate

3-178. There are two options for measuring depth. Pressing the depth soft key will toggle between these modes. Live depth is a continuous measurement.1-Shot Depth is an averaging of the depth reading. When in 1-Shot mode, the unit will average the depth reading for three seconds, and then display the result on the screen.

WIRE AND CABLE INSTALLATION IN DIFFICULT CONDITIONS

3-179. Often installers are required to install wire and cable in difficult environments and weather. This section will discuss some challenging instances and provide some suggestions on how to mitigate through these challenging obstacles.

WIRE LINES CROSSING ROADS

3-180. During the construction of wire lines, it is necessary to cross roads. Accomplish this by placing the lines through a culvert, installing aerial lines, or burying the lines. Ladder the wire across hard-surface roads that are subject to wheeled-vehicle traffic and do not permit burial. Accomplish this by cutting the wire and by splicing one or more lengths of twisted pair to each conductor. Lay these lines across the road in parallel paths at distances greater than the longest vehicle expected to use the road. Splice the ends of the laddered arrangement to the original conductor on the other side of the road in the identical manner. When properly staked, these laddered lines (each rung serving as a single conductor) provide initial communication, and replace laddered lines with an aerial crossing when policing the line.

3-181. Placing wire lines through culverts is the fastest method of getting wire lines from one side of the road to the other. Pass the wires through the culvert, tie, and tag at each end of the culvert. Place stakes at an angle so that the wire line tied to the stakes is tight and near the top of the culvert to protect it from water and debris. Where the wire lines contact the culvert, wrap the wires with friction tape to prevent damage to the insulation.

3-182. Suspend aerial lines across roads from trees, poles, or other supports. Tie aerial lines at ground level, as well as aerially. Tag these at the base of the support on both sides of the crossing just above the tie.

3-183. Lay wire line across a road by burying using the following process—

1. Dig a trench 6 to 12-inches deep across the road. The trench should extend at least 2 feet beyond each side of the road. In loose, sandy soil, a trench at least 3-feet deep is necessary to afford protection from tracked vehicles.

2. Lay the wire loosely in the trench and place the stake 1 foot from where wire comes out of the ground.
3. Tie the wires to a stake at each end of the trench and tag wire approximately 6 inches from tie on outside of stake.
4. Back fill the trench with dirt. Do not place stones or sharp objects on the wire when backfilling the trench. These objects could crush the wire insulation when passing vehicles cross over the trench.
5. Leave enough slack on the running end of the wire, rolled up and taped, to permit replacement of the wire in the trench if damage occurs. Another useful technique for wire replacement is to place a spare wire in the trench with the working wire; tag and tie to stakes, with sufficient slack for splicing, the spare line.

WIRE LINE CONSTRUCTION UNDER RAILROAD TRACKS

3-184. When a wire line crosses railroad tracks, exercise great care in selecting the crossing site. If possible, the lines should cross underneath, through culverts, or aerially on bridges or viaducts. If none of these is available, lay the wires under the rails. To accomplish this—

1. Pull sufficient slack from the wire reel to reach across the railroad track.
2. Cut the wire at the reel and pull the end of the line under the rails of the track.
3. Bury the wire lines from the rails to a point outside the shoulders of the track.
4. Tie the line at the far end to a stake. Pull the line taut and tie it to another stake.
5. Splice the free end to the end of the wire on the reel. Place tags approximately 6 inches from the stake on both sides of the railroad tracks and continue to lay the line.

WIRE LINE CONSTRUCTION CROSSING RIVERS

3-185. When laying a wire line across a river, lay it on a bridge, construct an aerial span, or submerge it under water. Where a bridge is used, attach the wire lines to the bridge so that traffic will not damage the lines. When possible, make a multi-pair wire cable by combining all wire lines crossing the river. Attach the cable to the bridge supports below the road surface.

3-186. Make a narrow stream crossing in the same manner as the aerial construction to cross roads. The wire lines vary in height, but must be high enough to clear waterborne traffic. For long-span construction across streams, support wire lines using a steel suspension strand.

3-187. Submerge wire to cross a stream. The longer the wire remains in the water, the more rapid the circuit quality deteriorates and the talking range of the submerged wire decreases. Selecting the proper crossing site is the most important factor when crossing a stream. Make the crossing at a point where there is little vehicular traffic and the stream flow is relatively slow. After selecting the, proceed as follows—

1. Lay the wire line to the stream bank and tie it securely to some object such as a tree or stake.
2. Tag the wire line at the tie.
3. Bury the wire line to the water's edge. (Be sure that there is enough un-spliced wire left on the reel to cross the stream. If there is not enough, cut the line and splice on a new reel.)
4. Lay the wire across the stream, and anchor it in several places. Anchor at both sides of the stream and several times in the middle, depending on the width of the stream. There are many ways to lay wire across streams (rafts, trucks, helicopters, or boats).
5. Bury the line on the far shore from the water's edge to a tree or stake on the bank of the stream.
6. Tie the wire to the tree or stake.
7. Tag the wire line at the tie, and continue to lay the line.

WIRE AND CABLE INSTALLATION IN EXTREME WEATHER

3-188. Terrain and climatic conditions affect speed and types of construction used in installing wire and cable lines. Speed of installation, however, should not restrict good construction practices. Wire lines installed under unusual conditions require greater care than those installed under normal conditions. Some of the construction practices that should be emphasized are as follows—

1. Tag wire lines more often for identification during maintenance.
2. Install test stations to facilitate maintenance.

3. Use suitable wire ties for the climatic conditions and to the type of construction. Make wire ties carefully to hold the wire lines in place.
4. The construction techniques discussed in the beginning of the chapter apply to construction under unusual conditions of terrain and climate. Certain factors that are peculiar to each condition of terrain or climate are in succeeding paragraphs.

WIRE CONSTRUCTION IN MOUNTAINS

3-189. The construction and maintenance of wire lines in mountainous terrain is usually more difficult than in other areas. The lack of roads may make it necessary to lay wire lines by man pack wire-laying equipment. In addition, the laid wire lines require constant maintenance because of ice, rock falls, and snow slides.

3-190. In selecting the routes for wire lines, it may be necessary to make an aerial reconnaissance of the area as aerial reconnaissance more clearly identifies roads and trails from the air. As required establish supply points along the routes to accommodate airdrop delivery of supplies by helicopter. Constructing lines above the snow line or during the winter, construct the lines aerially on trees or lance poles to facilitate locating of the wires for maintenance.

WIRE CONSTRUCTION IN ARCTIC AREAS

3-191. Modify the construction techniques for wire lines for use in arctic areas. Construct wire lines aerially in arctic areas to protect from deep snow and vehicle and foot traffic. Utilize lance poles for aerial construction when there is limited availability of trees and telephone poles. The following paragraphs note other construction techniques unique to arctic areas.

3-192. A heated shelter mounted on a 2 1/2-ton truck or tracked vehicle provides wire-laying crews in arctic regions a good facility for wire laying. The shelter keeps the wire warm and pliable when splicing and feeding the wire out the rear door of the shelter. In deep snow, the shelter should be mounted on a tracked vehicle or if possible a high flotation vehicle to ease movement over the snow.

3-193. To place the aerial wire lines, proceed as follows—

1. Tie three lance poles together at the top to form a tripod.
2. Never tie wire lines in arctic areas. Bending the lines causes crack and break the insulation, causing a short circuit.
3. Use Electrical Insulation Tape TL-600/U (polyethylene) when taping wire lines for any reason. This tape retains its adhesiveness in cold climates.

WIRE CONSTRUCTION IN DESERT AREAS

3-194. Desert areas provide the most suitable climatic conditions for installation and maintenance of wire lines. Wire lines properly installed and maintained give good service for a long time. Certain factors peculiar to desert areas require consideration during wire construction. Since there are no trees or poles in the desert, utilize lance poles or other erected supports for aerial construction. However, aerial wires are easily identified from the air and difficult to conceal.

3-195. Buried wire lines give good service in the desert. To ease identification and maintenance, tie and tag buried lines when splicing a new reel of wire to the line. Plot on a map the location, and direction of buried wire to ease maintenance. At frequent intervals tie and tag, wire lines laid on the ground as shifting sand covers the lines and makes location of the lines difficult.

WIRE CONSTRUCTION IN TROPICAL AREAS

3-196. Continual dampness and fungus growth in jungle areas reduces the effective range of wire lines. Utilize the construction techniques listed in the following paragraphs to maintain the effective range and extend the life of wire lines. Selection of the best route for a wire line is extremely important to construction and maintenance. Ground reconnaissance is more effective than aerial reconnaissance, because dense jungle growth hides trails and roads from aerial observation.

3-197. Utilize repeaters and amplifying telephones to increase the range of wire circuits. Laying two wire lines, using two wires for each side of the circuit, increases the range of wire circuits. When using two wire lines for one circuit, one wire of each pair is connected together for one side of the circuit, and the other wire of each pair form the other side of the circuit to prevent cross talk and extraneous noise (unless the lines are spaced and transposed on insulators as open wire).

3-198. If possible, construct aerial wire lines on forestry-type insulators (Insulator IL-3/G). This type of construction gives better service and requires less maintenance than wire lines laid on the ground. When maintenance becomes difficult, emplace wire maintenance teams at close intervals along the lines. Maintenance is easier when installing test stations at frequent intervals. Tag the lines often for ready identification.

WIRE CONSTRUCTION IN CHEMICALLY, BIOLOGICALLY, RADIOLOGICAL, NUCLEAR, AREAS

3-199. In many instances, it is not possible to avoid chemical, biological, radiological, and nuclear contaminated areas when installing wire or cable line throughout an area of operations. Some areas of the battlefield may receive contamination with liquid chemical agents on the ground and vegetation, while in other areas a vapor hazard may exist (especially from downwind vapor hazard concentrations). In these instances, Soldiers should wear the joint service lightweight integrated suit technology equipment to accomplish the mission.

3-200. For wire or cable installations, communications are especially difficult in a chemical, biological, radiological, and nuclear environment. Speech is difficult to understand because of the voice emitter in the mask. Voice communications while wearing the joint service lightweight integrated suit technology protective mask are impaired, both in volume and in quality, on communications equipment. Hearing is impaired because of the hood. Field of vision narrows because of the eye lenses, and identification of personnel is difficult.

ESTABLISHING AND TESTING CABLE SECTIONS

3-201. Install test stations at important wire line junctions to simplify locating and clearing trouble on wire lines. In wire installations, test stations consists of one or more terminal strips. Test stations may or may not be manned. A manned test station coordinates with the technician on the line for rapid troubleshooting. The wireman should previously arrange signals or instructions to the test personnel to monitor a particular circuit. If need be, a simplex or phantom circuit can be set up temporarily to help in this operation.

3-202. As soon as each section of cable is installed, test and connect it as follows—

1. Beginning with the first section of cable, test it for opens and shorts. If the tests are negative, connect the first section of cable to the second section.
2. After installing the second section of cable, test the connected cable sections for opens and shorts. If the tests are negative, connect the first two sections to the third section and install the third section of cable.
3. Continue the above method until all sections are tested and connected to form the cable line.
4. If one section tests positive for opens or shorts, repair this cable section or substitute a new section.
5. After cable sections have been tested and connected, connect the cable to the terminal equipment. The terminal equipment operator then makes a system test. When the cable system is in operation, place the cable on aerial supports.

TROUBLESHOOTING TACTICAL WIRE CIRCUITS

3-203. Maintenance of field wire lines includes both the prevention and the correction of circuit failures. Prevention of troubles on wire lines and equipment begins with careful planning and selection of wire routes, and continues with installation of a system that uses approved methods of construction. Trouble may occur, regardless of the care with which the circuit installation takes place. To efficiently diagnose and correct circuit failures, maintenance personnel should be familiar with common troubles to field wire lines and their effect on circuit quality and speech transmission.

Common Issues Associated with Tactical Wire Circuits

3-204. Trouble occurs either in the wire line or in the terminal equipment connected to the line. Wire circuit failures include open circuits, short circuits, grounded circuits, crossed circuits, or combinations of these defects at one or more points in the circuit. These common troubles are defined as follows—

1. A short circuit, or short, occurs when the two conductors of a pair come in electrical contact. Shorts are usually the result of damaged or stripped insulation.
2. An open circuit, or open, is a break or cut in one or both conductors of a pair. It occurs most frequently on long-span aerial construction or at other stress points.
3. A grounded circuit, or ground, occurs when one or both conductors of a circuit come in electrical contact with the ground or a grounded object. Grounds are the result of damaged insulation or poorly taped splices. They occur most frequently during rainy weather or during installation of the line in wet or damp areas.
4. A crossed circuit, or cross, exists when two conductors, each of a different circuit, are in electrical contact. It occurs most frequently in field wire cables supported on aerial spans, at points where multi-pair wire lines converge, or installed along the same route.

Symptoms of Trouble on Tactical Wire Circuits

3-205. Field wire troubles can exist in various degrees of severity. For example, opens and shorts can cause intermittent troubles often difficult to locate. In this case, the wireman must utilize test instruments and logical troubleshooting procedures to determine the nature and location of the trouble. Symptoms are as follows—

1. An open disrupts communications completely. An intermittent open, caused by a poorly made splice or loose contact, introduces a high resistance in the circuit. It may be possible to communicate over a highly resistive circuit, but the transmission is usually weak and noisy.
2. A complete (low resistance) short disrupts communications completely. A partial (high resistance) short usually causes weak transmission and signaling.
3. A ground on both sides of a circuit produces the same effect as a short. Usually, a ground occurring on one side of a circuit will not interrupt communications; however, it introduces hum or noise in the circuit.
4. A cross usually causes cross talk or interference between the two crossed circuits. This cross talk or interference can make the separate conversations unintelligible.

Methods of Testing Tactical Wire Circuits

3-206. Conduct tests on field wire lines before installation to determine condition and serviceability. While constructing a line, test at the end of each reel length and before connecting the line to the terminal equipment.

3-207. Testing during construction will disclose troubles that have developed during the wire laying operation. Proper maintenance requires routine tests at regular intervals on all working circuits and equipment. The frequency of these tests vary according to the nature and importance of the circuits, the equipment, the type of installation, the amount of traffic handled, and the amount of trouble experienced. Never interrupt communications to make a routine test. Maintenance personnel should make routine tests during slack traffic periods. These tests must include all operating functions normally required of the circuit and equipment.

3-208. Conduct tests when a circuit reports or detects trouble on a circuit. The wireman must quickly analyze the fault, determine its location, and clear the trouble with the least possible interruption of service. Reroute high-priority circuits or place spare lines into service at patch panels or test points.

3-209. Conduct tests from the construction center, test station, or switching center utilizing field wire test equipment. If no test equipment is available, a field telephone can be used to determine several types of trouble in field wire circuit and equipment, utilizing the following methods—

1. To test for an open, connect the ends of the circuit to be tested to the line terminals of the test telephone, and turn the generator crank of the telephone rapidly. If the crank turns freely without drag, the circuit is open.

2. To test for a short, follow the same procedures as for open and if the crank turns hard with a heavy drag and a jerky movement, a short exists on the circuit.
3. To test for a ground, connect both conductors of the circuit to the test telephone. Weak communications, noise, and weak reception usually indicate a ground on the circuit.
4. To test for a cross, cross talk and cross signaling indicate a cross on the circuit.

LOCALIZING AND TROUBLESHOOTING FAULTS

3-210. If trouble is on the line after verification, it is necessary to test and localize the fault to the particular section of a circuit. Conduct further tests within the section until the trouble is located. Before testing a line, always check the circuit to determine if it is in use. Never open a circuit that is in operation.

3-211. If tests indicate trouble is in the wire line, the wireman should determine nature and approximate location of the fault. Often, information such as the type of terrain, unusual troop activities, or shellfire in an area, aids the installer in locating the trouble.

3-212. Normally, a wire team physically inspects a line route with the required maintenance equipment. The wire line is carefully examined with particular attention to—

- Condition of insulation and splices.
- Underground and aerial crossings.
- Ties on swaying trees.
- Places where the wire crosses vehicular traffic.

3-213. Along the route, repair and test damaged insulation, poorly made splices, and other possible trouble spots. If there are no issues, run tests at frequent intervals along the line to the terminal testing point.

3-214. When possible, always open a circuit at a splice or at a test point nearest a terminal end. Tape all pierced or removed insulation points on the line that occurred during testing. If each test proves that the line is serviceable toward the terminal testing point, the trouble exists farther out along the line. If the installer cannot communicate with terminal test point, the fault has been passed, therefore the installer works back along the line, dividing in half the distance between successive tests. Since a defective circuit could have trouble at more than one point, it is essential that the repairperson make a complete circuit test after removing each trouble. Steps for testing the complete circuit are—

1. When checking for an open circuit, connect the test equipment across the circuit without cutting the wire line.
2. When checking for a ground or short, it is necessary to cut the line.

3-215. Testing at frequent intervals at the start of troubleshooting procedures delay detection of the line trouble. Splicing the circuit after conducting tests for shorts and grounds requires considerable time. A visual inspection of the wire lines often discloses the trouble sooner. However, if the installer is unable to inspect a long section of the line, tests at each end of that particular section.

3-216. If it is determined, trouble is in the terminal equipment, conduct tests according to procedures listed in the technical manuals on the specific equipment. Only qualified personnel at the proper echelons perform equipment repairs. In certain critical areas, patrols commonly supplement the routine maintenance and testing of sections of a wire line most subject to damage. When possible, assign the wiremen who constructed a given section of a line the mission of patrolling that section. Wire patrols repair trouble where needed, replace poor splices or sections of the line, tape any insulation abrasions, and generally improve the line construction.

USE OF TEST STATIONS IN TESTING TACTICAL WIRE CIRCUITS

3-217. Install test stations on a wire line to simplify the testing and rearranging of circuits. Generally, a test station has a geographic designation assigned. The equipment used at these points are junction boxes. See figure 3-37 on page 3-46. Test stations are usually located—

- At points where circuits diverge.
- At the end of a wire line that does not terminate in a switchboard.
- Near points where circuits are most exposed to damage.

- At probable future locations of command posts.
- At other convenient points along the line.

Figure 3-37. Junction box

3-218. The site selected for a test station should afford concealment and cover from hostile observation and fire. In addition, the site should be readily accessible for testing purposes. A test station consists of one or more junction boxes fastened to a tree, fence post, or other support. Tag and tie wire circuits before connecting to the binding posts of the terminal strip in the junction box at a test station. Connect the circuits in numerical order, beginning at the top with the lowest numbered circuit. Install a test station after initial installation of the wire lines, ensuring that the installation occurs without any interruption to communications service.

3-219. When abandoning a test station, the usual practice is to leave the terminal strip connected. When removing the test station, splice the circuits. Remove test stations without interrupting communications.

3-220. Typically, establishment of command posts occurs at a former test station location. When converting a test station into a telephone central, it is important to place wire lines aerially or bury the wire line, and ensure to setup the switchboard as near the test station as possible to simplify the cutover. Utilize the junction boxes used at the test station as a main distributing frame for the switchboard or as part of a signal center for a switching central. When the transfer is completed, the operator should check the circuits and notify the units concerned. Wire tags should be staggered to prevent one tag from covering another.

3-221. Cross-patching circuits at test stations or switching centrals frequently enable continuous communications during the troubleshooting period. For example, assume that two circuits passed through a common test station connecting two telephone centrals; one circuit has trouble on the near side of the test station, and the other circuit has trouble on the far side. To reestablish one serviceable circuit, take the good section at each side of the test station and connect (crosspatch) the sections together. Restore the original connections after completing the repairs.

Maintaining Records For Troubleshooting

3-222. It is essential to maintain installation and maintenance records. These records, which include line route maps, circuit diagrams, and traffic diagrams, must show all changes in a wire line throughout its operation. In addition, maintain trouble reports, test records, and work schedule rosters when necessary.

RETRIEVAL OF CABLES AND WIRE

3-223. Due to various reasons, an installer may be required to retrieve cable/wire runs. This section will provide insight on things that an installer should consider during and after the retrieval process.

Retrieving Cable and Wire

3-224. Recover cable and wire for re-use whenever possible. Recover cable and wire lines as soon as they are no longer required. After recovery, repair, test, and store the cable or wire in preparation for future use. In cable and wire recovery, an installer removes all tags, unties the cable or wire lines, and places the cable or wire along the side of the road in the path of the recovering equipment. To recover the cable or wire, installers proceed along the line and wind up the cable or wire en route using reeling devices. Under some conditions, it may be necessary to have the recovery equipment stationary, dragging in the cable or wire by hand. Avoid this method if possible because it damages the insulation and may cause the cable or wire to break. Installers must wear leather gloves or use pads to protect their hands during cable and wire recovery.

Servicing Cable and Wire

3-225. The greatest service the Soldier can perform after recovering cable or wire is preventive maintenance checks and services. Always perform preventive maintenance checks and services on used cable, wire, and equipment. This prevents the use of faulty cable or wire in the future. Use soapy water and then rinse with clear water to remove oil and grease on recovered cable or wire. Always cap connector ends when not in use. Ensure to account for all equipment and recondition the cable or wire for future use.

3-226. For wire, mount an empty reel on one reel unit. Mount the reel containing the used wire on another reel unit. Position the reel units to wind to the empty reel from the full reel. Pass the end of the wire through the holes provided on the drum of the empty reel. Secure the wire and allow the ends to protrude from the side of the reel. Leave these ends free for future testing.

3-227. Station one man at each reel and position another between the reels to examine the cable or wire as it winds slowly on the empty reel. Tape each abrasion or break in the insulation. For wire, carefully splice every break in the conductors. Examine each old splice, cut out each poorly made splice, and re-splice the wire properly. Damaged insulation over a long section of the wire, or several splices located very close together, require cutting out the entire section and re-splice the two ends of the wire. For cable, if insulation has any identifiable breaks, abrasions, or damage turn cable in to the communications and electronics section for repair.

3-228. For wire, after each splice and at the finish of the reel, test the wire on the wound reel for open circuits, short circuits, or high loop resistance. A high resistance usually indicates poorly made splices. Tag the reel after servicing the wire.

3-229. For wire, if the wire passes the physical and electrical tests, and repairs/splices are limited to no more than four per conductor per 1/2-mile length, tag it Class A, fully serviceable. Reels or spools that pass the electrical test but have more than four repairs/splices per 1/2-mile length are considered serviceable but should be tagged Class B for training issue only in the zone of the interior or for training purposes only.

Chapter 4

Inside Plant Operations

Inside plant operations is the installation and maintenance of all cabling, wiring, and equipment in a facility. This includes the main distribution frame (MDF) and all equipment extending within the facility, such as the private automatic branch exchange for central office lines, central office equipment, MDF heat coil protectors, and grounding systems.

ENGINEERING INSTALLATION PACKAGE STRUCTURE

4-1. An EIP is the technical document describing the installation steps and acceptance testing of an information systems project. Although the supervisor is responsible for the installation, all team members should be able to interpret the EIP before starting the installation tasks.

4-2. Tailor each EIP to the specific requirements of the site or task. An EIP typically contains the narrative, site preparation, project concurrence memorandum, installation instructions, engineering drawings, bill of materials (BOM), and testing criteria.

4-3. The EIP consists of the following standardized structure—

- Numbering system.
- Cover page.
- Content.
- Format.

NUMBERING SYSTEM

4-4. The Configuration Management Officer (CMO) upon preparation of the EIP issues document identification numbers. The following seven characters are utilized and printed in the upper right corner on all pages of the EIP—

- First character (letter) identifies the major command responsible for preparing the EIP. This character will be one of the following four letters—
  - H-Headquarters-FTH, AZ.
  - C-CONUS-Fort Detrick, MD.
  - E- Europe-Mannheim, GE.
  - K-Far East.
- Second character (number) depicts the initiated calendar year of an EIP.
- Third and fourth characters (letters) identifies the functional element. The following codes apply—
  - SV-Voice.
  - SD-Data.
  - SS-Secure voice/Army airfield.
  - TS-Satellite.
  - TR-Radio.
  - TI-Transmission.
- The last three characters (numbers) identify the chronological order of each command's EIP beginning with 001 each calendar year.

Cover Page

4-5. The cover page includes the project title, project number, organizational data, date, and distribution statement.

Content

4-6. The content includes the signature page and disclaimer page. The signature page includes the project title, project number, distribution statement, directorate name and command name. The signature page also has signature lines for the project team leader and installation activity. The disclaimer page has any changes to the EIP and distribution and disposition instructions.

Format

4-7. Format of the EIP typically consists of four paragraphs and appendices. The following describes each paragraph and an overview of what appendices may consist of—

- Paragraph one (1.0 General) is a project overview that provides a brief description of the project for use by the installing activity to determine required capabilities, team size, and time standard.
- Paragraph two (2.0 Installation Team Responsibilities) identifies actions and responsibilities the installation team is required to perform for the project. This can include, but not limited to—
  - Inventory and inspect the BOM.
  - Redline drawings.
  - Distribute drawings.
  - Approve minor changes to the installation.
  - Use of spares to the installation.
  - Point of contacts for problems encountered.
  - Providing an after action report to the project engineer upon completion of the installation.
- Paragraph three (3.0 Points of Contacts) lists all points of contact information the installation team may need for engineering, material developers, project management, and others as required.
- Paragraph four (4.0 Appendixes) identifies and describes appendices that are included as required for the project.
- Appendixes. The number of appendixes depends upon the engineer and the project. The appendixes are identified alphabetically and the following are most common to an EIP—
  - Installation steps and instructions.
  - Bill of materials.
  - Project concurrence memorandum.
  - Cable running lists.
  - Standard drawings.
  - Site-specific drawings.
  - Validation and test information.

Note. Add other appendices as required.

HAND AND POWER TOOLS

4-8. There are many types of tools available to the installer. This section identifies the various tools and an overview of their use.

Note. Tool handling is an important aspect of the installer's job.

Hand Tools

4-9. There are various hand tools the installer must maintain and understand how to use. Hand tools include screwdrivers, wrenches, sockets, files, hacksaws, hammers, and squares.

Screwdrivers

4-10. The two basic styles of screwdrivers are flat tip and cross tip (Phillips). The two types of tips come in a variety of sizes. Figure 4-1 shows how to select the proper size tip. There are various types of specialty screwdrivers required.

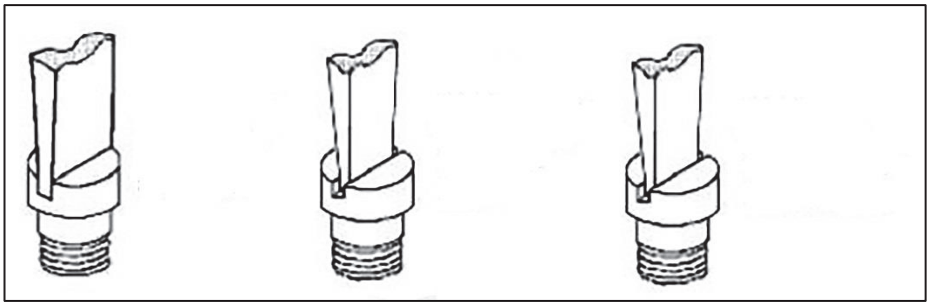

Figure 4-1. Selecting correct screwdriver size.

Wrenches

4-11. Installers use a variety of wrenches. The most common are open end, box end, combination open and box, and adjustable. Select the proper size and type of wrench for the task. A wrench that is too large for the bolt can potentially damage the bolt head.

Sockets

4-12. There are various types and sizes of sockets. Sockets are attached to either a ratchet wrench or a break over bar to tighten, loosen, or apply torque to a bolt. Ensure to use the correct type and size that fits the bolt or damage to the bolt head may occur.

WARNING

Never use a cheater bar to loosen, tighten, or torque bolts or screws. Use a break over bar and socket to apply more torque. Failure to comply may result in injury.

Files

4-13. Files come in various sizes, shapes, and texture. A fine, single cut file will leave a smooth surface. A coarse double cut file leaves a rough surface. Some file sets come with removable handles.

WARNING

Do not use a file without a handle. Failure to comply may result in injury.

Hacksaws

4-14. Use hacksaws on metal only. Ensure to install the blade with the teeth pointing away from the handle. It is possible to rotate the blade up to 360 degrees to make different cuts.

WARNING

Always support the metal item appropriately prior to cutting to avoid binding the blade. Failure to comply may result in injury.

Hammers

4-15. Hammers are available in different weights and types for various tasks. Use the weight of the hammer to do the work by holding it near the end of the handle. Different hammer types include—

- Rubber mallet.
- Carpenters Claw.
- Ball-peen.
- Soft plastic.
- Non-spark.

Squares

4-16. Installers usually uses either a carpenter's square or the combination square. The carpenter's square has markings for making angular measurements. The combination square is multipurpose and adjustable and has a small level and scribe on the top. The scribe can make lines on wood or metal.

GENERAL TOOLS

4-17. General tools are tools not common to any one trade and the Army categorize them as general tools. General tools include soldering iron, tape measures, levels, pliers, and tap & die sets.

Soldering Iron

4-18. Soldering irons can come in either variable or fixed wattages. The recommendation for electrical connections is 60 or 100-watt irons.

Tape Measures

4-19. Tape measures come in various lengths and can be made of cloth, metal, or wood. Metal tape measures are the most accurate of the three.

WARNING

Do not use metal tape measures where they would present an electrical safety hazard, to include live (energized) communications and electronic (C&E) equipment. Failure to comply may result in injury from electric shock.

Levels

4-20. Levels come in various lengths. The longer the level, the more accurate the readings. Handle levels with care as they often break when dropped.

Pliers

4-21. There are numerous types of pliers. Select pliers for the particular task being performed. Different pliers include lineman's pliers and slip joint pliers.

4-22. **Tap & die set.** The tap cuts threads inside a metal object drilled to size. The die cuts threads on rods or bolts. Tap & die sets are categorized as either standard, national fine (NF), or coarse thread.

WIREMAN'S AND INSTALLER TOOLS

4-23. Wireman's/installer tools are specialized tools used only in the installation trade. Wireman's/installer tools include wire strippers, butting and stripping tools, electrician scissors, soldering iron, and spudgers.

Wire Strippers

4-24. Wire strippers are tools designed to strip the insulation off individual conductors without damaging the wire. Two types of wire strippers are Miller strippers and Bradley strippers, see figure 4-2. Miller strippers are adjustable and used on various sizes of insulated wire. Bradley strippers come in set sizes and you must use different models to strip different size wire. Bradley strippers come with or without a wire cutter. If they come with a wire cutter, will leave 1 5/8" of bare wire (shiner) for wire wrap purposes.

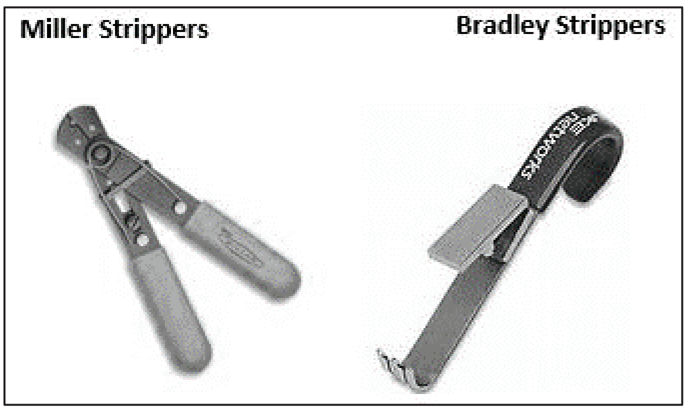

Figure 4-2. Wire strippers

Butting and Stripping Tools

4-25. Use butting and stripping tools to cut through the protective covering or sheathing on a signal cable. Three types of butting and stripping tools are-the Neuses Butter; the Neuses cable stripper; and the Kabi-fix (see figure 4-3 on page 4-6).

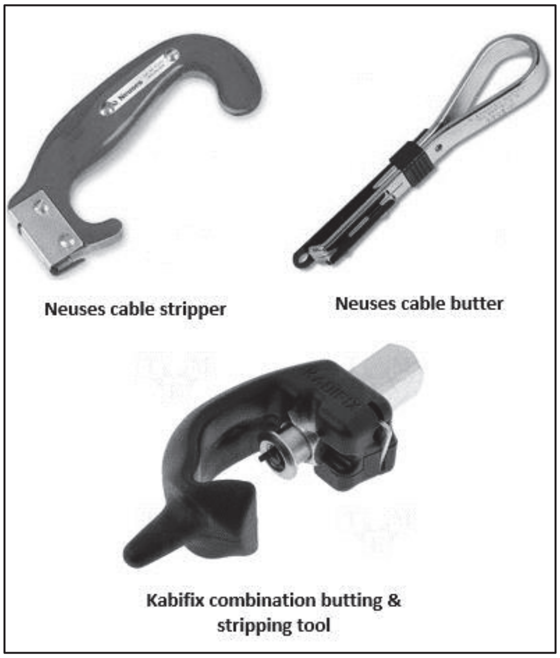

Figure 4-3. Cable butting and stripping tools

The Neuses Butter

4-26. The Neuses Butter is also known as the razor edged butter and will cut plastic, fabric, or rubber cable sheathing. It can cut to a maximum depth of 1/32” and can handle a cable up to one inch in diameter. Use this butter in conjunction with the Neuses cable stripper.

The Neuses cable stripper.

4-27. The Neuses cable stripper strips cable jackets from all sizes of plastic and fabric covered cables. If used properly, it will not damage wires or binder markers.

> ***Note.*** The blades on the Neuses stripper and the Neuses butter are not interchangeable and are not adjustable for sheath thickness.

Kabi-Fix

4-28. This tool can both butt and strip a cable. The cutting blades rotates 360 degrees, allowing it to go automatically from a circular butt cut to a lengthwise strip cut. The blade is adjustable for different cable sheathing thickness.

Electrician Scissors

4-29. These are small, sturdy scissors with scrapers and files on the outside of one blade. Some have a serrated blade to minimize wire slippage and the other blade has notches to strip 19 through 23-gauge wire.

Soldering Aids

4-30. Come in various combinations of tool ends. The metal repels solder even when in contact with flux, see figure 4-4, page 4-7. Some tip styles are—

- Brush/fork.
- Brush/scraper.
- Hook/fork.

- Straight.
- Angled reamer/fork.
- Scraper.

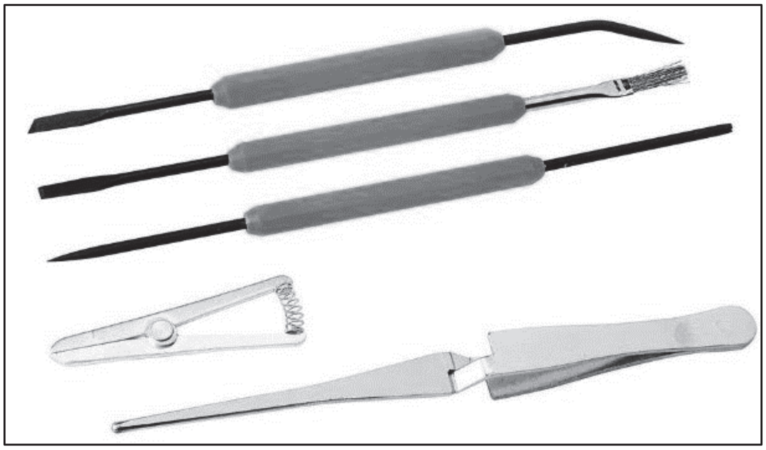

Figure 4-4. Soldering aids

Spudgers

4-31. **Spudgers** are made of vulcanized fiber or fiberglass and used where metallic tools are impossible to use because of energized circuits. Use for forming conductors and as an aid in many other installer tasks (see figure 4-5). Some spudgers points are—

- Flat and tapered.
- Blunt.
- Long and coned

Figure 4-5. Spudger (flat)

POWER TOOLS

4-32. Power tools that the installer should be familiar with are the sawzall, worm driven saw, Greenlee Hydraulic Knockout, hammer drill, electric drill, jigsaw, circular saw, and portable band saw. This section will covered these power tools in-depth.

WARNING

Be extremely careful when operating power tools and ensure to wear hearing protection. Failure to comply may result in serious injury and hearing loss.

CAUTION

It is a tendency of saws to lift and back-out of the work piece when the blade binds, or encounters resistance. This can occur when using a dull blade or improper support.

Sawzall

4-33. The sawzall is a reciprocating or non-reciprocating, rough-cut, hand held power saw used to cut different material (see figure 4-6). It has a blade action control lever labeled either Wood/Metal or 2/1. The wood/2 position causes the blade to go up and down, keeping the blade free of debris. The metal/1 position uses an in and out motion.

4-34. Use the sawzall with different types of blades for different types of material. The blade color codes are as follows:

- **Wood.** Color codes are silver, black, or orange.
- **Metal.** Color codes are red, yellow, or blue.
- **Plaster.** Color code is white.

Figure 4-6. Sawzall

Greenlee Hydraulic Knockout

4-35. The Greenlee Hydraulic Knockout is a manual pump tool that comes with punch cups and cutters in the1/2–4 inch range of conduit sizes. The pump cuts a hole large enough to pass the conduit through. Pull the cutter and cup together by hydraulic pressure until the unit goes completely through the metal. The knockout cuts metal up to 10-gauge (see figure 4-7 on page 4-9).

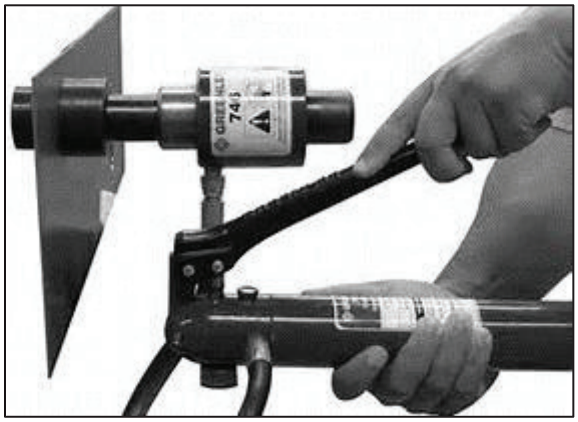

Figure 4-7. Greenlee hydraulic knockout

Hammer Drill

4-36. Also called a rotary hammer used for masonry. Use where the amount of pebbles, stone or other hard aggregate in the concrete makes use of carbide tipped masonry drills difficult. The hammer drill can use spline or slotted shank drill bits. Spline drill bits range in size from 1/2” to 1 ¼”. Slotted shank drill bits range in sizes from 1/4” to 1”.

4-37. Accessories include the chuck head, anchor ejector key, the star or twist drill, and blow out bulb. Use a hammer to drive the star or twist drill for starting holes for the hammer drill. Also, use the hammer and star or twist drill when the use of the hammer drill is impractical. Additionally, use the star or twist drill to break up pebbles or hard aggregate when setting self-drilling anchors (see figure 4-8).

Figure 4-8. Hammer drill

Skill Worm Driven Saw

4-38. Also called the circular saw, can hold a variety of blades for cutting wood, metal, or masonry. It has an upper and lower guard, two handles, line guide, bevel, and depth adjustment (see figure 4-9 on page 4-10).

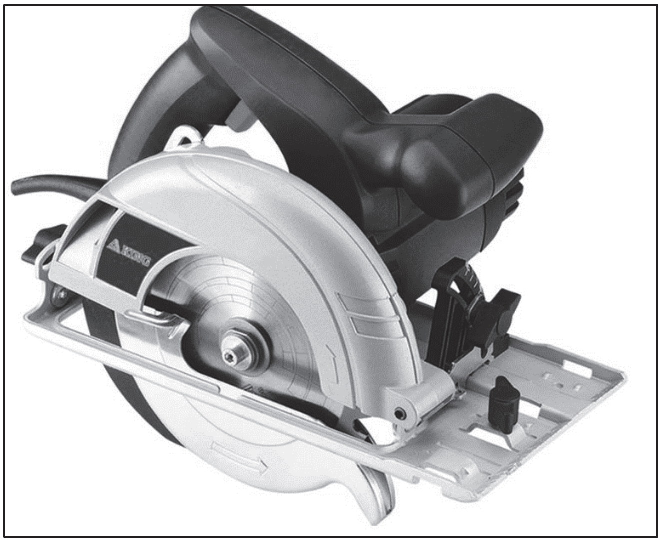

Figure 4-9. Skill worm driven saw

MARKING THE SITE LAYOUT

4-39. Marking procedures are methods used by installers to lay out and mark an area in preparation for equipment installation. Install equipment in a facility as shown on the floor plan drawing. Installers must draw lines on the floors, walls, or ceilings to mark the location of the pre-installed equipment (also called *marking the site layout*). The following tools are used to mark a site layout:

- Chalk of various colors.
- Grease pencils.
- Level, 24 inches long.
- Rule, wood, folding, 6ft.
- Fabricated compasses.
- Transparent tape.
- Chalk line and reel.
- Felt tip markers.
- 16 oz. plumb bob.
- Carpenters square.
- 6 ft. stepladder.
- 12 ft. stepladder.
- Steel and linen measuring tapes.

MARKING SITE LAYOUT PROCEDURES

4-40. Verify that the dimensions and reference points on the drawings match those of the room itself. In an empty or partially equipped area, that has no energized equipment, use a steel measuring tape. If using a linen tape, double-check measurements with a wooden ruler.

4-41. Whenever possible, lay out and mark the entire room before placement of equipment and installation materials. This includes laying out lines for equipment that will be attached to walls, ceilings, or supported from overhead. This will also assist with identifying measuring errors.

4-42. When using a chalk line, ensure to sufficiently coat the line with chalk by stretching the line taut, extending the ends a minimum of 6” past intersecting lines or the end of equipment lineups. This provides a means of checking alignment of equipment. Snap the chalk line approximately centered in increments on 10’ to 15' while continuing to hold the ends in place at the reference points. To avoid bouncing the chalk line, snap it along the edge of a square (see figure 4-10).

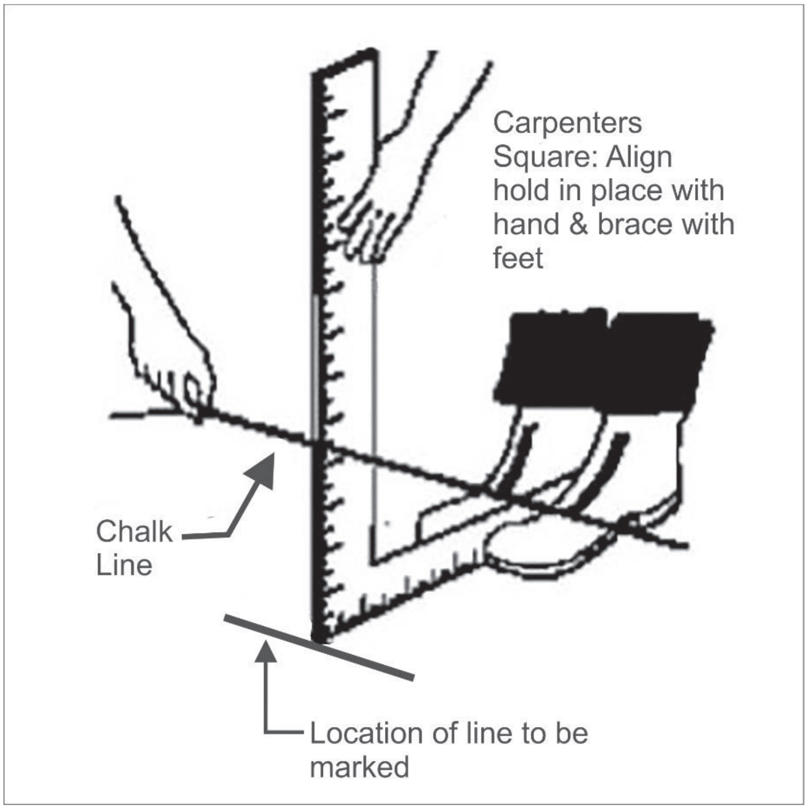

Figure 4-10. Using a square to avoid bouncing the chalk

4-43. To preserve the chalked lines, retrace each chalk line with a grease pencil or marking crayon sharpened to a fine point. Protect the lines with transparent tape or shellac. Fabricate a compass to draw the arcs required to laying out the site (see figure 4-11).

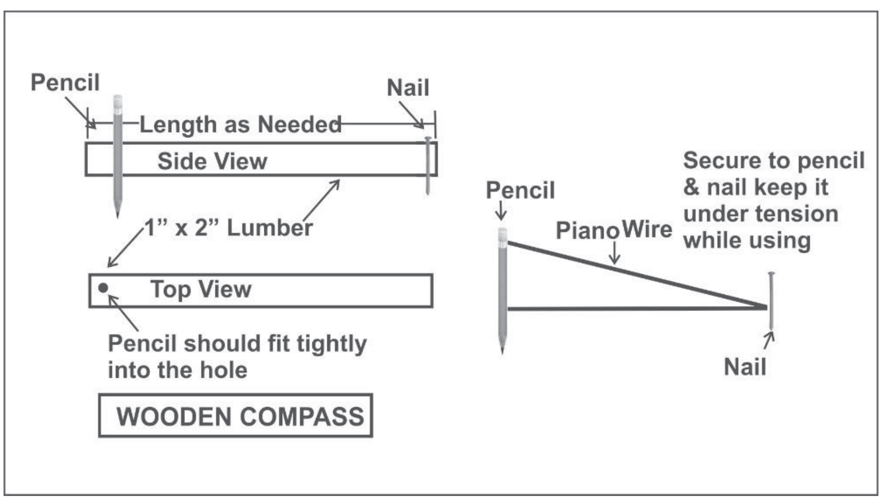

Figure 4-11. Fabricated compass

MARKING REFERENCE LINES

4-44. A reference line is a straight line laid between two or more predetermined points, parallel to the longest unbroken wall in a room. Make all measurements for equipment layout markings from the reference line. Use two methods when marking reference lines. They are—

- Level and square method.
- Plumb bob method.

Level and Square Method

4-45. Level and square method. Place a carpenter's framing square upright on the floor with the longer side parallel to the wall and butt the end of the shorter side against the wall. Place the level along the side and shift the square until it is plumb, but still in contact with both the wall and floor. Mark the point of contact between the floor and bottom of the inner edge of the square. Any marks made this way will be fourteen inches from the wall (see figure 4-12).

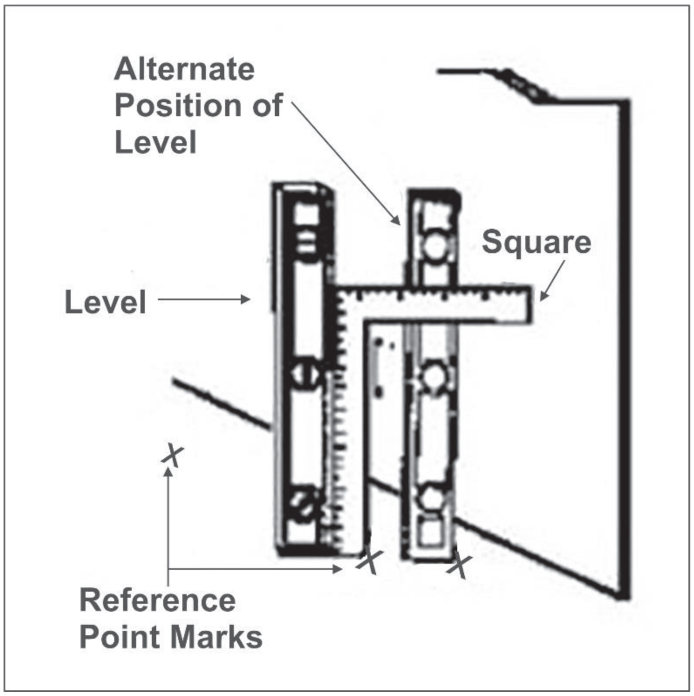

Figure 4-12. Level & square method

Plumb Bob Method

4-46. Place the longer side of a framing square against the wall approximately 3 feet above the floor. Plumb the square with a level. Drop a plumb line from the short side of the square and mark this point on the floor. The plumb bob must hang from the same point of the square for each succeeding operation. Mark the floor in at least three locations, one near each end of the wall, and the third near the center. The more marks the better the chance of detecting deviations in the wall. See figure 4-13, page 4-13.

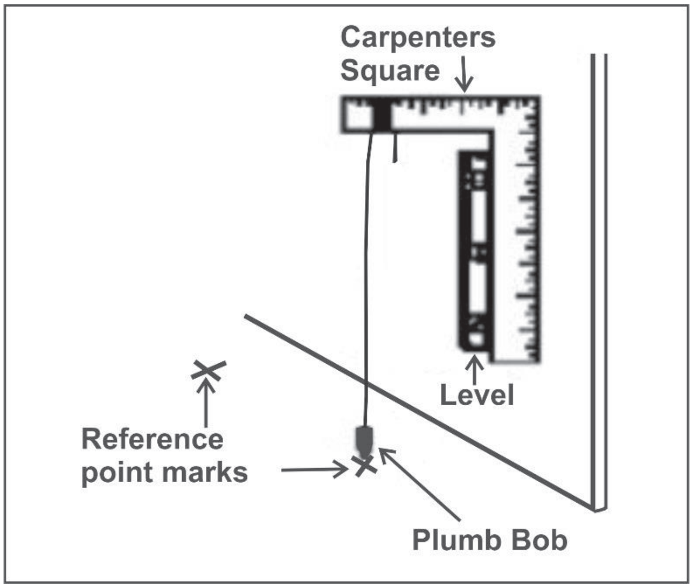

Figure 4-13. Plumb bob method

CHALKING LINE USE

4-47. After marking the reference points using either the level and square method or the plumb bob method, stretch a chalk line to intersect the points and snap the line on the floor. When reference points are not directly in line due to variations in the wall structure, mark the chalk line so to intersect the greater number of points, including those at either end.

MARKING BASE LINES

4-48. Equipment room walls may not be at true ninety-degree angles, nor are they necessarily true through their entire length. Since it is not practical to draw a line of considerable length at a right angle to another using a carpenters square, use either the 3-4-5 method or the geometrical bisection method to mark a true ninety-degree angle.

3-4-5 Method

4-49. Use any multiple when using the 3-4-5 method if space is not restricted. For example, the numbers can be double to 6-8-10 or tripled 9-12-30 and so on, if space allows. This is the best method for laying out right angles in corners or confined areas. See figure 4-14 on page 4-14. The following are the steps to use the 3-4-5 method—

1. Using the EIP drawing, determine where the right angle is to be located. Mark the location on the reference line or base line and label it point 1.
2. From point 1, measure 4 feet along the reference or base line and make a second mark labeled point 2.
3. Using a 3’ long fabricated compass, swing an arc perpendicular (90 degrees from point 1).
4. Using a 5’ long fabricated compass, swing an arc from point 2 to intersect the arc made at point 1. Label the intersection of the two ars as point 3.
5. Snap a chalk line through point 1 and point 3, holding the ends of the chalk line beyond both points. This line will be at a righte angle to the base line.

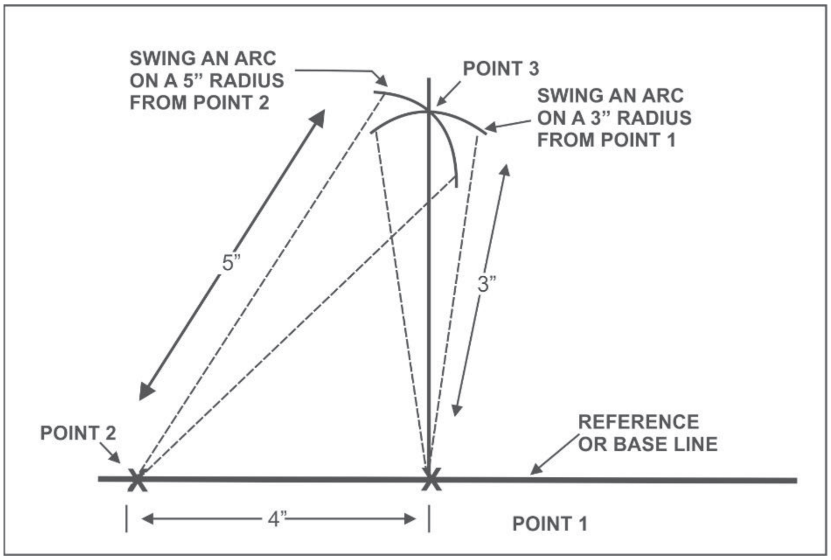

Figure 4-14. 3-4-5 method

Geometrical Bisection Method

4-50. The geometrical bisection method (also called the linear bisection method), is another method that can be used for laying right angles (see figure 4-15). The following steps discuss how to apply the geometrical bisection method—

1. Use the EIP drawings to determine where the right angle is to be located. Mark the location with an "X."
2. Measure along the line an equal distance on either side of the "X" and mark these points as "A" and "A1" as shown in figure 4-15 on page 4-14.
3. From "A" and "A1", using a fabricated compass, swing arcs an equal distance above and below the "X." Mark the points where the arcs intersect as "B" and "B1."
4. Snap a chalk line through the marks of "B", "X", and "B1", if the three points are not directly in line, check all measurements for errors and make the necessary corrections.

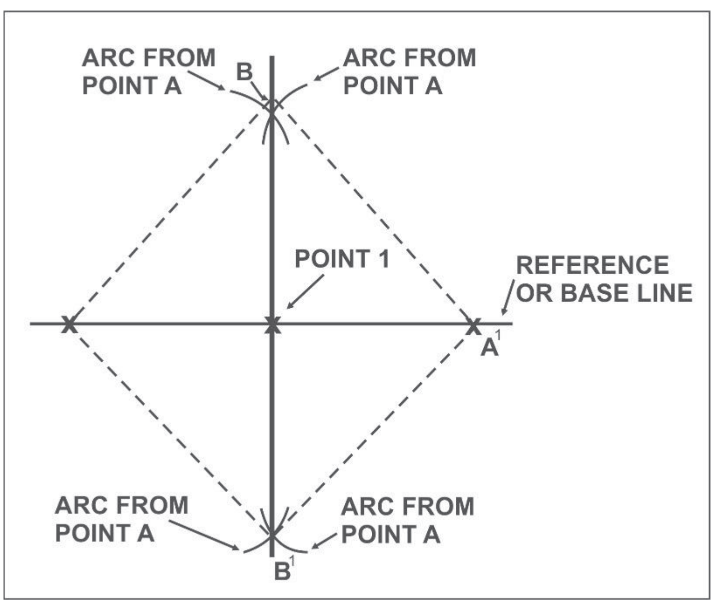

Figure 4-15. Geometrical bisection method or linear bisection method

EXTENDING LINES BEYOND OBSTRUCTIONS

4-51. Occasionally an extended line that extends past existing equipment or similar obstructions is required. This can be accomplished by using one of three methods—

- Bisecting Arcs.
- Tangents of Arcs.
- Right Angle Method.

Bisecting Arcs

4-52. The bisecting arcs method uses arcs swung from the base line (see figure 4-16). Steps to perform the bisecting arcs method are as follows—

1. Mark three equal points A, B, and C, on the reference line. Lengths AB and BC must be equal distance apart.
2. Using a fabricated compass with a radius long enough to clear the obstruction, swing intersecting arcs from A and B; and B and C.
3. Snap a chalk line through the points of bisection (points where the arcs intersect). Make sure the chalk line is long enough to project the line past the obstruction.
4. Repeat above steps from the projected line swinging the acrs in the opposite direction. Use the same measurements for A1, B1, and C1 as for A, B, and C.
5. Snap a chalk line through the second set of points of bisection. This new line is an extension of the original reference line.

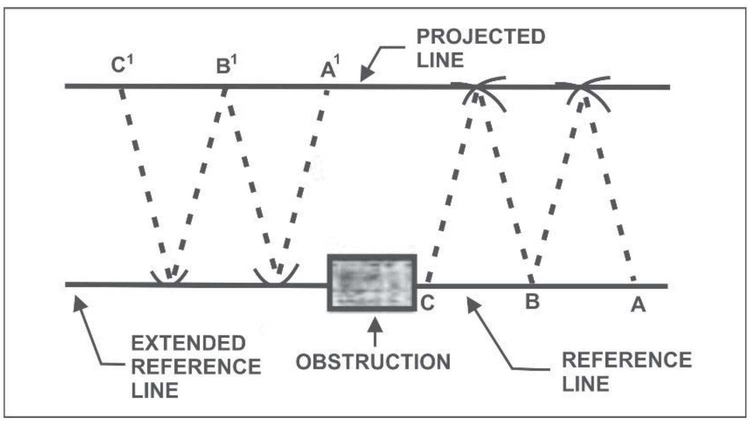

Figure 4-16. Bisecting arcs

Tangents of Arcs

4-53. The tangent of arcs method another method to extend lines past obstructions (see figure 4-17 on page 4-16). The following steps explains how to use tangent of arcs—

1. Using a fabricated compass with a radius long enough to clear the obstruction, swing at least two arcs out from the base line.
2. Snap the chalk line so that it contacts the tangent of the arcs. Make sure the chalk line is long enough to project the line past the obstruction.
3. Repeat the above steps, using the same radius for the arcs, but swing them in the opposite direction. Snap the chalk line as in step 2. This new line is the extension of the base line.

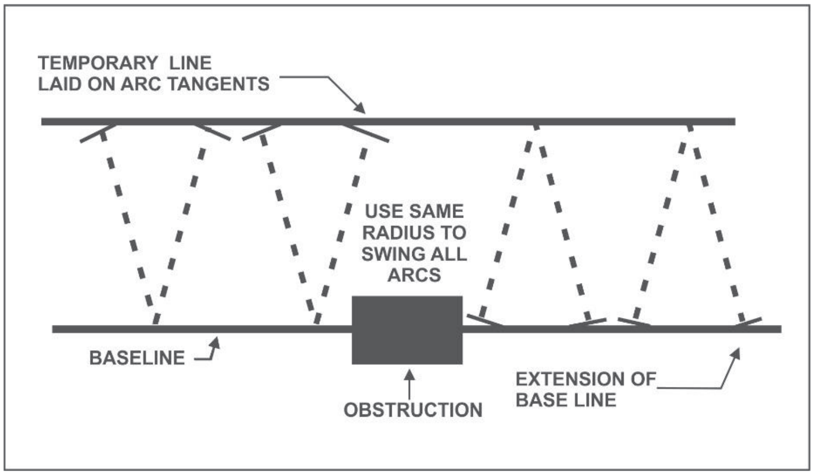

Figure 4-17. Tangents of arcs

Right Angles Method

4-54. This method uses ninety-degree angles to extend a line past an obstruction (see figure 4-18). The following steps explains how to use the right angle method:

1. Use either the 3-4-5 or the linear bisection method to lay at least two lines at a right angle perpendicular to the line to be extended. Be sure the lines are long enough to clear the obstruction.
2. Measure an equal distance along each perpendicular line and make a mark (point A).
3. Snap a chalk line through the points. This is the temporary line. Be sure it is long enough to clear the obstruction.
4. Repeat the steps above, marking perpendicular lines from the temporary line. Make sure to use the same measurements for the new marks as the point A mark. Snap a chalk line through the new marks starting from point A. This new line is the extension of the base line.

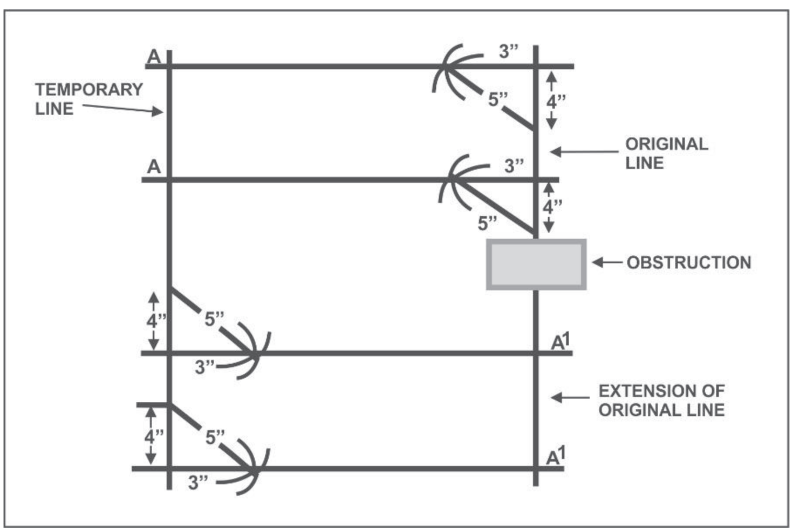

Figure 4-18. Right angle method

OVERHEAD LAYOUT

4-55. Mark overhead layout using the plumb bob method (see figure 4-19 on page 4-17). Whenever possible, avoid marking the locations of pre-drilled holes for overhead supports directly on ceilings. Working in an uncomfortable position is unsafe and will likely cause measuring mistakes. Make you overhead layout using the following steps—

1. Layout reference line or points from the reference line for ceiling locations on the floor.
2. Transfer the lines and points from the floor to the ceiling using the plumb bob method. Wrap the free end of a plumb line around the long side of a carpenters square, leaving slack approximately equal to the height of the room.
3. Using the short side of the square as a handle, hold the plumb line against the ceiling with the bob located near the reference mark on the floor.
4. Shift the square as necessary to center the plumb bob on the floor reference mark. Mark the ceiling at the point of contact with the plumb line. Point A is the reference point being transferred from floor to ceiling.
5. In buildings where space and height permit, use a scaffold or maintenance platform.

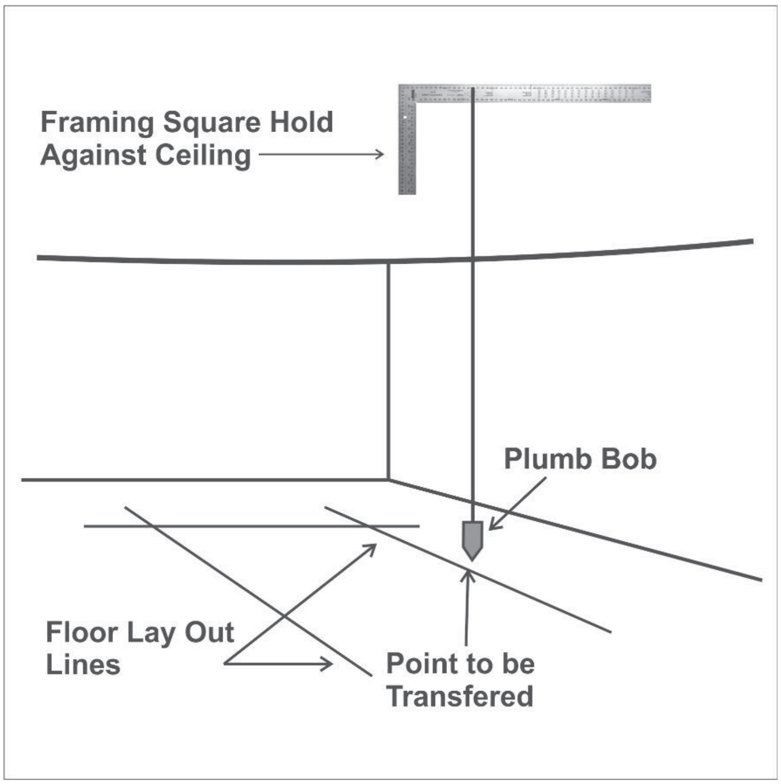

Figure 4-19. Ceiling layout using plumb bob method

WALL LAYOUT

4-56. Points and lines for installation of equipment on walls are also marked by means of plumb bob method. Wall mounted equipment will be plumbed vertically and leveled horizontally. Mark layouts on the wall as follows—

1. Determine the distance from one side of the equipment to be installed to a wall or other reference point using the EIP drawings. Further measurements should be made from the centerline for locating mounting holes to be drilled. Measure and mark this point on the floor in line with the wall location. If obstructions prevent marking the location on the floor, mark the wall at the approximate height of the equipment.
2. Determine the distance from the floor to the bottom (or center as applicable) of the equipment and mark the wall.
3. Align the plumb line on the mark that was made in step 2. This indicates where the side of the equipment will be located. Make additional marks on the wall to provide a reference for vertical alignment.

4. Align a level on the mark made vertically denoting the lower edge of the equipment, and draw a reference line to be used for locating purposes.

Note. **Use** this process for vertical and horizontal alignment of conduit. For long runs, it is more accurate and practical to snap a chalk line.

DETERMINING FLOOR LEVEL

4-57. Ensure to install most types of equipment racks, especially those installed in a line or those that roll out for maintenance, on as level a surface as possible. For this reason, check the floor for level before any equipment installation. This can be accomplished using the following three methods—

- Twine and Block.
- Chalk line.
- Level and straightedge.

Twine and Block Method

4-58. Determine floor level using the twine and block method by following these steps—

1. Secure a length of twine, not longer than ten feet, to two blocks of wood of equal height.
2. Place one block at the end of the lineup and the other block on the floor far enough to stretch the twine taut.
3. Next, slide a third block of equal height to blocks in step one the full distance beneath the twine.
4. If there is more than one high spot along the length of the twine, use a ruler at each location to measure the distance from the twine to the floor to locate the highest point (see figure 4-20).

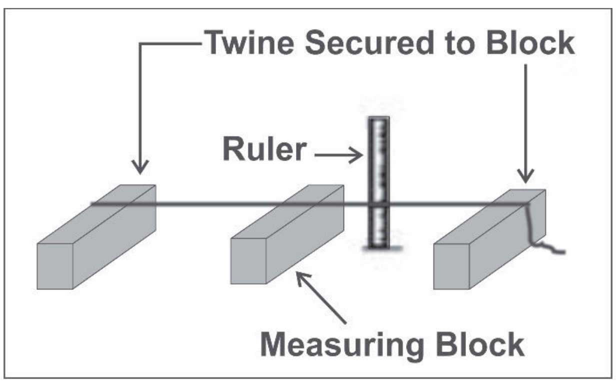

Figure 4-20. Twine and block method

Chalk Line Method

4-59. Determine floor level using the chalk line method (figure 4-21, page 4-19) by following these steps—

1. Hold one end of a heavily chalked line tightly against the floor at one end of the proposed equipment lineup.
2. Stretch the line taut across the area in which the equipment is to be located and drag the other end back and forth.
3. The chalk will rub off on the high spots while the lower spots will remain clear.

Note. The chalk line should not be longer than ten feet. If the equipment lineup is longer than ten feet, repeat the operation as many times as necessary, each succeeding operation overlapping the previous one.

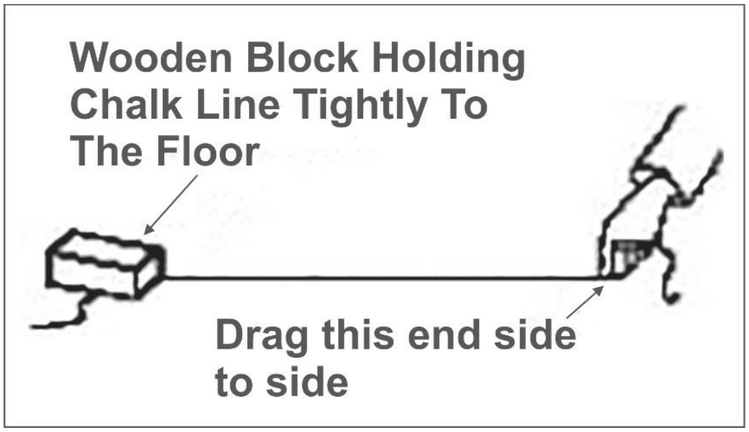

Figure 4-21. Chalk line method

Level and Straightedge Method

4-60. The high spots can be found by use of a straightedge (2 x 4 wood board or straight length of metal) laid on the section of floor where the equipment is to be placed. Place the level on the straightedge and move it over the entire area. Air space under the straightedge will indicate low spots and deviations from the level will indicate high spots (see figure 4-22).

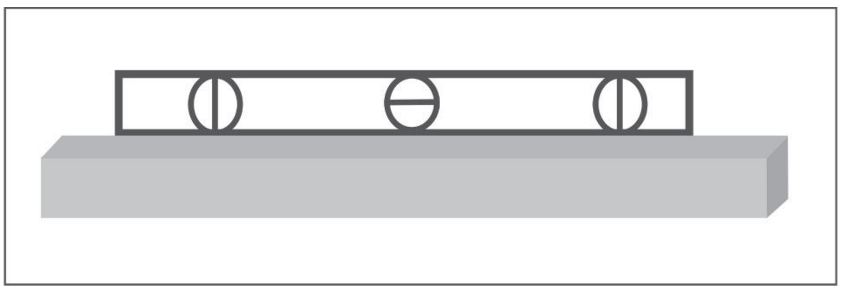

Figure 4-22. Level and straightedge method

ANCHORING

4-61. It is necessary to determine the correct type of anchoring devices before starting the installation of equipment. Select the type and size of the anchoring device according to information contained in the EIP specifications and drawings. The material of the floor, wall, or ceiling is also a determining factor for the type of anchoring device to use and indicated in the EIP.

4-62. The following tools are recommended for installation of anchoring devices—

- Electric drill, in sizes 3/8 and 1/2 inch.
- Masonry star drill in sizes 1/2 to 1 inch.
- Masonry carbide tipped drill bit in sizes 3/8 to 7/8 inch.
- Masonry twist fluted drill bit in sizes 1/4 to 1/2 inch.
- Ball peen hammer.
- Double 1/2 lb. sledgehammer.
- 6 ft. folding wood ruler.
- Screwdrivers.
- Linen measuring tape, 100 ft.
- Steel measuring tape, 100 ft.
- Adjustable wrench.

- Hand chuck and star drill.
- Hammer drill.

LOCATING DRILLING HOLES

4-63. Location of drill holes in masonry and other surface materials may be determined by-the base angles of equipment, templates, and measuring.

BASE ANGLES OF EQUIPMENT

4-64. Use detachable base angles of equipment as templates by placing them in the respective locations. The location of the holes can then be marked, on the floor, through the mounting holes. This is the simplest method, but not always feasible depending on the weight and size of equipment involved.

TEMPLATES

4-65. When installing several frames or cabinets of the same type, fabricate a template to the contour of the base with holes indicating the location of the mounting holes. Place the template in the designated location on the floor layout and the mounting holes marked.

MEASURING

4-66. This method has its advantages when mounting holes are parallel to the base or centerline of the equipment. Use this method using the following steps:

1. Measure from the center or base line and mark the location of the mounting hole center at each end of the lineup.
2. Snap a chalked line between the marks made in step 1.
3. Determine distance between the centers of each mounting hole and mark off along the chalked line (see figure 4-23).

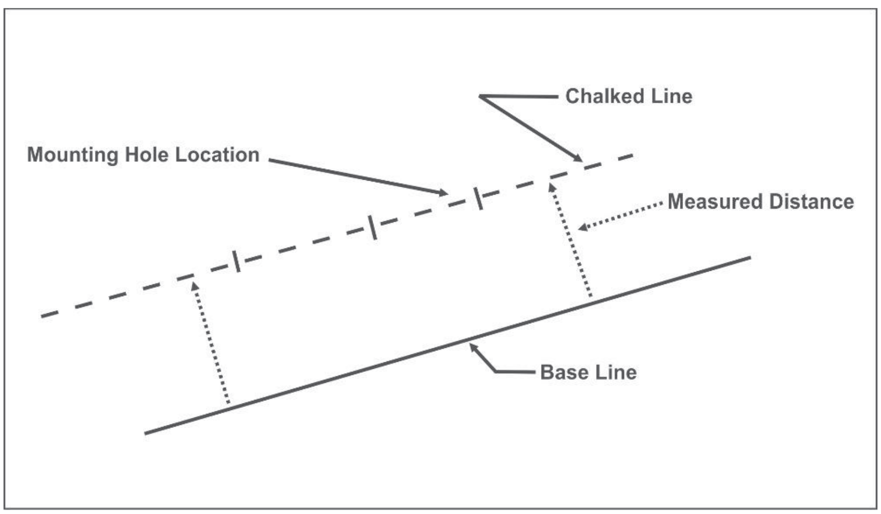

Figure 4-23. Measuring method

DRILLING CONSIDERATIONS

4-67. Certain considerations is to be applied prior to and during drilling. Installers must check for accuracy and be aware of procedures on how to drill into masonry or concrete. Installers should also have an understanding of drilling in ceilings, as well as anchor spacing requirements.

ACCURACY

4-68. The accuracy of the drilling may be checked by lines drawn through center points of the hole locations. The lines should extend a minimum of three inches beyond the center point (see figure 4-24).

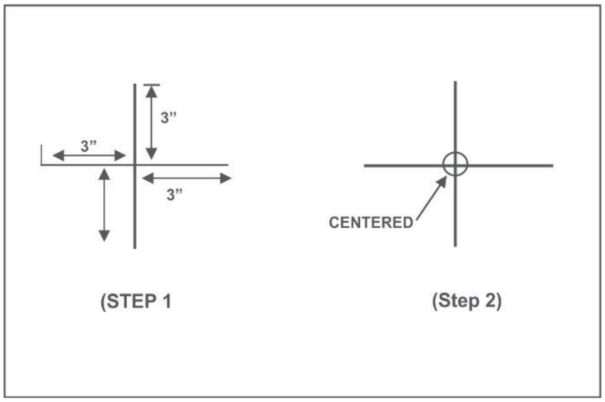

Figure 4-24. Determine accuracy

DRILLING INTO MASONRY, CONCRETE, AND CEILINGS

4-69. Holes in masonry or concrete for expansion shields and anchors should be deep enough to permit the complete insertion of shields or anchors in the hole. Where plaster covers the surface, the hole should be deep enough to permit the installed shield or anchor to be flush with the concrete, not the plaster.

4-70. Drilling is a two-person operation. The drill operator concentrates on applying drill pressure, while the assistant aids in keeping the drill perpendicular to the surface and monitors safety. The size and type of anchor determines the diameter of the hole.

4-71. When drilling in masonry or concrete with an electric drill, impact drill, or hammer drill, it is advisable to wrap several layers of tape around the shank of the bit to serve as a guide for depth. During and after the drilling operation, clear the hole of debris; especially when working on an active site.

4-72. When drilling hollow tile, once there is a drill hole, limit forward motion. When drilling holes close to trenches where there is a possibility of concrete breaking or chipping off, avoid the use of impact tools, such as electric hammers.

4-73. When drilling holes into ceilings, a cardboard box or plunger cup can be taped to the drill to catch falling debris.

ANCHOR SPACING REQUIREMENTS

4-74. Equipment manufacturers have established minimum spacing for anchors. An anchor transfers its load weight to the material in which it is installed. Establish a minimum standard of ten anchor diameters for spacing; and five anchor diameters for edge distance to assure 100 percent anchor performance. You can reduce these distances by as much as 50 percent with a proportionate reduction in efficiency.

TYPES OF ANCHORS

4-75. There are many types of anchors, used for various applications. It is important to use the correct anchor for the job. The following is a list of some of the various anchors that will be discussed in this section:

- Two element/self-drilling expansion shield.
- Two element/non-drilling expansion anchor.
- Bolt/stud type.
- Single element expansion anchor.
- Hammer driven anchor.

- Wood screw anchor.
- Machine bolt anchor.
- Lag screw anchor.
- Toggle bolt anchor.
- Crimp type/molly screw anchor.

Two Element, Self-Drilling Expansion Shield Anchor

4-76. This type of anchor consists of two elements: a pressed steel shell with an external expanding element. This anchor, as with all self-drilling anchors, is the simplest to use and each anchor acts as its own drill bit for installation (see figure 4-25).

4-77. The following steps are used when installing the two element/self-drilling expansion shield—

1. Determine the location, depth and diameter of the hole.
2. Insert a spline chuck shank bit of the correct size into the barrel of the hammer drill. The anchor shield is used to drill the hole.
3. Set the Roto-Stop Control (RSC) on the hammer drill to the hammer position and operate the tool on impact until the teeth of the anchor penetrates the surface (approximately 1/8”).
4. Turn the RSC to the rotation position and drill the anchor into the concrete until the bottom of the chuck is approximately 1/16” from the surface.
5. Remove the anchor and clean out debris with a blow bulb.
6. Place the internal expander into the end of the anchor.
7. On the hammer drill, reset the RSC to hammer position and place the anchor back into the hole. Expansion takes place as the hammer drill hammers the anchor flush with the concrete.
8. Snap off the cone.

Note. When anchors are not in use, immediately cover hole of anchor with masking tape.

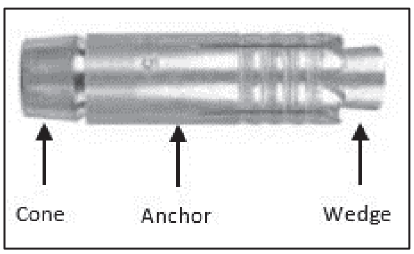

Figure 4-25. Two element, self-drilling expansion shield anchor

Two Element, Non-Drilling Expansion Anchor

4-78. The two element/non-drill expansion anchor, also known as a soft shell anchor, has a soft lead outer shell and cone shaped copper threaded insert. The general intention of this anchor is for lighter loads and requires presetting (see figure 4-26, page 4-23).

4-79. The following steps are used to install the two element/non-drilling expansion anchor:

1. Determine location, depth, and diameter of hole and drill as required.
2. Insert the set tool and strike several times with a hammer
3. Check the anchor for firm setting. The setting is accomplished by forcing the shield down over the cone shaped core that in turn expands the shield in an outward direction.

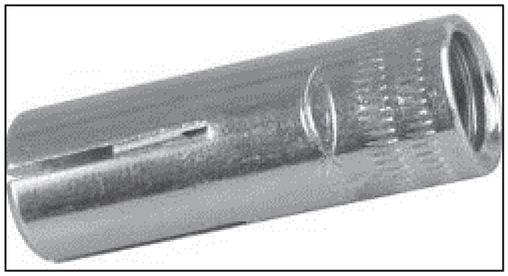

Figure 4-26. Two element, non-drilling expansion anchor

Bolt/Stud Type Anchor

4-80. Procedures for installing the bolt/stud type anchor is similar to installing two element, non-drilling expansion anchors. A setting tool fits over the threaded portion of the bolt, then struck with a hammer that forces the lead sleeve over the cone shaped head of the bolt (see figure 4-27).

4-81. The following steps are used to install the bolt/stud type anchor:

1. Determine the location, depth, and diameter of the hole.
2. Pre-drill the hole ensuring that the hole is large enough to accommodate the bolt head with lead sleeve in position.
3. Remove all debris from the hole that has been drilled.
4. Remove the nut from the bolt and insert the anchor in the hole until the bolt head bottoms. It may be necessary to lightly tap the bolt with a hammer; however, ensure not to damage the thread.
5. Place the set tool over the bolt and strike several blows with a hammer.
6. Check the anchor for firm setting.

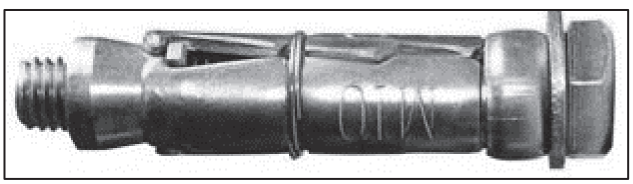

Figure 4-27. Bolt/stud type anchor

Single Element Expansion Anchor

4-82. The single element expansion anchor consists of an expansion shield and a wood screw, machine bolt, lag screw, nail, hammer drilled, toggle bolt, or crimp type/molly. The wedging element is the securing device. This anchor secures lightweight items such as conduit and clocks. To obtain maximum holding power, the diameter of the drill hole must be identical to the outside diameter of the unexpanded shield. The size designation of the anchor, including the diameter and length, is generally stamped on the shield.

Wood Screw Anchor

4-83. The depth of the pre-drilled hole required for a given size. The length of the expansion shield determines wood screw anchor, and additional depth to accommodate the screw point (see figure 4-28 on page 4-24). The following steps are used to install a wood screw anchor:

1. Locate and drill the hole corresponding to the diameter of the unexpanded anchor.
2. Insert the shield into the drill hole.
3. Tap the shield lightly with a hammer (preferably a rubber mallet) until the head is flush with the mounting surface.
4. Insert the screw into the expansion shield and turn the screw until it is firmly seated.

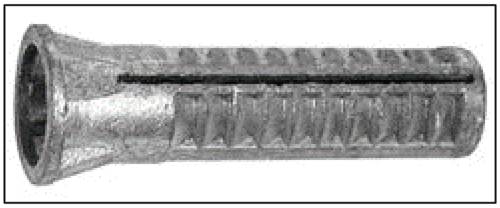

Figure 4-28. Wood screw anchor

Machine Bolt Anchor

4-84. Use the machine bolt anchor to attach fixtures to masonry or concrete surfaces. This anchor provides a greater holding capacity than a wood screw anchor and can accommodate fixtures of greater thickness than hammer driven anchors of comparable size. A machine bolt anchor consists of an expansion shield and a machine bolt wedging element (see figure 4-29). Use the same steps describe in paragraph 4-82 to install the machine bolt anchor.

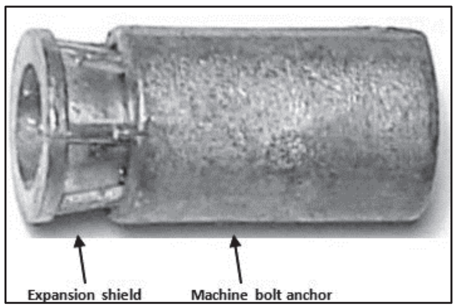

Figure 4-29. Machine bolt anchor

Lag Screw Anchor

4-85. The lag screw anchor consist of an expansion shield and a fitted lag screw used as a wedging element (see figure 4-30). Install lag screw anchors in the same manner as the wood screw anchor and machine bolt.

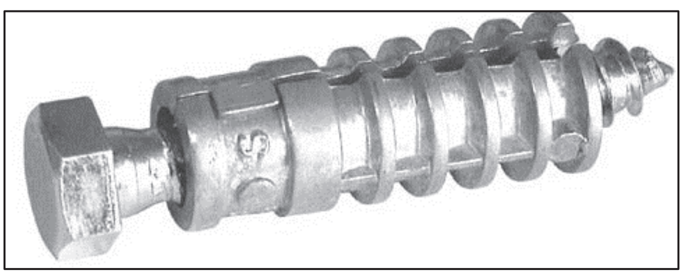

Figure 4-30. Lag screw anchor

Nail Anchor

4-86. A nail anchor, or hammer-drilled anchor, requires a pre-drilled hole that is 3/16" longer than the depth of the shield. The depth that the shield will enter the hole will differ from the actual length of the shield since the thickness of the fixture to be attached at the point of support must be accommodated under the expansion shield flange (see figure 4-31 on page 4-25).

4-87. The following steps are used to install a hammer drill anchor:

1. Locate and drill the hole corresponding to the diameter and depth of the unexpanded anchor, ensuring to drill an addition 3/16" in depth. The drilled hole should receive the anchor snugly.

2. Insert the shield through the mounting hole of the fixture into the drilled hole. Tap the shield lightly until the flange of the shield rest against the fixture.
3. Insert a nail into the expansion shield and drive the nail in until the head is firmly seated. Do not hammer the nail after it has been seated because it will reduce the holding power.

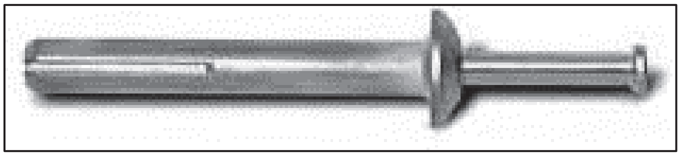

Figure 4-31. Nail anchor

Toggle Bolt Anchor

4-88. Use the toggle bolt anchor to attach fixtures to hollow structures such as tile and cement blocks. When inserted into the hollow space, the toggle bolt anchor goes into the holding position by spring or flop over action. This requires some force. The effectiveness of the toggle installation is dependent upon a satisfactory bearing area for the expanded toggle (see figure 4-32).

4-89. The following steps are used to install a toggle bolt anchor:

1. Drill a hole the size that will accommodate the minimum spread of the toggle bolt anchor.
2. With the bolt installed into the toggle bolt anchor, push the anchor through the drilled hole. With a spring action toggle bolt anchor, ensure the anchor is installed with the screw so that the toggle anchor closes around the bolt shaft when installing.
3. Screw the bolt until the toggle expands into the hollow chamber.
4. Pull the bolt in an outward direction to secure the toggle anchor against the surface on the opposite side and begin tightening the bolt by hand until the bolt head contacts the mounting surface or until the bolt may be turned with an inward pressure without turning the toggle anchor.

Note. Both the spring and flop over toggle anchors allow shifting for centering purposes due to the over-sized hole drilled for insertion of the toggle anchor.

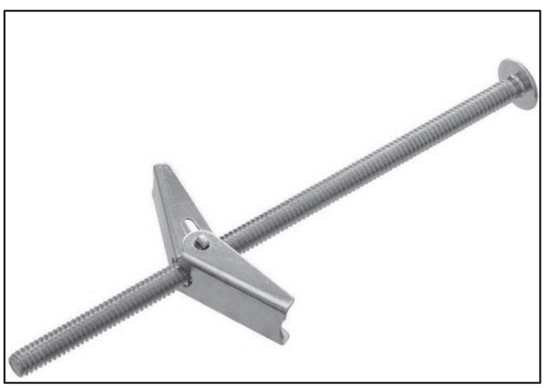

Figure 4-32. Toggle bolt anchor

Crimp Type, Molly Screw Anchor

4-90. Use the crimp type, molly screw anchor wherever a toggle bolt can be used or when there is not enough clearance behind the wall to allow use of a toggle bolt anchor (see figure 4-33 on page 4-26). The mounting hole is the same size as the anchor unexpanded and allows no alignment play; therefore, accurately positioning the anchor is important. Crimp type, molly screw anchors have less strength than toggle bolt anchors when subjected to a force away from the wall.

4-91. The following steps are used to install a crimp type, molly screw anchor:

1. Drill the hole the same size as the outside diameter of the anchor.
2. Thread the anchor on the mouniting screw.
3. Insert the anchor into the mounting hole and tighten screw. This will expand the anchor behind the wall.
4. Once the anchor is installed and expanded, the screw can be removed without disturbing the anchor.

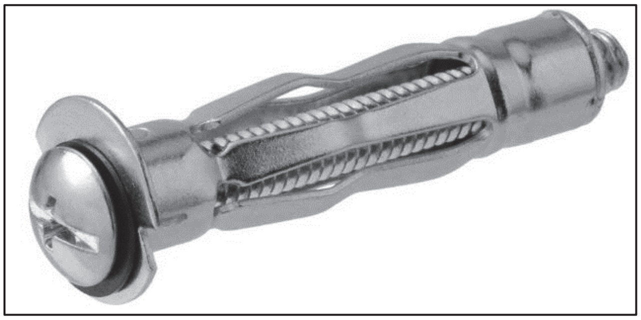

Figure 4-33. Crimp type, molly screw anchor

CABLE RACK AND WIREWAY

4-92. Installers may be required to install or extend various types of cable racks, troughs, and wireways in fixed station facilities. This section will assist the installer with identifying and assembling the more common types of racks and wireways.

CABLE LADDER RACK

4-93. Use a cable rack is a ladder-like assembly wherever exposed cable is acceptable. It consist of two parallel side members called stringers and cross straps that welded at regular intervals. It is manufactured in widths from five to 24 inches and in lengths of 10 or 20 feet (see figure 4-34).

Note. Use cable racks in full stock lengths whenever possible.

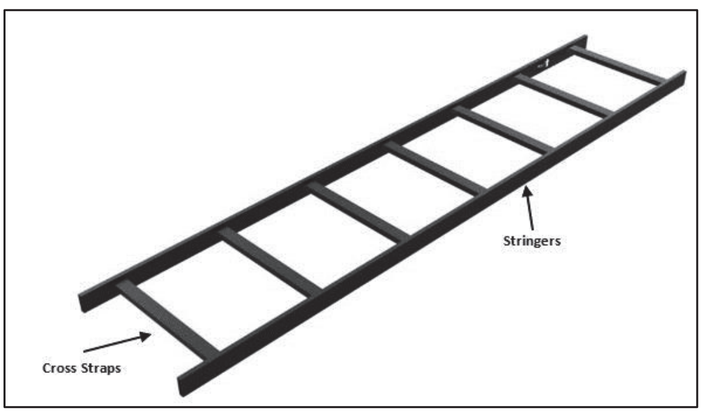

Figure 4-34. Cable ladder rack

WIREWAY

4-94. Wireways, or ducts, are troughs made of steel, other metal types, or other non-metallic material. They have a hinged cover in which several conductors and/or cables may be located. Wireways provide physical protection of cables and conductors. When properly grounded, metal wireways provide electromagnetic interference (EMI) and radio frequency interference (RFI) protection. Wireways are available in standard lengths of 1 to 5 feet and 10 feet and can be obtained with or without knockouts (see figure 4-35).

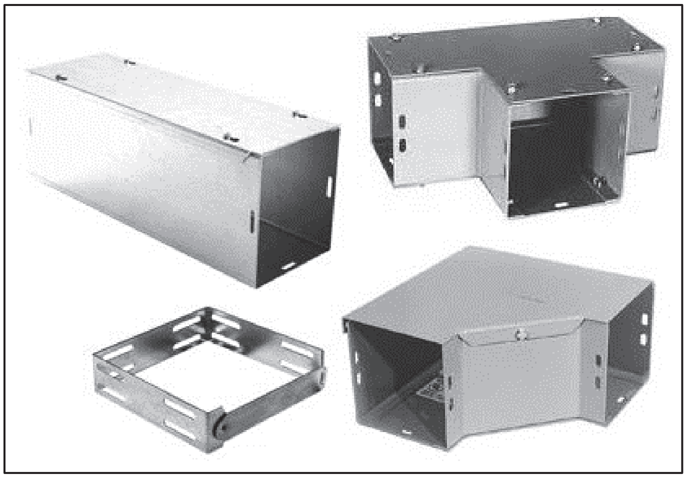

Figure 4-35. Wireway

INSTALLATION PLANNING

4-95. Cable racks and wireways should be located according with the EIP drawings. Existing equipment, building structures, and consideration for future expansion may require deviation from the drawings. Install racks before installing other equipment at a new site.

4-96. Install cable racks to meet clearance requirements for installation and maintenance of equipment. Adherence to drawing dimensions of frames, rack openings, bays, and relay racks is essential to eliminating future difficulty when running and securing cables.

Note. Avoid locating cable racks close to pipes, radiators, windows, doors, or equipment that might damage the cables.

CABLE RACK HARDWARE

4-97. Use cable rack hardware to connect lengths of rack, join offsets, change direction, or end a cable rack run. Always turn bolt heads toward the cable.

CAUTION

Never over-tighten a hardware clamp. It may buckle, resulting in it loosening.

Straight Splicing Clamp

4-98. Use the straight splicing clamp to join lengths of rack (see figures 4-36). The spacing requirements between the end of the stringers of two cable rack sections is a minimum of 3/8 inch and a maximum of 5/8 inch, and the spacing should be equal on both sides of the bolt. One splice is allowed between supports. Use straight splice clamps to attach rack feet at the end of the cable rack run.

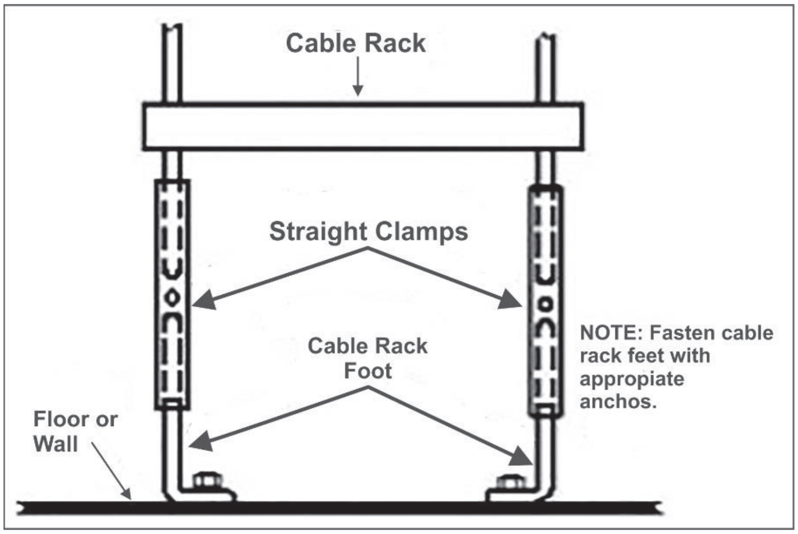

Figure 4-36. Straight splicing clamp

4-99. Figure 4-37 is a close up depiction on how to install a straight splicing clamp

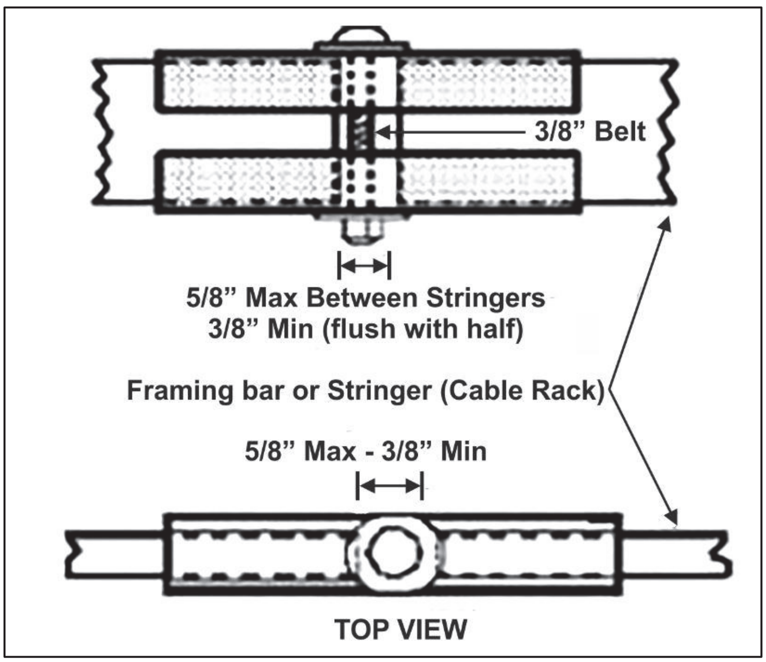

Figure 4-37. Straight splicing clamp (close up)

Corner Clamps

4-100. Corner clamps are used to end a cable rack run, make turns, form a “T” intersection and for horizontal offsets (see figure 4-38 on page 4-29). The maximum gap between the end of the rack and the cut length of stringer is 1/8 inch.

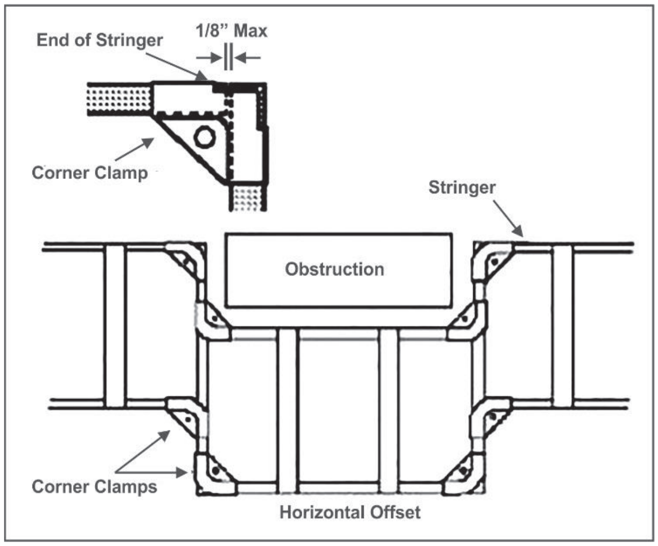

Figure 4-38. Corner clamps

Corner Braces

4-101. Corner braces are diagonal bracing for cables requiring a gradual turn where cables could possibly come off the cable rack or to add rigidity (see figure 4-39).

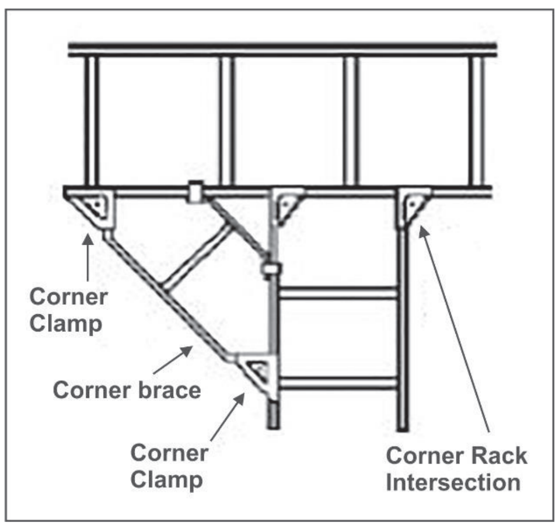

Figure 4-39. Corner brace

Edge Clamps

4-102. Use 90 and 45-degree edge clamps for vertical offsets, to change vertical direction (inside and outside bends). Join cable racks that form a 90-degree vertical turn, with a turn radius of six inches or less, with two sets of 90-degree edge clamps. To form a 90 degree vertical turn with a radius of more than six inches, four sets of 45 degree edge clamps can be used to join the cable rack (see figure 4-40 on page 4-30).

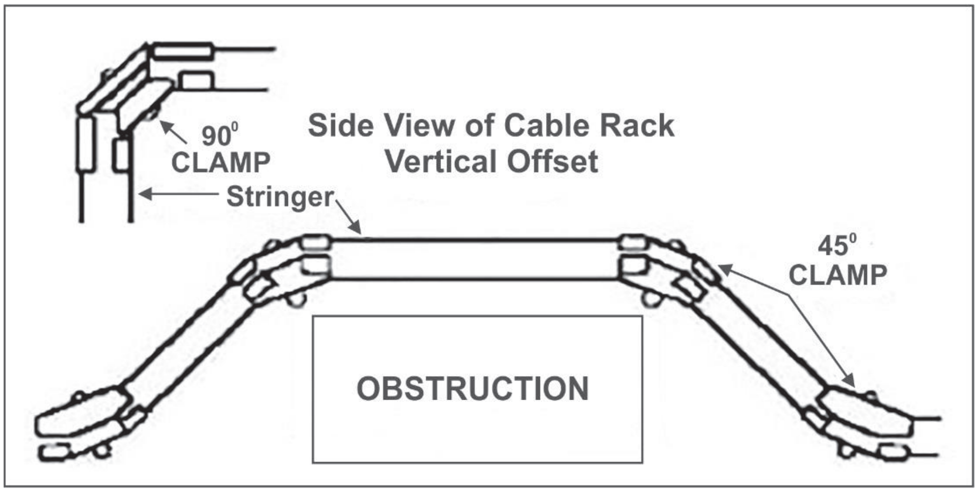

Figure 4-40. Edge clamps

Hanger and Alignment Clips

4-103. Use hanger clips to secure threaded rod to the cable rack stringer. Use alignment clips with hanger clips to prevent upward movement of the hanger clips. Place a hex nut on the threaded rod and tighten at the bottom of the hanger clip to ensure the rod remains secure (see figure 4-41).

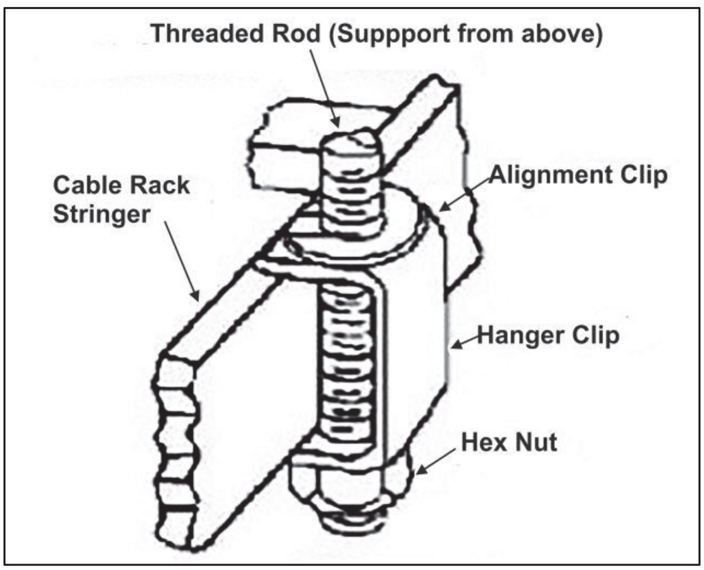

Figure 4-41. Hanger and alignment clip

J Bolt and Rack Feet

4-104. Use J bolts to mount cable racks to framing bars or channels (see figure 4-42 on page 4-31). Use the rack feet to attach rack ends to walls or floors (as previously shown in figure 4-36 on page 4-28).

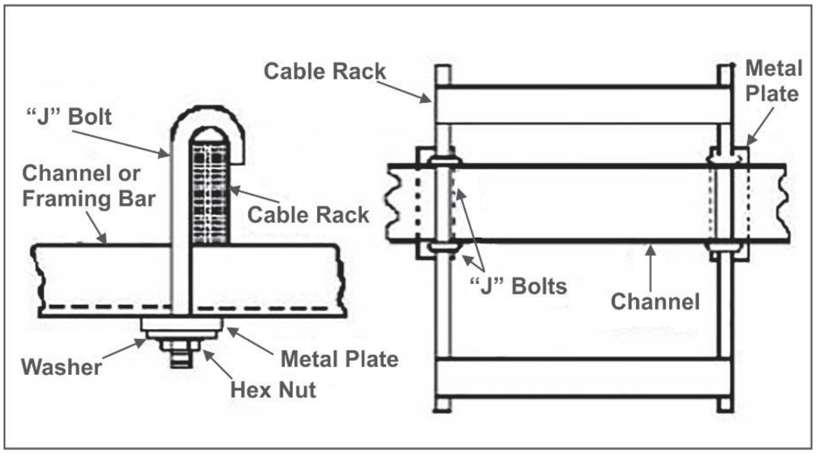

Figure 4-42. J bolts

SUPPORT MATERIAL

4-105. Installers can use lipped channel, channels, or framing bars for metal support. Cable racks or ducts are attached to this support for both horizontal and vertical installation when not directly attached to permanent building structural members.

Lipped Channel

4-106. Lipped channels are square or rectangular that come in 12, 14, or 16-gauge and are 10 or 12 feet in length. Use these channels with a 5/8 inch threaded rod to support cable racks or ducts. Install lipped channels in full stock length whenever possible. The open side of lipped channel has two 90-degree bends that form clamping ridges on the inside edge that are designed to position and lock a spring nut. One side of the spring nut has two grooves that engage the clamping ridges inside the channel and the other side has a spring to keep it in place until the bolt tightens. The grooves in the nut securely bridge the sides of the channel together when drawn tightly against the clamping ridges (see figure 4-43 on page 4-32).

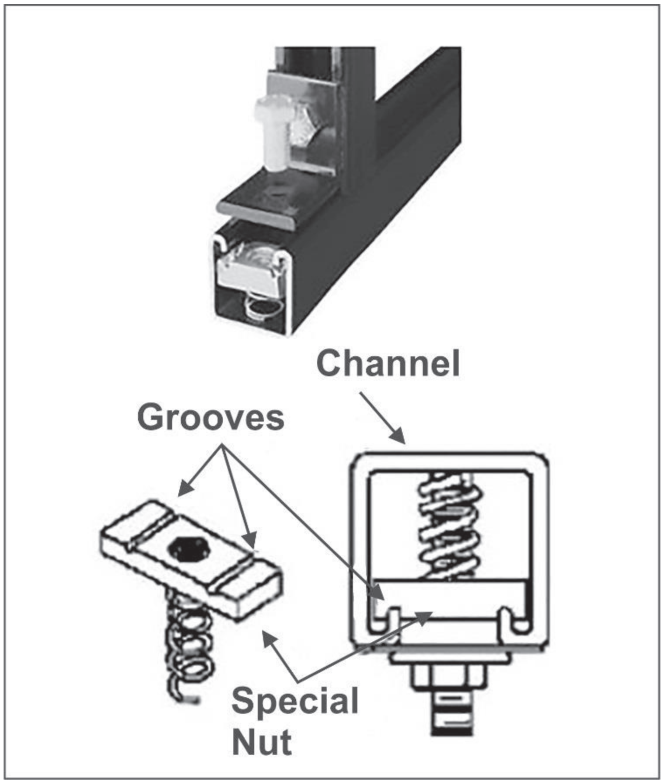

Figure 4-43. Lipped channel

Channels

4-107. Use channels for rack support. Channels come in 20 feet lengths and measures 2 inches by 9/11 of an inch. These are the same channels used with lipped channels, but without the spring nut. Channels come in various styles and can have pre-drilled holes and slots for different applications (see figure 4-44). Attach using various types of fittings and brackets. All rules for lipped channel and framing bar apply to channel. The use of channel for cable rack support is limited to short runs and light loads.

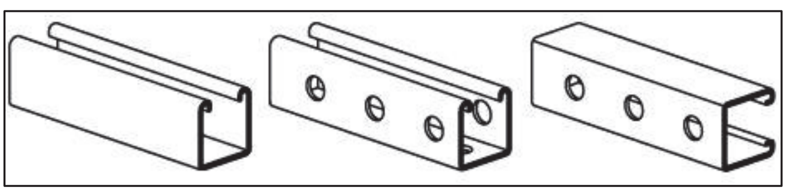

Figure 4-44. Channels

Framing Bars

4-108. Use framing bars in lieu of lipped channels except where the channel must mount directly to the ceiling. Attachment of framing bars near the ceiling requires a minimum spacing of 2 inches between the ceiling and the top of the framing bar (see figure 4-45, page 4-33).

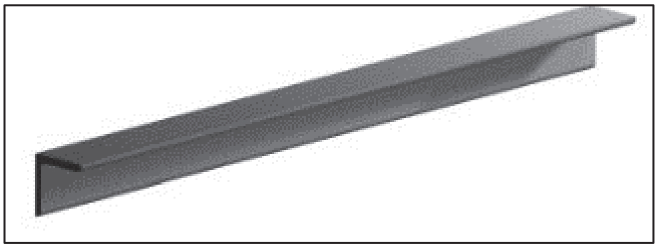

Figure 4-45. Framing bar

TYPES OF SUPPORT

4-109. The four classifications of support are overhead supports, floor or equipment supports, vertical supports, and mutual cable rack supports. Use all four types in various combinations and may be used in practically every project requiring cable rack installation. Table 4-1 shows spacing of support depending of the classification.

Table 4-1. Spacing of supports

Type of support	*Spacing of supports*
Horizontal supports (framing bars, channel or other) fastened to ceiling or floor	5 feet centers (6 feet maximum)
Distance of support from end of horizontal support	3 feet maximum
Expansion shields, ceiling inserts, brackets attached to ceiling	5 feet centers
Securing devices attaching lipped channel directly against ceiling	4 feet centers (2 feet from end to end)
Wall supports, horizontal or vertical	5 feet centers

OVERHEAD SUPPORT

4-110. Use permanent building structural members or securing devices installed at the time of rack installation for overhead support. Permanent structural members include ceiling inserts, steel beams, and wooden joists. To establish the overhead support positions, the site layout must indicate the positions beforehand. Check installation drawings for the position of supports and equipment and mark the positions directly on the floor (see figure 4-46 on page 4-34).

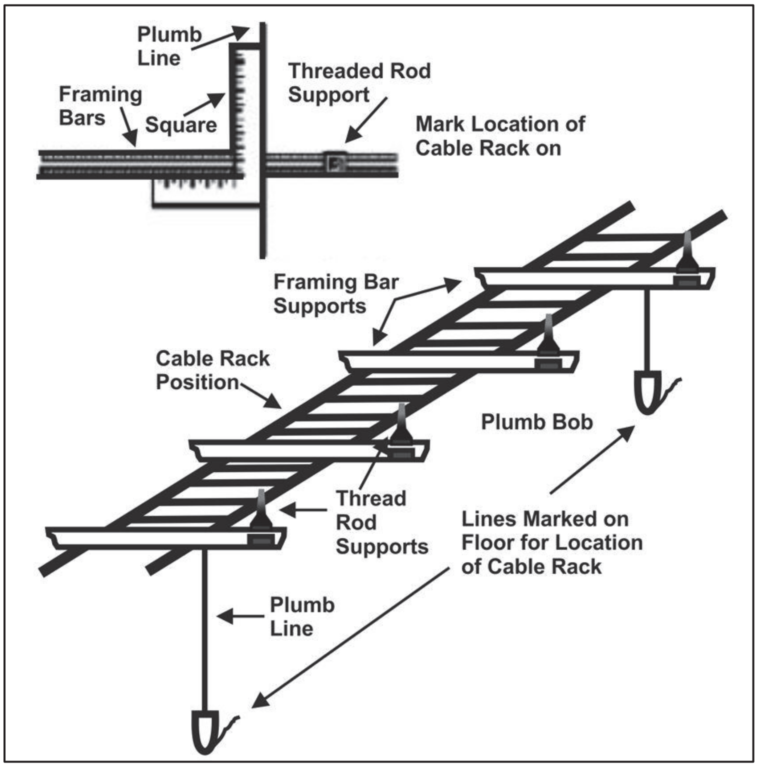

Figure 4-46. Marking positions for overhead support

4-111. Serious consideration and various techniques are when installing overhead support. Installers should be aware of techniques to provide direct and indirect support, as well as understand how to install thread rods correctly.

Direct Support

4-112. Installs can support cable racks directly from the ceiling using threaded rods by one of two methods (see figure 4-47 on page 4-35). They are as follows—

- Attach thread rods to overhead support (permanent structural members or securing devices). This method is required if the width of the cable rack is 20 inches or more.
- Thread rod attaches to a short length of lipped channel fastened flush against the ceiling by one securing device (including bolts or screws) in the center of the lipped channel. Use this method to support 12 and 15-inch cable racks.

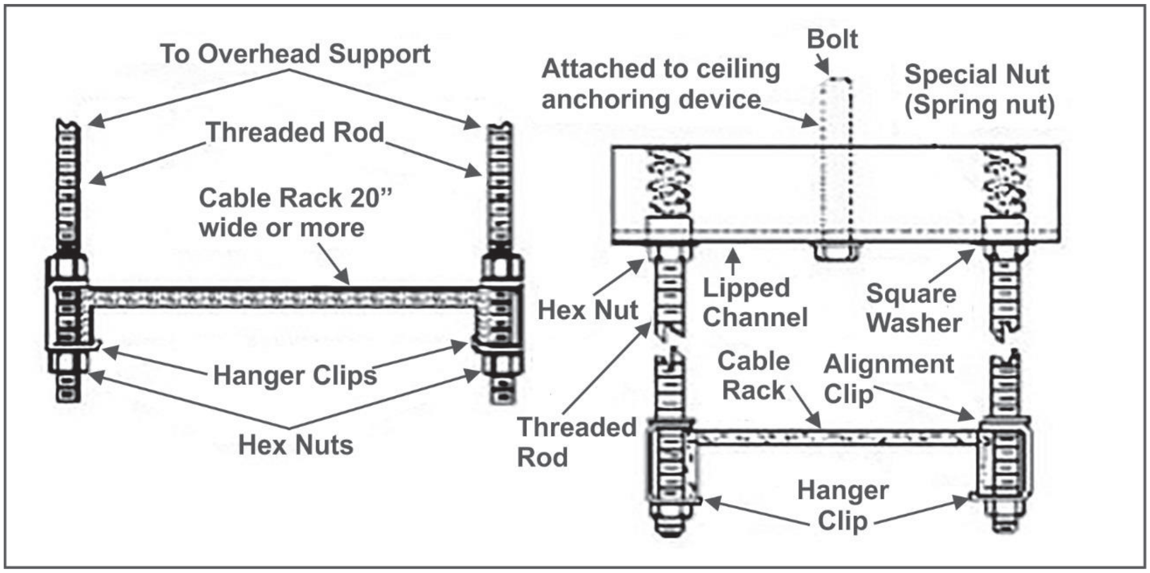

Figure 4-47. Two methods to support cable racks directly from ceiling

Indirect Support

4-113. Consider indirect support when spacing of ceiling inserts, wooden joist, steel beams, or other means of attachment makes it impractical to support cable racks with threaded rods attached directly to the ceiling. In such cases, support cable racks indirectly by attaching framing bars to the ceiling and then suspending the cable rack below the framing bars with threaded rods (see figure 4-48).

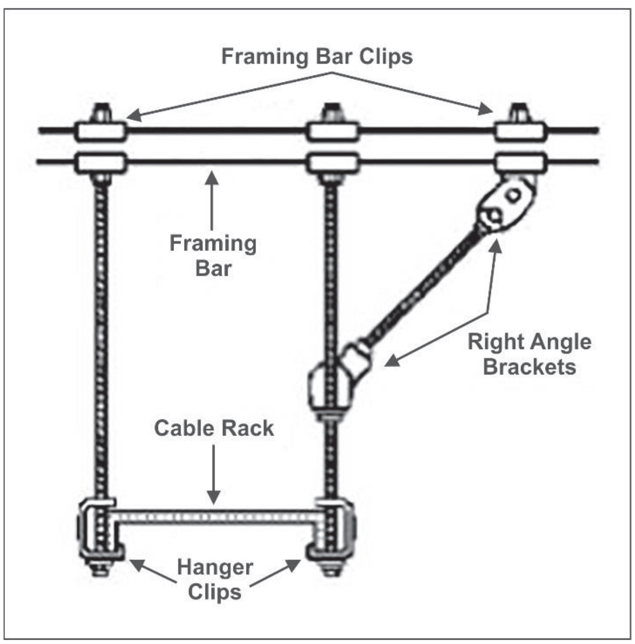

Figure 4-48. Supporting cable rack indirectly

Installing Threaded Rods for Overhead Support

4-114. For greater strength, 5/8 inch threaded rods are recommended for all cable rack installation. Use various attachments with threaded rods (see figure 4-49 on page 4-36). They include—

- "I" beams.
- "U" shaped brackets.
- Drive pins.

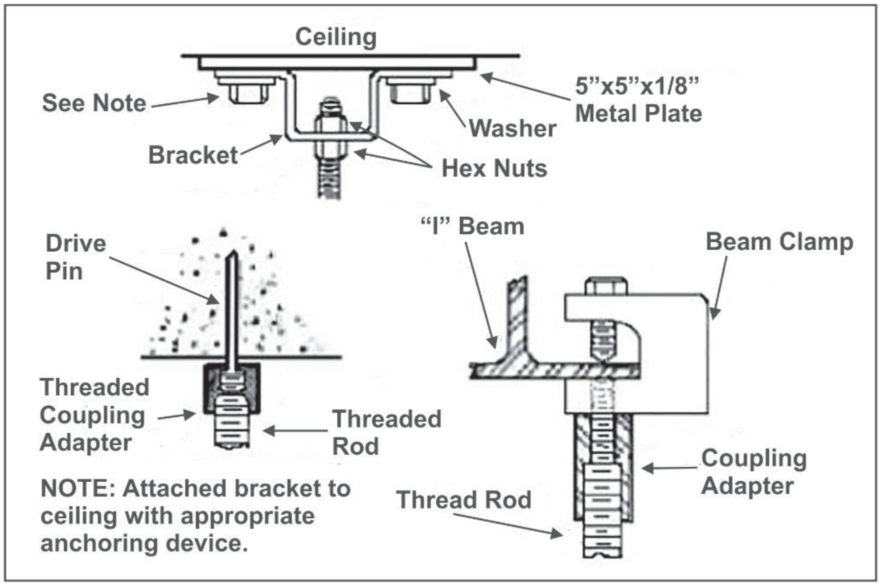

Figure 4-49. Attachments used with threaded rods

4-115. Securing threaded rods to wooden ceiling joist with loads of more than 300 pounds require drilling through the joist. A load of less than 300 pounds can be secured with a threaded rod attached to a bracket and two 3/8 inch by 2 inches long lag screws (see figure 4-50).

> **WARNING**
>
> **Never drill holes through an "I" beam to attach an anchoring device. Failure to comply can result in diminished structural strength with the installation.**

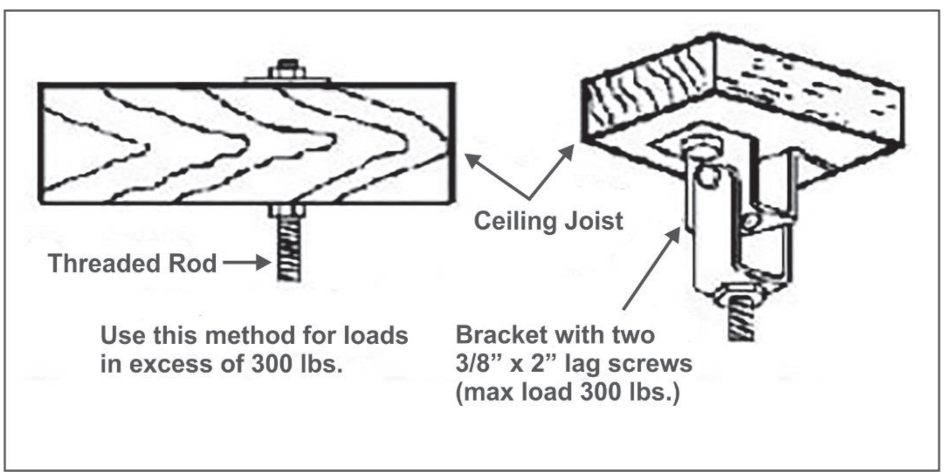

Figure 4-50. Securing threaded rod to wooden joist

4-116. Threaded rods should not be bent to provide offset unless necessary. Only if no other means of support is practical is bending threaded rods permissible. Bends should not exceed 20 degrees and the offset distance should not be more than 4 inches (see figure 4-51). Figure 4-51 also show an alternative to bending a threaded rod due to offsets.

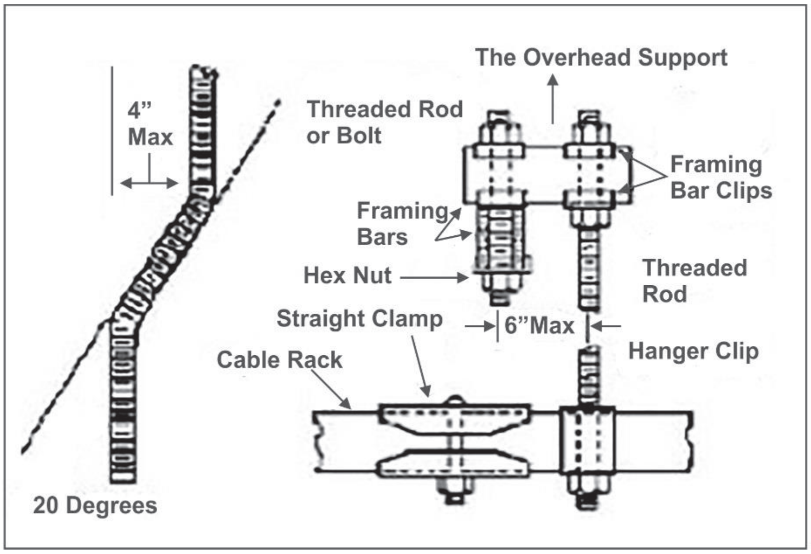

Figure 4-51. Bending threaded rod and alternative

4-117. When splicing threaded rods are necessary, the ends of the rods will be butted together in a splice coupling so the ends can be seen through the site hole (see figure 4-52).

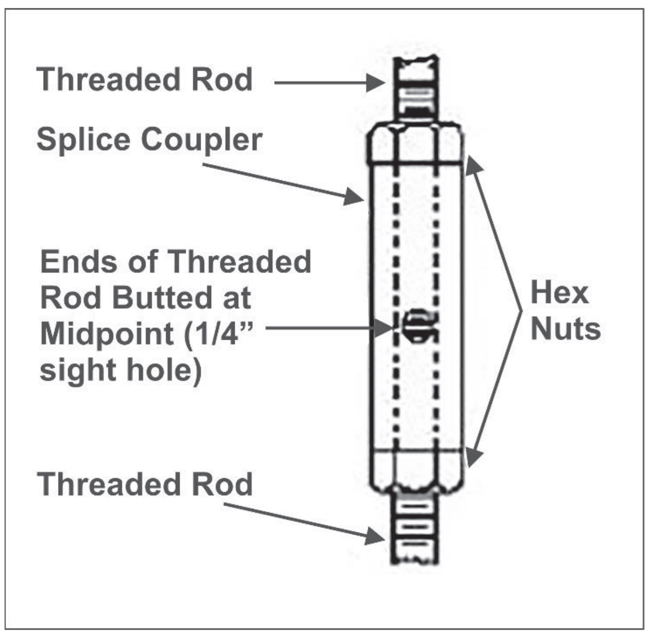

Figure 4-52. Splicing threaded rods

FLOOR AND EQUIPMENT SUPPORT

Floor Support

4-118. Cable rack runs that extend to the floor is provided support using of cable rack feet attached to the ends of the stringers with straight clamps. Attach the cable rack feet to the floor with appropriate securing devices. When a vertical run passes through a floor, secure the cable rack to the floor through which it passes. This prevents overloading the lower support (refer back to figure 4-36 on page 4-28).

Equipment Support

4-119. Channels secured to the tops of equipment cabinets, frames, relay racks, or use bays to support cable rack runs. Check installation drawings in the EIP for spacing of channels and the method of securing them to the tops of equipment (see figure 4-53).

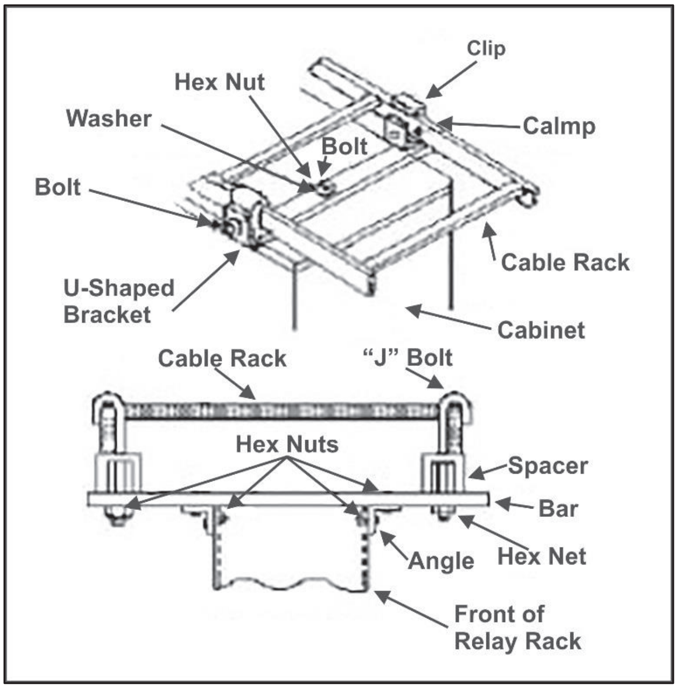

Figure 4-53. Cable rack support attached to equipment

WALL SUPPORT

4-120. Accomplish wall support for cable racks using vertical structural members. If prefabricated wall brackets are not available, steel angles with threaded rods may be used. Use framing bars three feet past each bracket to provided additional support (see figure 4-54 on page 4-39). If necessary, secure the framing bar to the wall using rack feet.

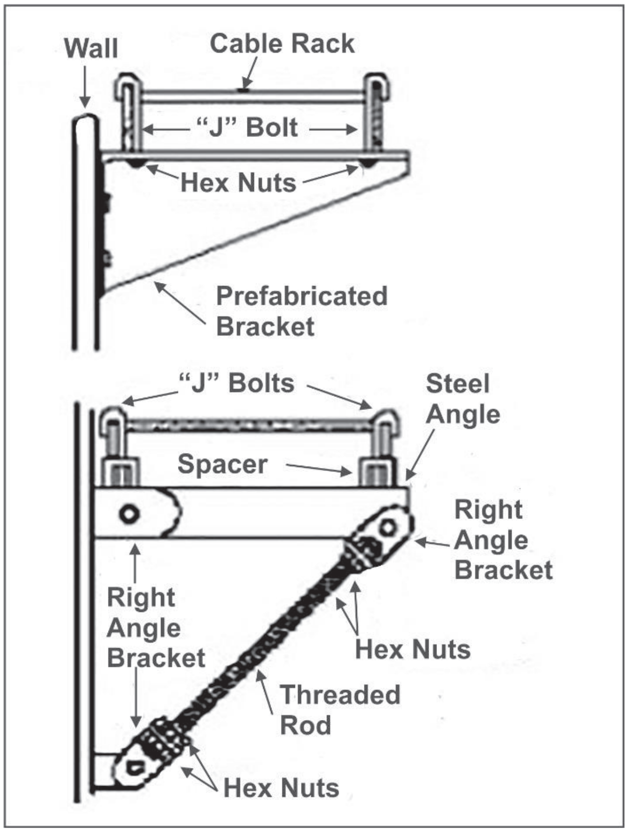

Figure 4-54. Wall supports and framing bars

MUTUAL CABLE RACK SUPPORT

4-121. The mutual cable rack support method is used to support cable racks perpendicular or parallel to another cable rack. A maximum of 18 inches between cable racks is standard. The load capacity of the supports for the upper rack must be sufficient to bear the additional load from the lower rack. The upper cable rack hanger clips, with hex nuts for each clip, are used to adjust the required space between cable racks (see figure 4-55 on page 4-40).

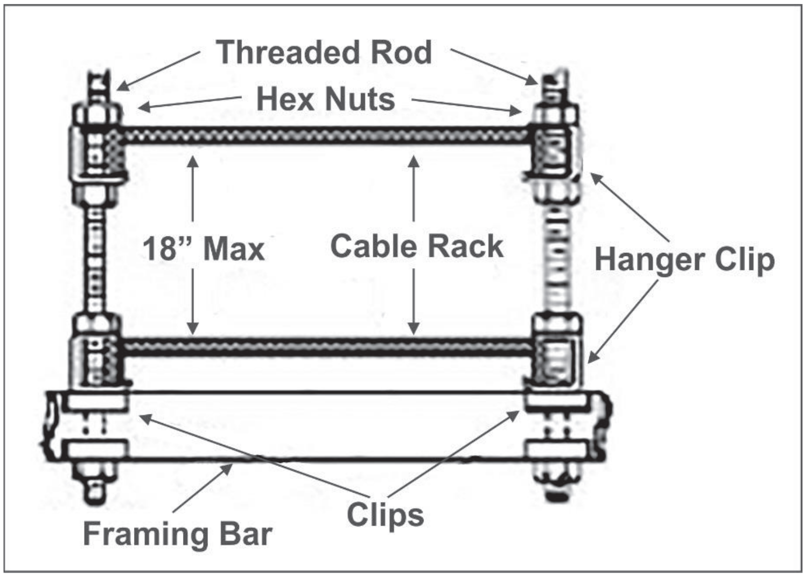

Figure 4-55. Mutual cable rack support

CUTTING CABLE RACKS

4-122. When required to cut a cable rack to end or change direction of a run, cut the cable rack squarely. Cut at a position that allows for placement of a corner or splice and maintain equal spacing of cross straps. The following steps are used to properly cut a cable rack:

1. Measure and mark the lengths of cable rack to be cut.
2. Cut the stringers at the marks with a hand hacksaw or a power hacksaw.
3. If the cable rack must be cut at the junction of the stringers and a cross strap, remove the cross strap by cutting as close to the stringer as possible without cutting the stringer.
4. File off all burrs on the ends of the stringer.

CABLE RACK GROUNDING

4-123. Connect (strap) grounding straps between all junctions or splices using the lug terminal on the grounding strap, two star washer, a 1/4 inch bolt, a flat washer, and a 1/4 inch bolt on the outside stringer, with insulated 12 American wire gauge (AWG) or larger copper wire. After the cable rack has been strapped, connect (bond) the cable rack to the site ground and to the fault protection bus in the nearest distribution box (see figures 4-56 and 4-57 on page 4-41).

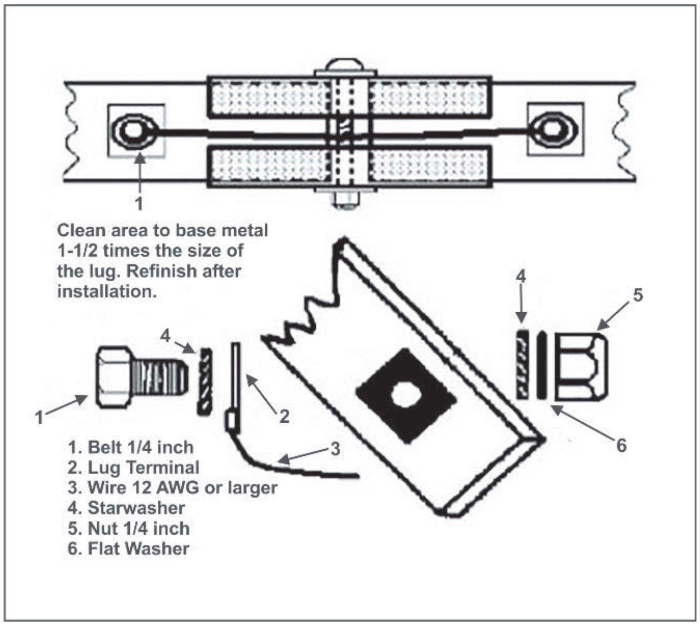

Figure 4-56. Strapping cable rack

4-124. Figure 4-57 is a depiction on how to bond a cable rack.

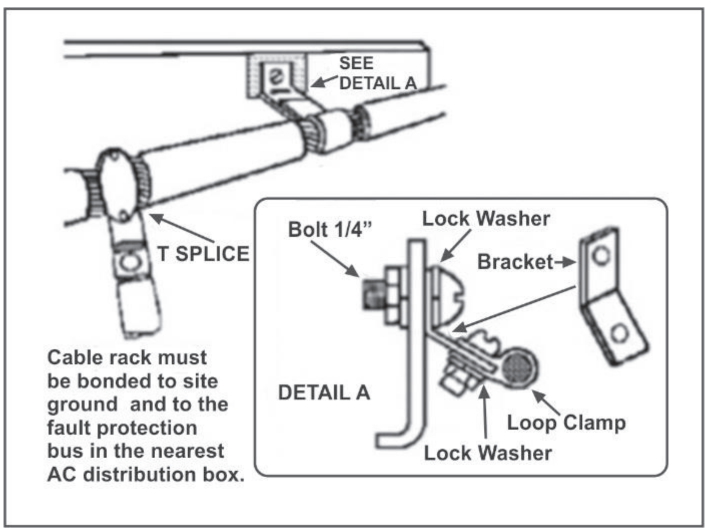

Figure 4-57. Bonding cable rack

INSTALLING WIREWAYS

4-125. Hang wireways, or ducts, in place with supports at 5 feet intervals and should be supported within one foot at the end of each section. Attach supports to beam clamps or mounting brackets.

WIREWAY HANGERS AND SUPPORT

4-126. Universal hangers can be used to mount wireways to the ceiling, walls, or floors. Thread rods can suspend Wireways or hanger straps (see figure 4-58 on page 4-42).

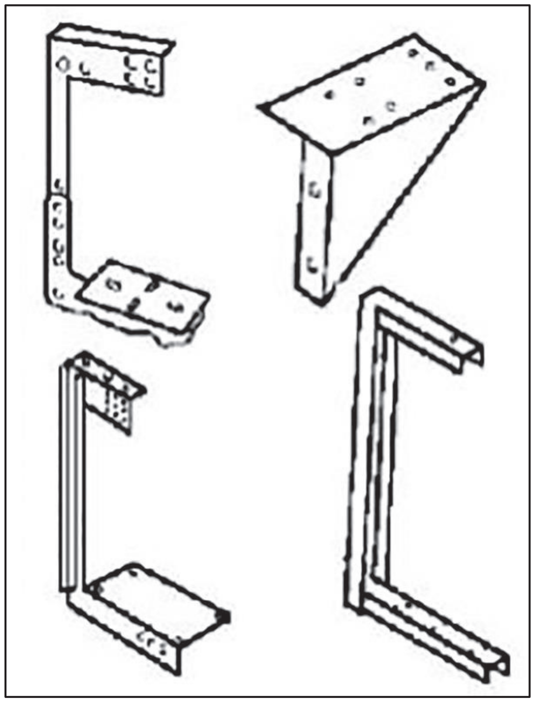

Figure 4-58. Supports for wireways

4-127. When wireways are suspended from the ceiling (trapeze supported), they can be supported by lipped channel with threaded rods (see figure 4-59).

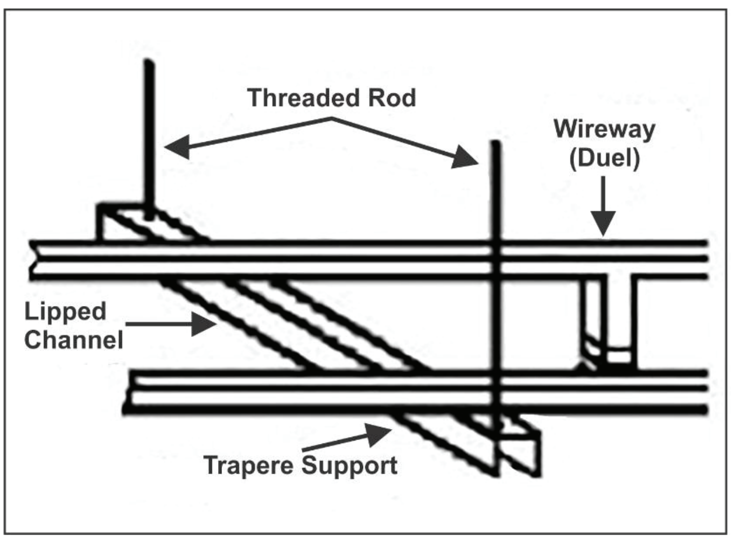

Figure 4-59. Trapeze support for wireways

Wireway Fittings

4-128. Use various fittings when installing wireways depending on its application (see figure 4-60 on page 4-43). Some of the most common fittings used with wireways are—

- Coupling or splice plates. Must be secured to sections and elbows on a least three sides with screws and star washers. The heads of the screws will always be on the inside of the wireway.

- Use closing plates to seal the ends of wireways or fittings. Heads of the screws will be on the inside of the wireway, and ensure to anchor the plate tightly in place. Knockouts in the closing plate allow extension of the wireway with conduit.
- Connectors (telescope fittings and slip-fittings) provide a means to adjust the length of straight connections from 1/2 inch to 11 1/2 inches. Setscrews provide grounding between the sliding wireway sections. The cover is removable and has self-aligning screws.
- End fittings connect duct to panels and cabinets. Cutting a hole and drilling mounting holes to match the end fitting can result in a solid connection free of rough edges.

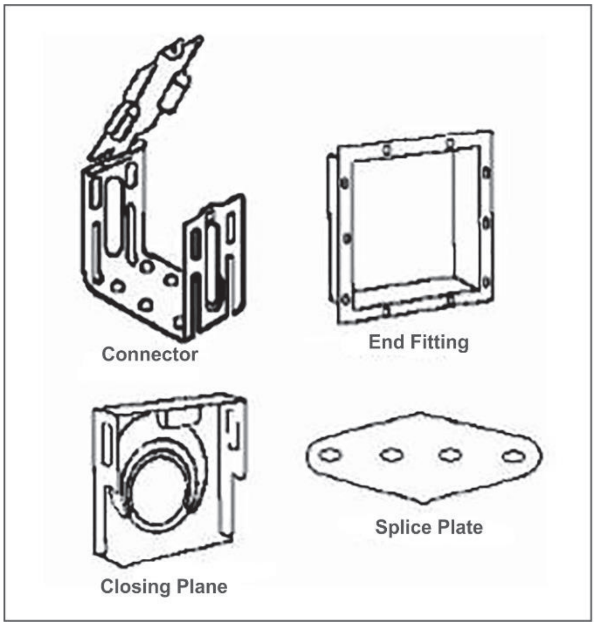

Figure 4-60. Wireway fittings

4-129. Tee fittings are used to branch from one section to another. The covers and sides are removable, with self-aligning captive screws (see figure 4-61).

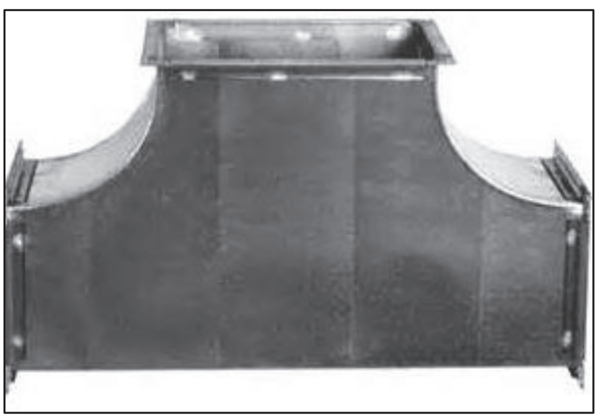

Figure 4-61. Tee fitting for wireways

4-130. Reducer fittings are available to connect different sizes of wireways together The standard reducer sizes are 4” X 4” to 2 1/2” X 2 1/2”; 6” X 6” to 4” X 4”; 8” X 8” to 6” X 6”; 12” X 12” to 8” X 8” wireways.

4-131. Wireway elbows are available in 221/2, 45, and 90 degree bends and attach to sections with a connector (see figure 4-62 on page 4-44). All covers and sides are removable on wireway elbows with self-aligning captive screws.

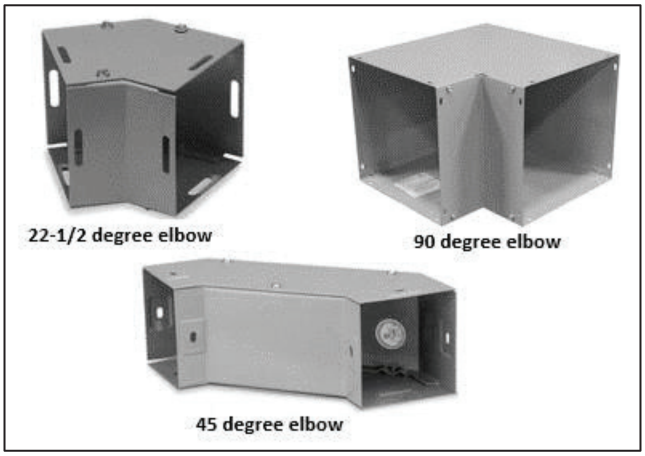

Figure 4-62. Wireway elbows

4-132. Junction boxes connect four to six wireway runs together. Seal unused openings with closing plates. Use large junction boxes (also called pull boxes) at junctions of several duct runs. Pull boxes have six openings, one opening on two sides and two openings on two sides. Finish two closing plates with each pull box.

4-133. Transposition sections permit the wireway to be rotated 90 degrees. These sections come with a removable side (typically secured using butt hinges and quick release latches) that allow cables to be laid in instead of having to be pulled through. They come in 1-foot lengths and are available in 2 1/2" X 2 1/2"; 4" X 4", and 6" X 6" sizes.

4-134. Install partitions or barriers inside wireways to separate power cables from communication cables. Wire retainers are also available to secure cables in wireways where the lid opens toward the floor or wall.

Restrictions When Using Wireways

4-135. Cable restrictions that must be applied when using wireways are as follows—

- Power cables—
  - Cannot exceed 600 volts.
  - Total number of the cables cannot exceed 20 percent of the interior cross sectional areal at any one point.
  - Cannot be more than 30 cables in any cross section of duct.
  - Areas is the wireway that have taps and splices must not fill the wireway to more than 75 percent of its area.
- Communications cable—
  - Total number of cables cannot exceed 30 percent of the interior cross sectional area at any one point
  - There is no restriction on the amount of communication cables.
  - Areas in the wireway that have taps and splices must not fill the wireway to more than 75 percent of its area.

Grounding and Bonding Wireways

4-136. Make wireways, whether used for power or communications, electrically continuous by bonding all sections together. Bond all wireways to the fault protection subsystem at the power panel. The following is applied when grounding and bonding wireways:

- Wireways must have a grounding strap installed at each junction and splice. Use star washers to provide a good bond. Connect all sections and lids using straps fabricated from 12 AWG or larger, solid or stranded, green, insulated copper wire (see figure 4-63).

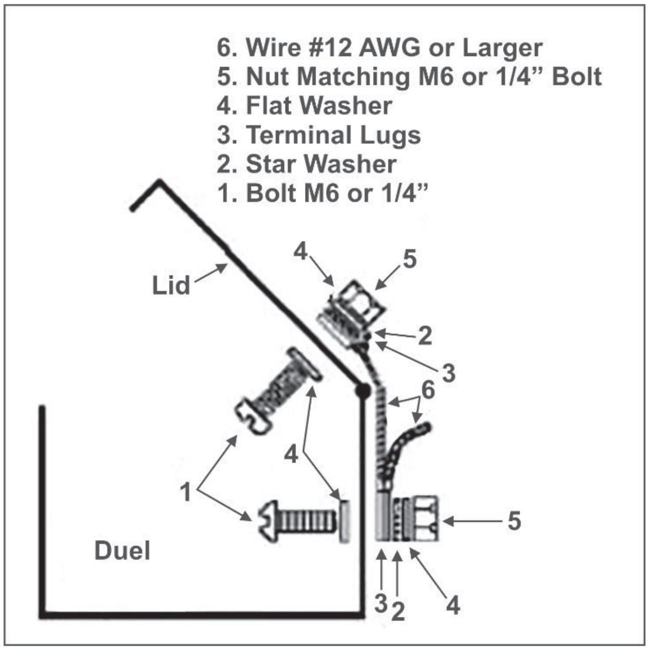

Figure 4-63. Bonding a wireway

- For strapped sections, bond the wireway to ground not more than two feet from each end of the run and every 50 feet along the run, using six AWG green insulated copper wire.

DISTRIBUTION FRAMES

4-137. Distribution frames are necessary for support and protection of cable, cross-connects, and the grounding buss bar. Distribution frames provide a permanent point of termination for outside and inside plant cables that go directly to fixed equipment. It also provides a temporary connection by using the cross-connects between outside and inside plant wiring cables going to fixed equipment. Typically, distribution frames ship preassembled, except for the guardrail and ground bar; however, give Soldiers installation instruction of the distribution frame at the basic installers’ course (BIC).

4-138. Distribution frames are open frameworks, usually of steel, with extending members that form a vertical and horizontal structure for mounting terminal and protective blocks. The approximate dimensions are 3 to 3 1/4 feet wide by 7 1/2 to 11 3/4 feet in height, with lengths varying to the site requirements and the amount of cable terminating on the frame. Frames require a minimum clearance of 36 inches from both sides and the ends for maintenance (see figure 4-64 on page 4-46).

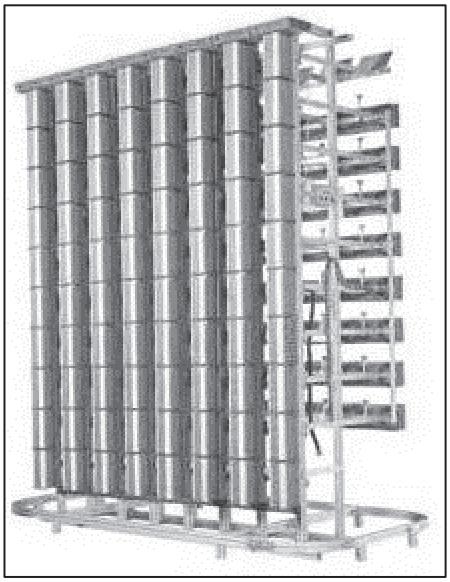

Figure 4-64. Distribution frame

COMPONENTS OF DISTRIBUTION FRAMES

4-139. Components of distribution frames are as follows—

- **Angles**. Angles support the vertical uprights. There is one connected to the vertical upright that secures it to the floor (floor angle) and one connected to secure the top vertical upright.
- **Vertical uprights**. Vertical uprights are the basic framework that fastened together using 8-inch centers.
- **Diagonal braces**. Typically weld diagonal braces to the protector-mounting bar and the vertical uprights for support.
- **Transverse arms**. Weld transverse arms to vertical angle and used to support cable.
- **Jumper ring bar**. Jumper ring bar has three steel bars extending the length of the distribution frame.
- **Jumper rings**. Use jumper rings to guide the cross-connects (jumpers).
- **Terminal block mounting bars**. Only use terminal block mounting bars on the horizontal side to support terminal blocks.
- **Terminal blocks**. Use terminal blocks to terminate cable.
- **Guardrail supports**. Use guardrail supports to protect the terminal blocks and protector blocks from damage by moveable floor equipment.
- **End guard**. Protects the ends of the frame.
- **Finishing bar**. A flat, finish strip bar that increases the strength of the frame and protects personnel from sharp ends of the bar.
- **Grounding buss bar**. A flat copper bar 3/4 inch by 3/16 inch. The length depends on the number of vertical uprights are in the assembly.

TYPES OF DISTRIBUTION FRAMES

4-140. There are three different types of distribution frames:

- Main distribution frame (MDF). The purpose and function of a MDF is to enable the greater part of the wiring in a dial central office to be permanent. The MDF provides a means for terminating outside and inside cables. It also provides flexibility without disturbing the permanent wiring and has convenient and easily identified points of access to the inside or outside cabling for testing.

- Intermediate distribution frame (IDF). The purpose and function of an IDF is to provide a neat and flexible point of termination for inside cable and cross-connects. The IDF has no protector devices and all equipment, patch panels, and tie cables from the MDF will appear on the IDF. This is also the main work area for most wiring changes and in-house troubleshooting.
- Combined distribution frame (CDF). The purpose and function of the CDF is to combine the functions of the MDF and IDF.

CONDUIT

4-141. Installers install various types of wiring systems. In some instances, installers may be required to protect wires and cables using conduit. Conduit is a tubular raceway through which installers pull insulated cable and wire (conductors). The tubing protects the conductors from mechanical damage and permits easy removal and replacement. Manufacturers make conduit from either steel, aluminum, copper alloy, or PVC plastic. Steel conduits provides the best grounding effect and the best shielding from EMI and radio frequency interference (RFI). Because of these qualities, use only steel conduit in communications and electronic (C&E) facilities. Steel conduit will be the only conduit type further discussed in this publication.

4-142. Connect lengths of conduit to various types of boxes, conduit bodies and equipment to form a distribution system for AC power (see figure 4-65).

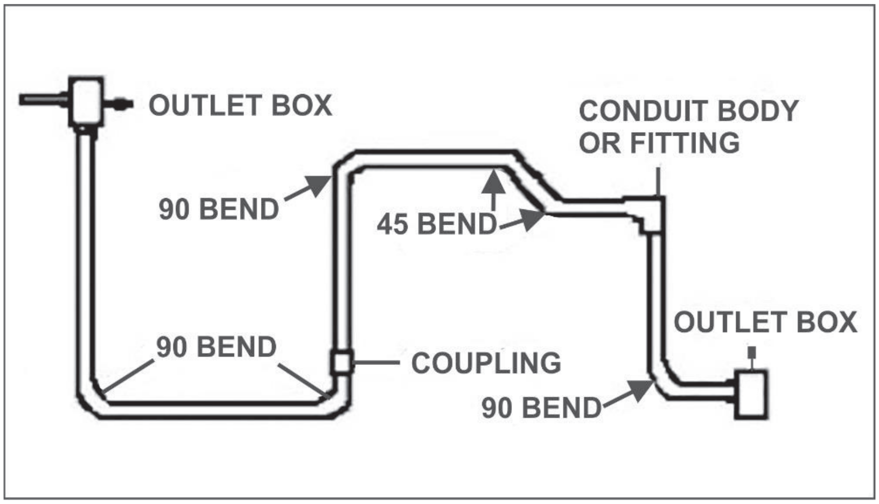

Figure 4-65. Conduit distribution system (conduit run)

TYPES OF CONDUIT

4-143. There are four types of conduit: rigid, electro-metallic tubing, flexible, and liquid tight flexible (LTF) conduit. The following discusses each type of conduit.

Rigid Conduit

4-144. Also known as thick wall conduit, can either be made of galvanized or non-galvanized steel. Use galvanized steel rigid conduit for outside plant installation when excessive moisture is present or when embedding conduit in concrete. Use non-galvanized steel rigid conduit in general inside plant installation. Rigid conduit is moisture proof, fireproof, and can withstand severe mechanical injury. Additionally, use rigid for both exposed and concealed work and in nearly all classes of buildings. Characteristics are as follows—

- Size: Ten feet lengths. Inside diameter ranges from 1/2 inch to 6 inches.
- Support: Every ten feet and within three feet of any box, cabinet, or fitting. Each ten-foot length will have at least one support.
- Voltage: No limit on voltage conductors loads.

- Restrictions: None.
- Lengths come threaded at both ends. When cutting a length, rethread it with a standard 3/4 inch taper per foot pipe cutting die.

Note. All conduit diameters are measured by the inside diameter.

Electro-Metallic Tubing

4-145. EMT is also known as thin wall conduit, is similar to rigid except it has thinner walls. Use of EMT for both concealed and exposed work in dry locations. You cannot thread EMT; therefore, it uses only threadless fittings. Characteristics are as follows—

- Size: Ten feet lengths. Inside diameter range from 1/2 inch to 2 inches.
- Support: Every ten feet and within 3 feet of any box, cabinet, or fitting. Each 10-foot length will have at least one support.
- Voltage: 600 volts.
- Restrictions: Not used outside of buildings, in battery rooms, or in excessively damp areas.

Flexible Conduit

4-146. Manufacturers make flexible conduit from a spirally wound strip of steel, interlocked on itself and normally used in presence of movement or vibration, such as connecting to motors, rectifiers. Additionally, use flexible conduit when use of other types of conduit is impractical due to limited space. Characteristics are as follows:

- Size: Comes on a reel and cut to desired length. Inside diameter ranges from 3/8 inch to 3 inches.
- Support: Support flexible conduit every 4 1/2 feet and within 12 inches of any box, cabinet, or fitting. Support flexible conduit at bends to aid in pulling conductors through the conduit. Flex may run a maximum of three feet unsupported for strain relief or vibration dampening.
- Voltage: 600 volts.
- Restrictions: Do not use flexible conduit outdoors where it is subject to physical damage. This includes areas that are-wet, underground, embedded in concrete. Additionally, do not use flexible conduits in battery rooms, hazardous locations, or locations where flammable or corrosive vapors are present.

Liquid Tight Flex

4-147. LTF is a steel flex conduit with a covering made of polyvinyl chloride (PVC) plastic. When used with liquid-tight box connectors, protect conductors from water or excessive dampness. Characteristics are as follows:

- Size, support requirements, and voltage limitations are the same as flexible conduit.
- Restrictions: With the exception of being embedded in concrete, LTF can be used anywhere. The total length of the run will not exceed 6 feet.

CONDUIT INSTALLATION

4-148. All conduit runs must be mechanically and electrically continuous and connections must be tight. Conduit will run vertically or horizontally on walls, floors, ceilings, and in equipment cabinets. Installers can run conduit under cable racks, false floors, and in false ceilings. Bend conduit to conform to walls, and equipment fittings. Straps can only support conduit, not hold it against the surfaces. Communications cabling and power conductors will never occupy the same conduit distribution system.

4-149. Separated conduit that contains conductors used for unencrypted data and power both physically and electrically from conduit containing encrypted data and power. Conduit running from an encrypted area (such as a crypto room) to an unencrypted area (such as a tech control facility) can have a piece of PVC conduit placed in the run at the point where it leaves the secure area to break the electrical connection between the encrypted and unencrypted area.

CONDUIT CUTTING TOOLS

4-150. The use of various types of cutting tools are available depending on the type of conduit to cut. The following is a list of conduit cutting tools and their use:

- **Pipe cutter**. A hand tool that consists of a handle and a sharp-edged wheel forced inward by screw pressure that cuts into pipe while rotating the tool (see figure 4-66). Use piper cutters on rigid or EMT conduit.

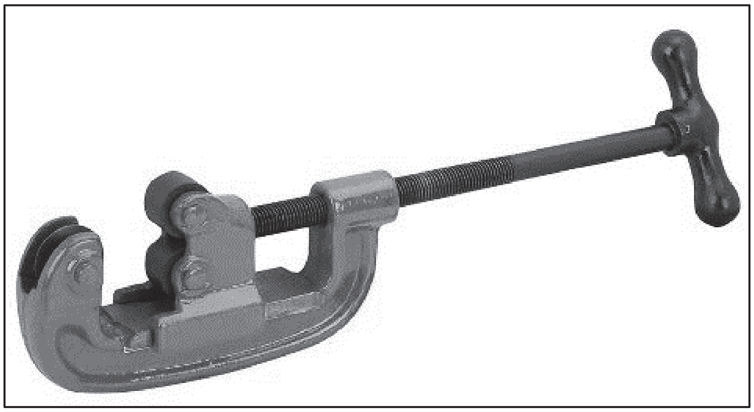

Figure 4-66. Pipe cutter

- **Conduit/Tube cutter**. A compact, lightweight hand tool equipped with a sharp-edged for cutting into pipe as pressure is applied by pumping the handle (see figure 4-67). Use this tool for cutting EMT conduit only.

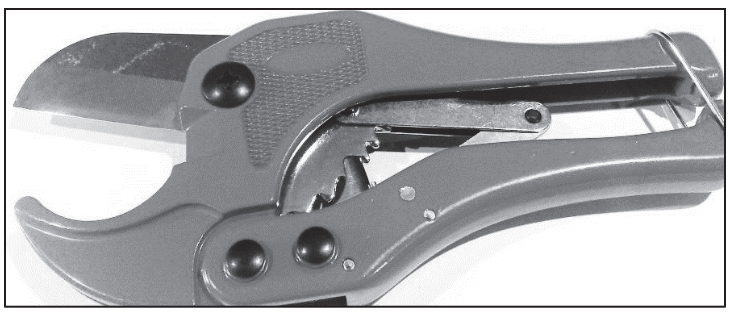

Figure 4-67. Conduit/tube cutter

- **Hacksaw**. A hand tool with a serrated blade under tension in a frame that is used for cutting metal materials (see figure 4-68 on page 4-50). The only type of cutter used to cut flex or LTF conduit.

Note. Do not use lubricant on the hacksaw blade or conduit when cutting

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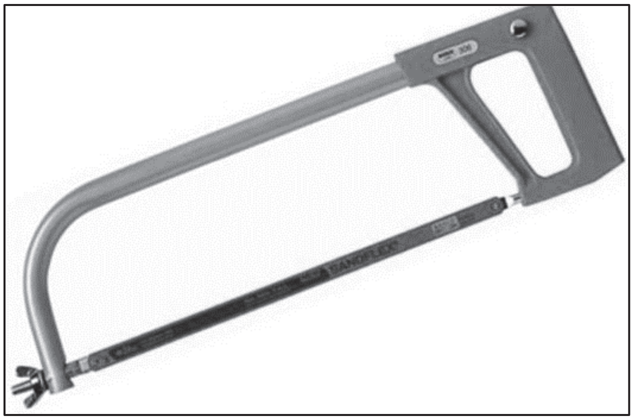

Figure 4-68. Hacksaw

- **Portable band saw**. An electric, two-speed worm gear and chain driven, heavy-duty saw used for cutting metals and other material (see figure 4-69).

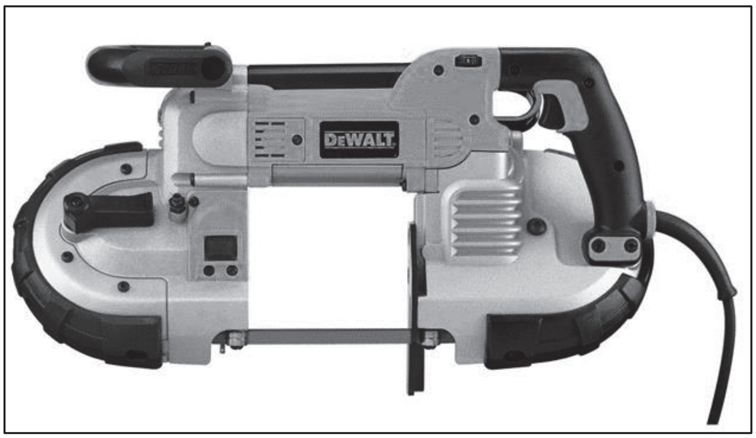

Figure 4-69. Portable band saw

Note. Do not use lubricant on the portable band saw blade or conduit when cutting.

- **Vise**. A tool usually attached to a table with two flat opposing sides brought together or spread apart using a screw type apparatus. It is used to hold objects firmly while work it is being done (see figure 4-70 on page 4-51).

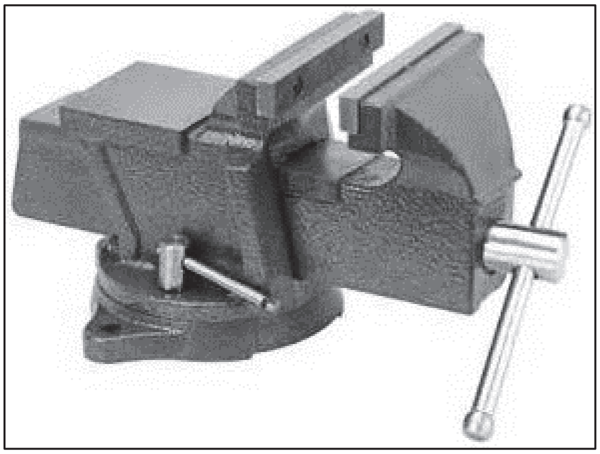

Figure 4-70. Vise

- **Reamer**. A rotating finishing tool with cutting edges used to enlarge or shape a hole or remove burrs (see figure 4-71).

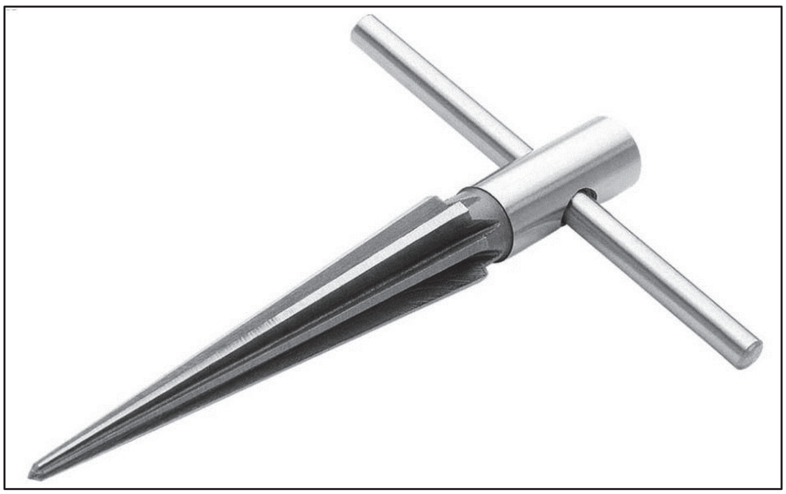

Figure 4-71. Reamer

PROCEDURES FOR CUTTING CONDUIT

4-151. Secure rigid and EMT conduit in a vise for cutting, reaming, and filing. Flex conduit can also be secured in a vise; however, not much pressure can be applied. Securely pad conduit in a vise with blocks of wood or pieces of cardboard to protect from scratches and dents. The following are steps for cutting conduit:

1. Place the conduit in a vise with padding and tighten the vise to necessary tightness.
2. For different conduit—
   - For rigid or EMT conduit—put the cutter over the conduit and adjust it until the cutting wheel makes contact with the conduit, ensuring to center the conduit between the rollers in the jaw of the cutter. Tighten the cutter just enough to score the conduit on the first turn. Turn the cutter around the conduit, tightening the handle about 1/4 of a turn for each revolution around the conduit until the cut is complete.
   - For EMT conduit using conduit/tube cutter. Place the conduit between the jaws of the conduit/tube cutter with the blade jaw on top. Begin pumping the handle of the conduit/tube cutter until it cuts the conduit.
   - For flex and LTF conduit. Ensure to select the proper hacksaw blade before cutting, with the teeth of the blade pointing away from the handle. Place the blade of the hacksaw on the

conduit. Begin cutting the conduit using a back and forth motion with the handle. When cutting flex conduit, cut at an angle so to cut through only one section of the steel strip through. A slight twist will separate the flex conduit. Ensure to support LTF when cutting. Cut straight through and do not remove the PVC covering.

Reaming and Filing

4-152. Cutting any type of conduit results in sharp edges or burrs on the inside that could damage the insulation on the pulled through conductors; therefore, it is important to ream and file after cutting conduit. For rigid conduit, use the reamer first to remove the larger burrs, following by a round (rat-tail) file to smooth off the interior edges and a flat file to smooth off the outside rim. Ensure to rethread rigid conduit after cutting. For EMT conduit, the procedure is the same except that less pressure is on the reamer.

CONDUIT BODIES

4-153. Conduit bodies are hardware used with conduit that is made of malleable iron or aluminum. Types of conduit bodies are-conduit elbows (figure 4-72) and conduit tee bodies. They come with covers that either clamped on or held in place with corner screws. The covers may have rubber gaskets, making them water tight. Conduit bodies are used to change direction or branching, provide access for easy installation or removal of conductors, provide openings for making splices and taps in conductors, connect conduit sections, or used as pull points which is required for every 360 degrees of bend when running conductors. Description of the different conduit bodies are as follows:

- Elbow (L) bodies. Used to make 90-degree turns. There are four types of elbow bodies:
  - LL. Open on the left.
  - LR. Open on the right.
  - LB. Open on the back.
  - L. Open on both sides.

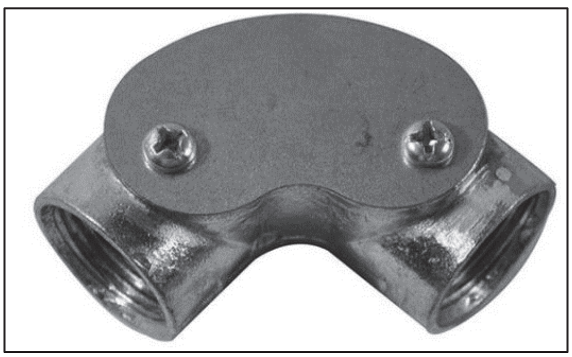

Figure 4-72. Conduit elbow body (LL version)

- Tee (T) bodies (figure 4-73 on page 4-53) are used to extend a vertical conduit run from a horizontal run. There are two types of tee bodies—
  - T. Opening rotated 90 degrees from the center hole.
  - TB. Opening on the back of the center hole.

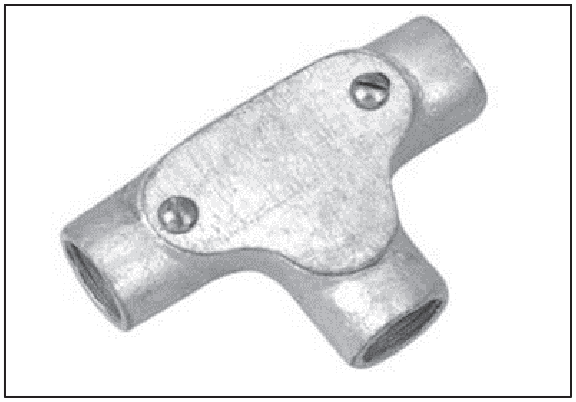

Figure 4-73. Conduit tee body (T version)

UTILITY BOXES

4-154. Use utility boxes to house electrical devices such as light switches, electrical outlets and lamps, or as junction boxes or pull boxes. They are usually made of sheet metal and come in a variety of sizes and shapes (see figure 4-74). The following are the various sizes and shapes that may be encountered with their uses:

- **Square box**. Used as junction boxes, single or double gang switch/outlet boxes. Square boxes come with or without knockouts for various sizes of conduits and measures 4” X 4”.
- **Handy box**. Used as switch/outlet boxes or pull points. Handy boxes come with or without knockouts and measure 2” X 4”.
- **Octagon box**. Used for mounting light fixtures, switches, outlets, junction boxes, and pull boxes. Octagon boxes come with or without knockouts and variety of sizes.

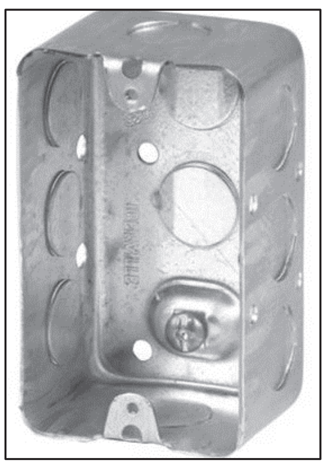

Figure 4-74. Utility box (handy box type)

Utility Box Covers

4-155. There are three basic types of utility box covers: blank, switch, and outlet. Utility box cover can be made of metal or plastic, but only use metal covers in C&E facilities (see figure 4-75 on page 4-54).

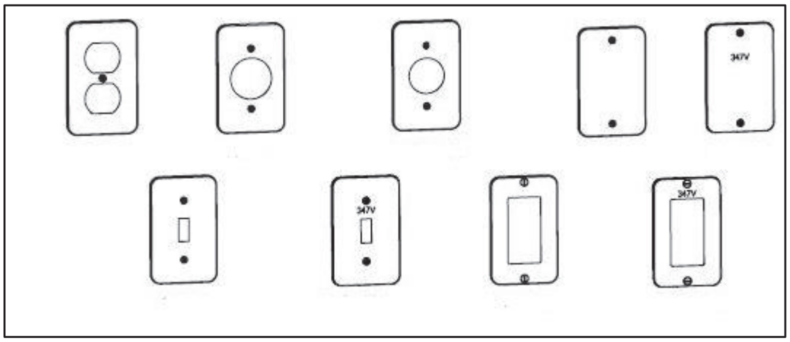

Figure 4-75. Utility box covers

Cast Boxes

4-156. Cast boxes are made of cast iron or aluminum with one or two hubs built into them. Thread the hubs to accept rigid conduit or an EMT box connector. Cast boxes are used to house electrical devices in areas where electrical magnetic protection (EMP) hardening, EMI/RFI shielding, or weather protection is required (see figure 4-76).

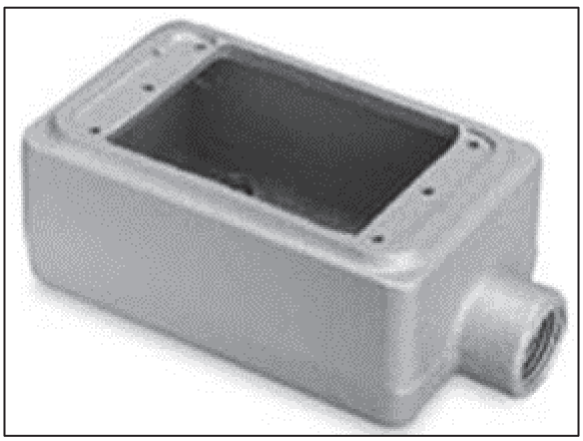

Figure 4-76. Cast box

Cast Box Covers

4-157. Cast box covers have rubber gaskets for a watertight seal. There are currently three types of cast box covers: blank, switch, and outlet.

Installation of Conduit Boxes and Bodies

4-158. Mount conduit boxes with the box cover flush with the surface or mounted exposed; however, securely fasten them to the surface on which they are mounted. Rigidly support conduit bodies by the attached conduit.

4-159. Close unused openings on conduit boxes or bodies by an approved method such as with a hole-button or pipe plug. Secure an appropriate cover to all utility boxes after installing and verifying the wiring.

Accessories Used To Install Conduits, Boxes, and Bodies

4-160. This section discusses the various accessories used to install conduits, boxes, and bodies. These accessories allow the ability to install conduits, boxes, and bodies in numerous applications.

Couplings

4-161. Coupling connects two lengths of conduit. Couplings can come either threaded or unthreaded. There are specialized couplings available for various applications. Unthreaded couplings can either be compression ring type or set screw type.

Box Connectors

4-162. Box connectors connect conduit-to-conduit boxes or bodies. They come in either threaded or unthreaded. Unthreaded box connectors are attached using a gland nut and compression ring over the end of the conduit and tightening. Additionally, there are numerous types of box connectors for the various types of conduit. This includes—

- Flex conduit connectors. Two types-internal and external.
- Liquid-tight box connectors.
- External Box Connectors or couplers.

Conduit Supports

4-163. There are two types of conduit supports—pipe straps or clamps and conduit hangers (see figure 4-77).

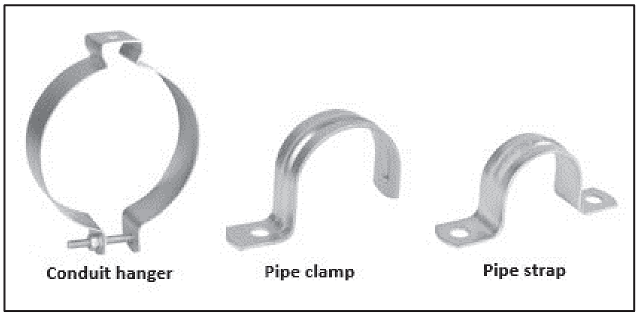

Figure 4-77. Conduit supports

Knockouts

4-164. Knockouts are usually for outlets, pull boxes and panel boxes. Also, use them to permit flexibility and ease for attachment of conduit. Knockouts are the pre-cut holes in boxes, bodies, or outlets. Often these pre-cut holes will still have the inner piece installed that you will have to "knockout" before using the hole. Knockouts come in different sizes either as single or concentric. Concentric knockouts are employed to permit the selection of the hole sizes that may be needed. Remove knockouts by striking them with a hammer or twisting them off with a pair of pliers.

CONDUIT BENDING

4-165. Installers must be able to bend EMT or rigid conduit to connect pieces of equipment, and make the conduit conform to a particular surface, fitting, or equipment. This section will discuss the basic types of conduit bends, types of conduit benders and general rules for conduit bending.

Note. *Shrinkage* is the loss of conduit length due to bending.

Conduit Benders

4-166. There are three types of conduit benders: manual, hydraulic, and mechanical. The type depends on the type and size of conduit that the installer must bend. The follow describes each type of conduit benders:

- **Manual benders**. There's two types of manual benders—

- **One-shot manual bender.** One-shot manual bender (see figure 4-78) is mainly used with EMT, but can be used with rigid conduit. The one-shot is so called because a full 90 degree bend can be made with a single motion. It consist of two parts, bender head and the detachable handle. The handle, a piece of threaded 3/4 inch diameter pipe or rigid conduit, is screwed on to the hub of the bender. The forward part of the one-shot bender is called the toe. The back part of the one-shot bender is called the heel. It also has conduit alignment marks. Use the arrow marking for offset, "B" and "C" bends of a saddle, angle bends, and stub 90-degree bends. The rim notch marking is used only for the "A" bend of the saddle; Star marking is used for the regular 90 degree bends only; Degree markings 22, 30, 45, and 60 degrees are on the heel of the bender. When bending conduit, the top edge of the conduit must be parallel with the degree line.

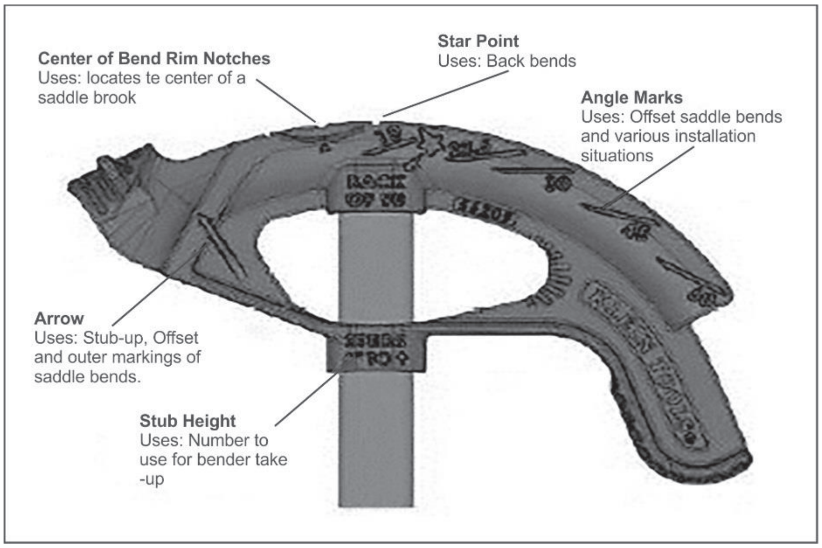

Figure 4-78. One-shot bender

Note. A manual conduit bender designed to bend one size of EMT can be used to bend the next smaller size rigid conduit.

- **Hickey. Use** the hickey mainly to bend rigid conduit. It consist of two parts, the bender and the handle (see figure 4-79). The handle of the hickey is the same as the handle on the one-shot bender.

Figure 4-79. Hickey

- **Hydraulic benders**. Use hydraulic benders to bend EMT larger than one inch and rigid conduit larger than 3/4 inch. The hydraulic benders consist of a hand operated hydraulic pump or reservoir, a hydraulic ram with its connection hoses and various shoes and rails. The shoe and rail used must match the size and type conduit the installer is bending. See figure 4-80.

Figure 4-80. Hydraulic bender

- **Mechanical benders**. Use mechanical benders to bend the same conduit sizes as the hydraulic benders. Mechanical benders use an electric motor and gearbox to apply force needed to bend conduit.

General Rules When Bending Conduit

4-167. When bending conduits consider the following general rules:

- Conduit bending is a two-person task. One person aligns the conduit while the other uses the bender.
- Always bend conduit on a hard, flat surface.
- When marking conduit for bending, use a grease pencil and place a 2-inch constant mark completely around the conduit at the point of the bend. The installer can also mark an arrow on the conduit in the direction of the bend.
- The *committed end* is the start of the conduit where the installer makes the first bend. The other end is the *non-committed end*.

4-168. Some common bends are:

- Offset bends.
- Saddle bends.
- Angle bends.
- Various 90 degree bends—regular, stubs, kick outs, and back-to-back.

Measuring Conduit Runs

4-169. Before making any bends, the installer should determine the total length of conduit required for the run. This total length is the distance the run covers plus any shrinkage and minus any gain. All fractions in the measurements will be left in 16ths of an inch until the final length is determined (see Appendix E).

FACILITY GROUNDING

4-170. The facility grounding system provides a direct path of known low impedance between earth and various power distribution systems, and communications equipment. It effectively extends a ground reference throughout the facility. A good station ground should not exceed 10 ohms. This section will cover the three primary functions that a facility ground should provide as well as subsystems of the facility grounding system.

4-171. A properly installed facility grounding system provides three primary functions—personnel safety, equipment protection, and electrical noise reduction. This section will discuss these three primary functions.

4-172. Facility grounding provides personnel safety by low impedance grounding between equipment, bonding between equipment, metallic objects, piping, and other conductive objects, so that currents due to faults or lightning do not result in voltages sufficient to cause a shock hazard.

4-173. Facility grounding provides equipment protection by low impedance grounding and bonding between electrical services, protective devices, equipment and other conductive devices, so that faults or lightning currents do no result in hazardous voltages within the facility. In addition, the proper operation of over-current protection devices is frequently dependent upon low impedance fault current paths.

4-174. Facility grounding provides electrical noise reduction in communication circuits by ensuring that the impedance to earth ground is minimal between signal ground points throughout a C&E facility. Though minimum voltage potential exists between the various equipment, facility grounding prevents noise sources from conducting to communications circuits.

FACILITY GROUNDING SYSTEM

4-175. To ensure the three primary functions of a facility ground system are covered, there are numerous subsystems that make up the facility grounding system. These subsystems are—earth electrodes, fault protection, lightning protection, and the signal reference subsystem. This section will further discuss each of the subsystems that make the facility grounding system.

EARTH ELECTRODE SUBSYSTEM

4-176. The earth electrode subsystem establishes the electrical connection between the facility and earth. This connection is necessary for lightning protection, power fault protection, and the minimization of noise between interconnected facilities. Various types of earth electrodes are—

- Metallic underground water-pipe networks.
- Metal structure of the building.
- Well-casting installations.
- Driven ground electrodes (commonly known as ground rods and most commonly used).
- Grid systems.
- Plate ground.
- Counterpoise.

FAULT PROTECTION SUBSYSTEM

4-177. Provides personnel and equipment protection against power fault currents. The equipment fault protective subsystem consists primarily of the ground lead of the interior AC power distribution system and is normally a single-point network. The color code for the conductors are green or green-yellow insulated wires running in the same conduit or wireway with the neutral and phase conductors. Key points to remember with fault protective subsystems are—

- Ground the conduit to the power panel at each end, but do not use in lieu of a ground conductor, which continues through the conduit to the protective buss bar.
- Ground the AC neutral lead at the main AC entry panel and this is the only ground point for each building for best results. Connect the AC neutral and protective ground at the main power source of the facility.
- Single access to earth electrode subsystem.

LIGHTNING PROTECTIVE SUBSYSTEM

4-178. The lightning protective subsystem is a structure for lightning protection purposes. A *structure* is a building mast, tower, or similar self-supporting object other than power lines, power stations, or substations. To provide minimum protection for structures against direct lightning strikes, four requirements must be met:

- Ensure to provide an air terminal to attract the leader stroke.
- Establish a path that connects the terminal to earth with such low impedance that the discharge follows it in preference to any other path.
- Make a low resistance connection with the earth electrode subsystem.
- Establish a low impedance interface between the earth electrode subsystem and earth.

SIGNAL REFERENCE SUBSYSTEM

4-179. With signal reference subsystems, ground circuits and referenced to ground to provide fault protection, control static charge, and establish signal return paths between a source and load. The desired goal is to accomplish each of the three grounding functions in a manner that minimizes interference and noise. When discussing the term network in this section, if refers to the grounding network of a subsystem. Signal reference networks are described as follows:

- Lower frequency signal reference networks are single point. The purpose of this network is to provide a single point reference for lower frequency signals (below 300 kilo-hertz), and in some cases below 30 kilo-hertz, minimize power frequency noise levels in sensitive lower frequency equipment, and provide fault protection and static discharge of otherwise isolated networks.
- Higher frequency signal reference networks are multi-point and provides reference for higher frequencies, above 300 kilo-hertz. This network is a conductive sheet or cable network mesh that provides multiple low resistance paths between any two points within the structure and the earth electrode system.
- It consists of three primary components:
  - The equipotential plane.
  - Equipment ground conductors.
  - The structural steel elements.

SHIELDING

4-180. Use shielding to prevent equipment from transmitting interference into adjacent equipment and to protect it from the effect of interference transmitted by other electronic devices. To be most effective, use shielding equipment, enclosures, and cables with low impedance to ground.

SHIELDING GUIDELINES

4-181. The following guidelines must be considered when shielding:

- Ensure that the shielding provided is sufficient to meet system needs.
- Ensure to maintain shielding continuity at points of entry of signal cables, power conductors, utility lines, and ground conductors.
- Equip all power lines supplying shielded areas with power lines filters.
- Use steel conduit in preference to aluminum conduit to take advantage of the improved magnetic shielding properties of steel.
- Use enclosed metal wiring ducts on raceways in preference to open mesh or unenclosed types.
- Use honeycomb for the shielding of ventilation ports wherever possible.

Note. Facilities that process classified information will be termed as RED throughout the remainder of this book. Facilities that process encrypted classified (classified information that has been transformed through crypto equipment) information will be termed as BLACK. Previous grounding, bonding, and shielding procedures discussed in this handbook covers practices for unclassified portions of facilities or systems. Special additional grounding and shielding considerations must be designed into facilities that process RED or BLACK facilities.

DIRECT CURRENT POWER SYSTEMS

4-182. This section covers general information for DC power systems and the associated batteries. DC power systems are more efficient than AC power systems, and unlike AC power systems, DC power systems are completely redundant. This means when commercial power is lost, batteries in the DC power system will continue to provide power to the equipment for a limited period without interruption. In normal operations, rectifiers convert commercial AC power to DC power and, if required, can be converted back to AC power using inverters to power the equipment and to recharge the batteries.

> ***Note.*** Rectifier-chargers can be a serious source of electrical noise if not adequately filtered. These noise sources must be isolated from the communications equipment and the signal reference subsystem to lessen the chance of electrical noise conducting to communications equipment through metal-to-metal contact. The battery bank acts as a filter to filter-out electrical noise produced by the rectifiers or chargers and other equipment.

TYPES OF BATTERIES

4-183. A cell refers to a single battery. The following are two types of batteries that can be used for application of DC power systems:

- **Flood batteries**. Flood batteries (also called wet batteries) are lead-acid batteries that contain positive and negative plates immersed in a liquid electrolyte solution of an acid and water mixture. Flooded batteries must be located in a separate, specially prepared room for safety reasons. It can vent explosive gases and requires close monitoring of the electrolyte.
- **Sealed batteries**. Sealed batteries (also called gel batteries) are nearly maintenance free. They are much safer than flood batteries and do not require measurements of the electrolyte. Install sealed batteries in a clean, cool, dry environment with level floors and install in proximity of electronic equipment; however, complete a risk assessment to address all hazards. Recommendation of an ambient temperature of 75 degrees Fahrenheit to 77 degrees Fahrenheit for optimal battery life and performance.

COMPONENTS OF A DC POWER SYSTEM

4-184. A DC power system consist of five primary components: rectifiers-chargers, station battery bank, DC power distribution system, inverters, and converters. This section will discuss each component in more detail.

Rectifier-Chargers

4-185. There are typically two rectifier-chargers in a DC power system. Rectifier-chargers convert AC power to DC power to charge the battery bank and provide DC power to the equipment. Each rectifier-charger has the capacity to assume the full load in case the other one fails.

Station Battery Bank

4-186. The station battery bank provides emergency power for station equipment and acts as a filter that removes AC transient (ripple) from the DC voltage. Keep storage batteries within the station battery bank at a fully charged level at all times, typically by self-regulated battery chargers that are set to maintain a specific DC bus voltage.

Battery Racks

4-187. Battery racks are the metal framework used to support the batteries in station battery banks. There are two basic configurations: tiered and stepped (see figure 4-81 on page 4-61). Do not remove protective coatings on the racks. Ensure to retouch any bare metal exposed on the battery rack with corrosive resistant paint. Sealed batteries do not require battery racks and come with their own support parts. Consider bolting battery racks to the floor, wall or both. Battery racks can also be built for earthquake protection.

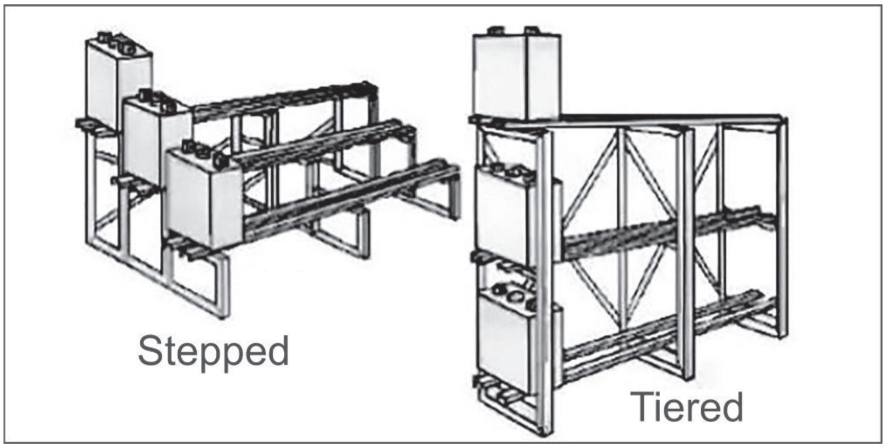

Figure 4-81. Tiered and stepped battery racks

DC Power Distribution System

4-188. The DC power distribution system generally consists of conductors, buss bars, circuit breakers, filters, and fuse panels. Use power distribution and control panels on the DC power distribution system to control and monitor the rectifiers-chargers. DC power is distributed from the DC power distribution system and is fused to protect equipment against an over current position.

Inverters and Converters

4-189. Inverters convert DC power into AC power. Not all sites use or require inverters. Converters converts 48 volt DC (VDC) into other DC voltages for alarm systems and other equipment.

UNPACKING AND INSTALLING BATTERIES

4-190. When unpacking batteries, it is important to understand numerous considerations. Installers must ensure that when unpacking batteries, no debris enters the battery through the vent openings. This chapter will discuss inspecting, moving, and installation of batteries.

> ***Note.*** All battery rooms must have a working eyewash and shower stall before battery installation can begin. At a minimum, provide a large bathtub filled with baking soda and water solution.

Inspecting Batteries

4-191. Inspect batteries for cracks, chips, debris, broken or warped components, and other signs of damage. If damaged, inform the team leader as soon as possible and do not install the damaged battery. The most common name brand of sealed batteries used by the military is Absolyte. Absolyte has a circular label located on one of the module ends with identification codes. Identification codes for Absolyte batteries are as follows:

- S = Standard assembly.
- R = Reversed assembly.
- SD = Standard assembly with dummy.
- RD = Reversed assembly with dummy.

> ***Note.*** Consult layout-wiring diagram for proper location in assembly of battery system before installation. Assemblies can be rotated 180 degrees for proper polarity location.

Installation of Batteries

4-192. The recommended equipment for battery installation are—

- Forklift or portable boom crane.
- Torpedo level (plastic).
- Plywood straight edge 1/2” X 4” X 48”.
- Torque wrenches.
- Vinyl electrical tape.
- Paper wipers.
- Scouring pads.
- Box wrenches (metric).
- Ratchet set (metric).
- Line cord.
- Chalk line.
- Hammer drill for floor anchoring.

4-193. All terminals, interconnecting straps, and coat bolts with “NO-OX-ID” grease at each terminating point to prevent oxidation. Remove any oxidation present using fine sandpaper, steel wool, or a fine wire brush.

4-194. Make battery terminal connections first with the positive terminal, then the negative terminal, to reduce the chance of accidental arcing.

WARNING

Do not attempt to perform tip-over of module manually as serious personal injury and module damage may result.

CAUTION

Battery posts and connecting straps are very soft. Tighten according to manufacturer’s specification, usually 100 to 125 inch pounds. Over tightening may damage the battery.

4-195. Wire all equipment to a circuit breaker. Do not connect equipment to power until completion of all testing for continuity and shorts.

4-196. Batteries may be connected and arranged in series, parallel or series-parallel, to provide the correct voltage and current.

4-197. Maintain a minimum of 36 inches of aisle space adjacent to the battery bank (see figure 4-82 on page 4-63).

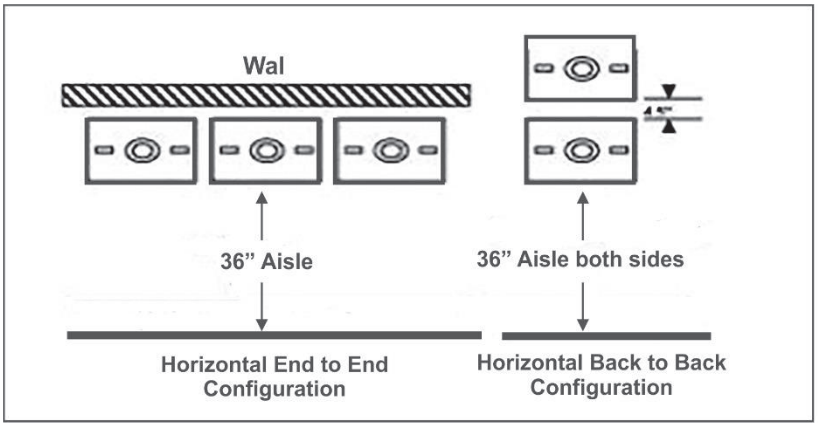

Figure 4-82. Battery bank spacing

Special Considerations when Installing Absolyte Sealed Batteries

4-198. To stack Absolyte battery modules horizontally, you must perform a tip-over procedure. Perform the module base assembly (the module with the I-beam) tip-over first. Accomplish this by using a portable boom crane or forklift. Tip-over is for single modules only (see figure 4-83).

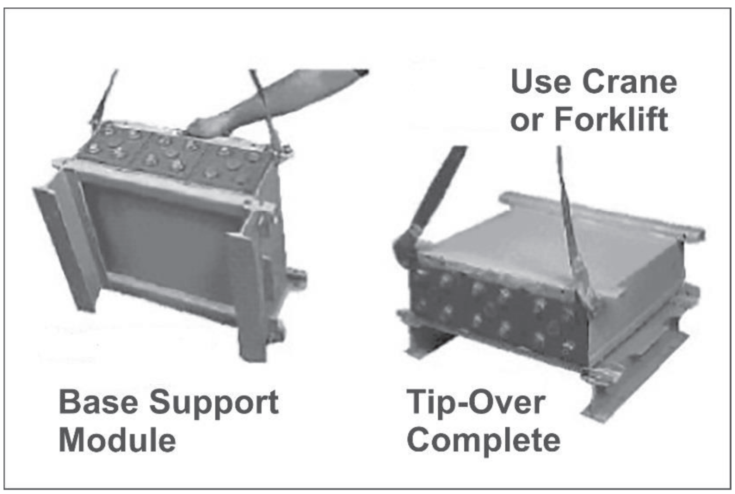

Figure 4-83. Absolyte battery tip-over procedure

4-199. Once the Absolyte module is in the horizontal position, install four lifting shackles and two lifting straps (see figure 4-84 on page 4-64). Attach the I-beam supports and seismic shims to the appropriate base module before removal from the shipping pallet.

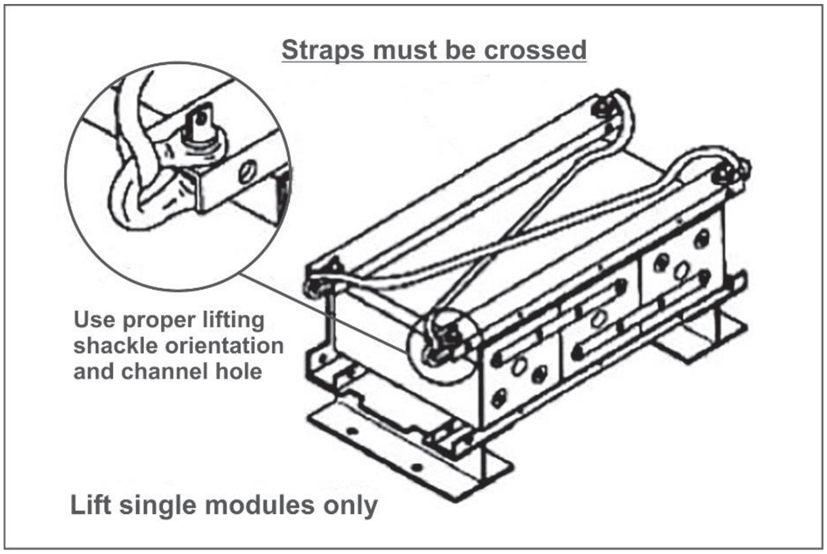

Figure 4-84. Absolyte battery module with installed straps

4-200. To anchor Absolyte battery modules, position the module/base assembly in desired location. Mark floor through the I-beam holes and remove the module/base assembly. Install anchoring devices and reposition module/base assembly over anchors. Check the assembly for level in both axes and level using shims provided. Torque nuts to 47 Newton-meters (35-foot pounds).

CAUTION

The Absolyte battery system comes with a terminal plate assembly for the positive and negative terminations to provide proper connection to equipment and module terminals. Attempting to connect load cables directly to the module terminal may compromise the battery system's performance and compromise the integrity of the battery post seals.

4-201. Absolyte batteries may either be arranged vertically (50 amps and 90 amps for float applications, 50 amps only for cycling applications) or horizontally (50 amps, 90 amps, and 100 amps). Horizontal arrangement is preferred.

4-202. When the application voltage requires, a dummy battery will replace a live battery in Absolyte modules. Most dummy modules will come with factory-installed connectors that either are the standard-dummy or reverse dummy arrangement.

Special Considerations when Installing Flooded Batteries

4-203. Flooded batteries require preparation and installation of electrolyte. Electrolyte is available in premixed solutions, which is safer.

WARNING

It is highly important to follow these procedures. If premixed electrolyte solution is not available, ensure to pour acid into water slowly. NEVER POUR WATER INTO ACID! An extremely violent chemical reaction can occur resulting in serious personal injury.

4-204. Properly arrange flooded batteries on battery racks. When installing in battery racks, place the lowest numbered flooded batteries in the lower racks. Tiered racks are filled from the lowest first, working from the center to the outside, finishing on the highest tier. Fill stepped racks by first installing a battery on each step, starting with the lowest step, then working toward the highest step. Install all other batteries in the same manner, alternating from left to right sides to provide stability of the racks.

4-205. After placing the flooded batteries in the battery racks, battery alignment must be done by stretching a piece of twine between the first battery terminal and the last battery terminal of each row. Ensure the twine is on the same side of all terminals, and then align the batteries (see figure 4-85).

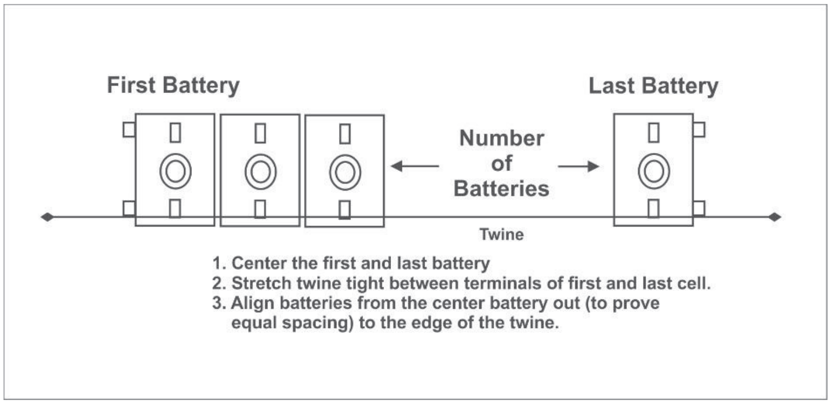

Figure 4-85. Flood battery alignment on battery rack

DC Power Equipment Protection and Continuity

4-206. This section discusses devices used to ensure continuity of electrical power and protection of DC equipment. This section will also cover wiring and connector types and best practices when installing wiring.

DC Equipment Internal Protection Devices

4-207. Most DC powered equipment stops functioning if the voltage drops below 42 to 44 volts. During power outages, if the voltage drops below a certain level, a low voltage disconnect circuit will operate to prevent further drain on the batteries.

Rectifier-Chargers

4-208. Under normal conditions, the two rectifier-chargers are set to share the load. If one of the rectifier-charger fail, the other rectifier-charger will assume the total load automatically.

Counter Electromotive Force Battery Device

4-209. Place a counter electromotive force (CEMF) battery device between the battery bank and the load to reduce the voltage to the load (see figure 4-86 on page 4-66). The CEMF senses the voltage at the battery and adds the correct drop needed to the load. If the output of the battery bank, however, drops to a preset level, the CEMF will be by-passed, allowing previously applied shunted voltage to fulfill the loads voltage requirement.

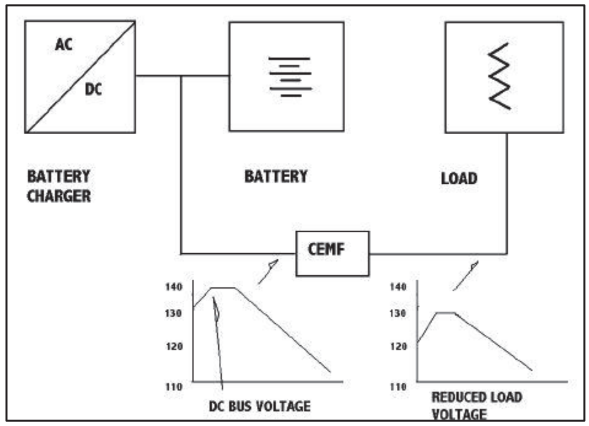

Figure 4-86. Counter electromotive force battery device schematic

End-Cell Battery Device

4-210. An end-cell battery device uses the charged end batteries by a separate battery charger than the remaining batteries. Add the end batteries to the battery bank if the voltage level drops too low. During a power outage a voltage-sensing unit (normally set to 46 volts DC) will detect the reduced voltage and automatically activate the end batteries, transferring additional voltage to the load (see figure 4-87).

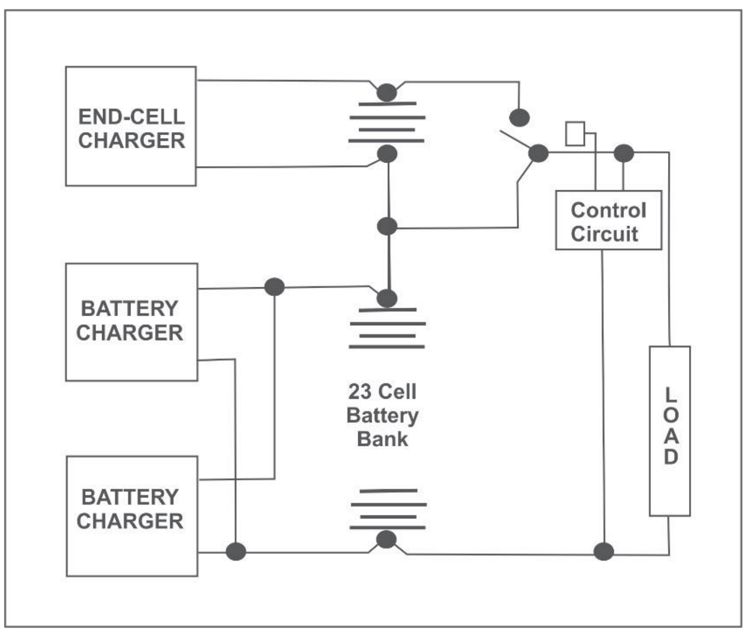

Figure 4-87. End-cell battery device schematic

Uninterruptible Power Supply

4-211. The uninterruptible power supply (UPS) provides power to equipment and subsystems that constitute a critical technical load or simply the critical load. Some systems require DC voltages, some require AC voltages, and some require both. The UPS converts AC to DC then back to AC, which prevents temporary power interruptions from reaching the site equipment. If the site loses primary power, the battery bank provides power to the inverter to convert DC to AC to power critical load(s). Generators are normally on standby and automatically provide power when commercial power is lost. Generators will then automatically turn off when commercial power returns (see figure 4-88 on page 4-67).

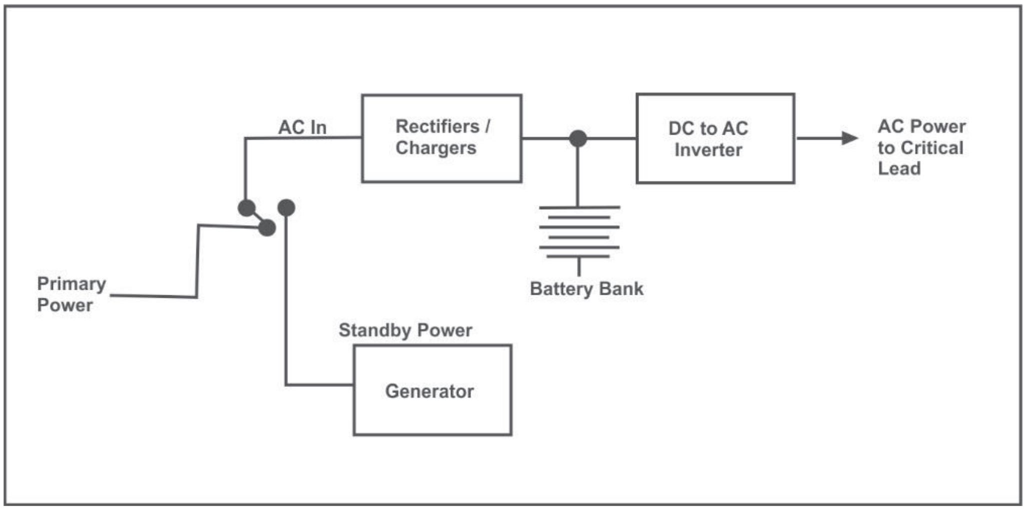

Figure 4-88. Uninterruptable power supply schematic

DC WIRING AND CONNECTORS

4-212. This section covers considerations when installing DC wiring. This section also covers types of connectors associated with installing DC wiring.

DC Wiring Considerations

4-213. Separate DC wiring from the signal wiring as far as possible in cable ladders, trays, and wireways. Use non-conducting material to separate the wiring if necessary. Leads should be continuous lengths, where practical. If splices are required, make splices by crimp-type or screw-type connectors and taped with rubber or plastic tape. Cable taps will be solder-less crimp or screw type taps.

4-214. DC wiring must use the gauge and type of wire called for in the EIP. There should be no more than one splice on the -48 volts DC side (HOT). Do not put splices on the output at the battery; therefore, the shortest connection to the equipment will result in maximum performance (lowest voltage drop).

4-215. Connect the rectifiers, control rack/power boards, converters, inverters, and supports together. Once connected, ground to the AC protective ground only. Install a 100-volt surge suppressor or transient peak limiter between the DC power equipment and overhead metalwork if contact is likely during lightning strike to the facility.

Connectors

4-216. Two types of connectors are crimps and setscrews. The following describes each type of connector:

- Use the crimp connector on multi-stranded cable only. Mark the cable depth into the connector and remove the correct amount of insulation. Thoroughly clean the cable using a wire brush before installing it into the connector. When inserted into the connector, the insulation of the cable should be flush against the connector, with 1/8 inch of bare cable visible on the other side. Crimp the connector onto the cable and inspect it for shiner length and a secure fit (see figure 4-89 on page 4-68).

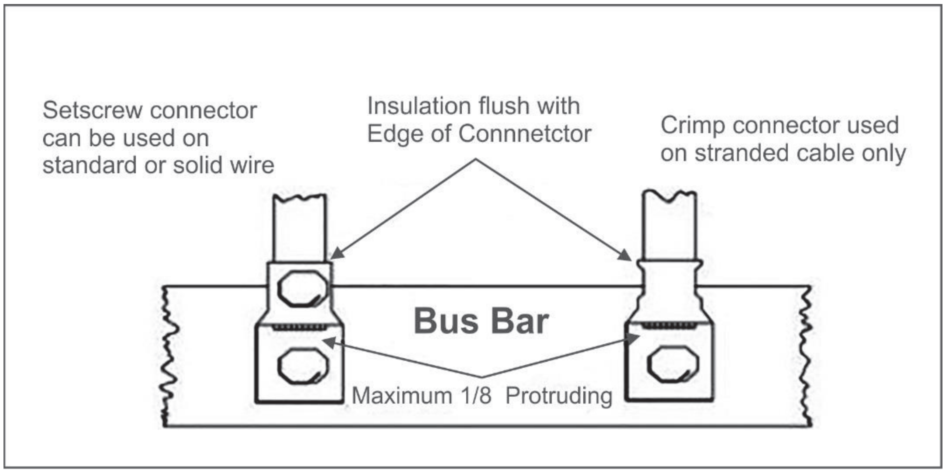

Figure 4-89. Crimp connector

- Use the setscrew connector on stranded or solid conductor cable. The cable preparation are the same as for the crimp connector.

SAFETY PRECAUTIONS WHEN INSTALLING BATTERIES

4-217. The following are safety precautions to consider when installing batteries. Constantly supervise the installation of batteries. The supervisor will not physically participate in the installation.

Safety Briefing and Installers

4-218. Give a safety briefing each day before work starts. Personnel must be aware of how to react to an accident involving battery acid.

4-219. A minimum of three people will be present while working on batteries. This includes the supervisor.

Hazardous Gas and Acid

4-220. Batteries produce hydrogen gas, which is highly explosive. Provide adequate ventilation using exhaust fans if required and smoking is prohibited.

4-221. Electrolyte is a mixture of acid and water that can come either pre-mixed or require manual mixing (acid and water). If manual mixing is required, pour acid into the water slowly and stir. Never pour water into acid. Before mixing electrolyte or filling batteries with electrolyte, mix one box of baking soda to one gallon of water for emergencies. This solution will neutralize acid spills. If anyone gets electrolyte in their eyes, follow these steps—

1. Close both eyes to keep eye movement minimized. This will allow the eyes to naturally wash while the victim is being escorted to the eye wash stand. DO NOT RUB EYELIDS!
2. Flush eyes with water for at least 15 minutes. Ensure that when flushing the eye with acid is below the non-injured eye, otherwise the non-injured eye will get acid in it as well. Seek medical attention immediately.

4-222. Wear proper safety gear (including face shield, gloves, and aprons) while working around batteries. Always follow manufacturer's instruction during battery installation and inspect all batteries for cracks or other damage before filling and installation.

4-223. Observe all safety requirements and recommendations.

ALTERNATING CURRENT POWER

4-224. A communications facility requires AC power for the operation of rectifiers, converters, environmental equipment, and other types of equipment. This section will discuss definitions of some common terms used when discussing AC power, AC power configuration, distribution panels, branch circuits, electrical devices, wiring boxes and electrical devices, wiring an AC toggle switch, wiring receptacles and lamps, wiring and labeling distribution panels, and AC safety.

COMMON TERMS AND DEFINITIONS

4-225. This section covers common terms used when discussing AC Power. Provide definitions of each term to assist the reader with better understanding the sections that follow.

Alternating Current Power Distribution Systems

4-226. AC power distribution system consist of all the service entry equipment, distribution panels, boxes, wiring, and electrical devices needed to distribute AC power throughout the C&E facility.

Current

4-227. Current is the movement of electrons through a conductor measured in amperes. The symbol for current in "I". The formula for current is I = E / R.

Electrical Appliance

4-228. An electrical appliance is a piece of electrical equipment that consumes electrical power, such as a rectifier, power supply, lighting, and power tools. The general term *load* can refer to any electrical appliance.

Electrical Device

4-229. An electrical device is electrical equipment that passes an electrical current but does not consume electrical power, such as an outlet or switch.

Load

4-230. Load is the power consumed by an electrical appliance to perform its function. Load is also defined as work.

Neutral Conductor

4-231. A neutral conductor (also called the *ground conductor*) provides a return path for the power conductor. Insulate the neutral conductor from the ground at all points throughout the C&E facility.

Power

4-232. Power is the rate of electrical energy consumption. The symbol for power is "P" and measured in watts.

Power Conductor

4-233. Also known as the hot conductor or un-grounded conductor, the power conductor applies AC voltage to the load. Do not expose the power conductor to any grounded parts. Commonly used references for AC power conductors are: L-1, L-2, L-3 or ø1, ø2, ø3, or phase A, phase B, or phase C.

Protective Ground Conductor

4-234. Protective ground conductors provide personnel an equipment protection. It should only carry current during a fault condition.

Resistance

4-235. Resistance is a circuit element designed to offer a predetermined resistance to current. Measure resistance in ohms, and its symbol is Ω. The formula for finding the resistance is Ω = E / I.

Voltage

4-236. Voltage is electrical pressure measured in volts. Voltage is the force that causes current to flow through an electrical conductor. Its symbol is "E". The formula for finding voltage is E = I x R.

ALTERNATING CURRENT POWER CONFIGURATIONS

4-237. This section discusses AC power configuration (see figure 4-90). General discussion on line feeders, branch feeders, line feeder color codes, branch feeder color codes, and service entry panels is also discussed in the section.

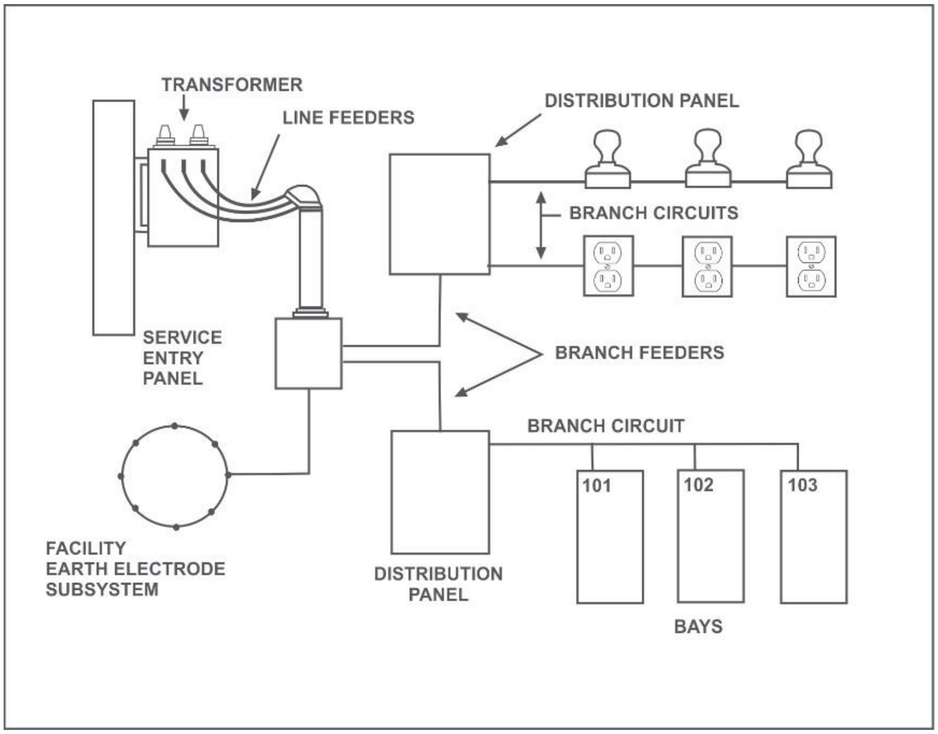

Figure 4-90. AC power configuration

Line Feeders

4-238. Line feeders are the continuous conductors from the service pole to the service entry panel. The service pole (also called a light pole) has transformers. The line feeders (also called power lines) are connected to the transformers on the service poles and connected to the service entry panel.

1ø3W Line Feeder Color Code

4-239. 1ø3W line feeder color code or single-phase-three-wire (see figure 4-91 on page 4-71) are as follows—Hot—L-1. Black insulated conductor.

- Hot-L-2. A black insulated conductor temporarily marked at the end to distinguish L-1 from L-2.
- Neutral. Usually a white or gray insulated conductor.
- Ground. Green insulated conductor.

Note. Do not consider the ground conductor as one of the three wires of 1ø3W. It originates at the service entry panel.

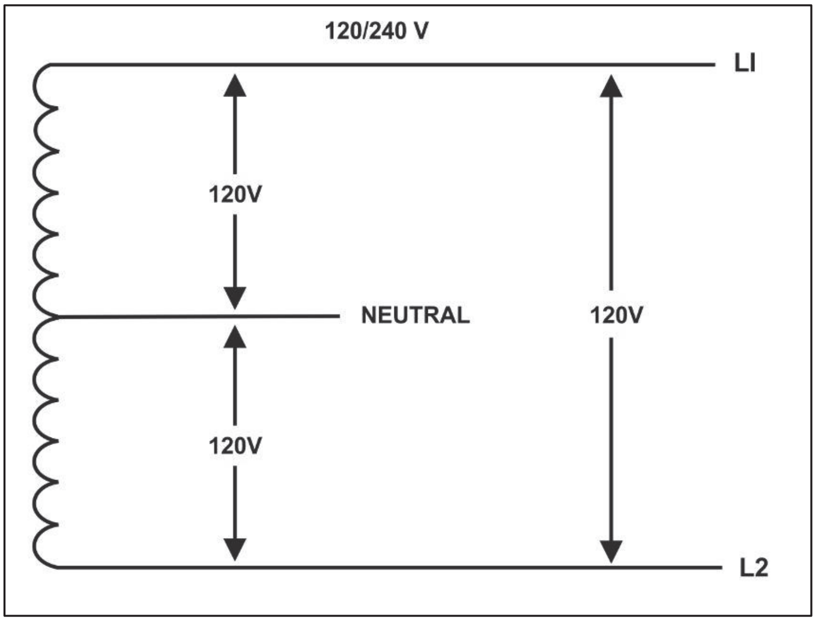

Figure 4-91. Single-phase-three-wire configuration

Branch Feeders

4-240. Branch feeders are the continuous conductors that run from the service entry panel to the power distribution panel(s) (also called the circuit breaker box). See the distribution panel section for further discussion.

3ø4W Branch Feeder Color Code

4-241. 3ø4W branch feeder color code or three-phase-four-wire (see figure 4-92 on page 4-72) color codes are as follows—

- Hot-L-1. Black insulated conductor.
- Hot-L-2. Usually black insulated conductor permanently marked at each end with red colored tape for the purpose of identification.
- Hot-L-3. Usually black insulated conductor permanently marked at each end with blue colored tape for the purpose of identification.
- Neutral. Usually a white or gray insulated conductor.
- Ground. Green insulated conductor.

Note. Do not consider the ground conductor as one of the four wires of 3ø4W. It originates at the service entry panel.

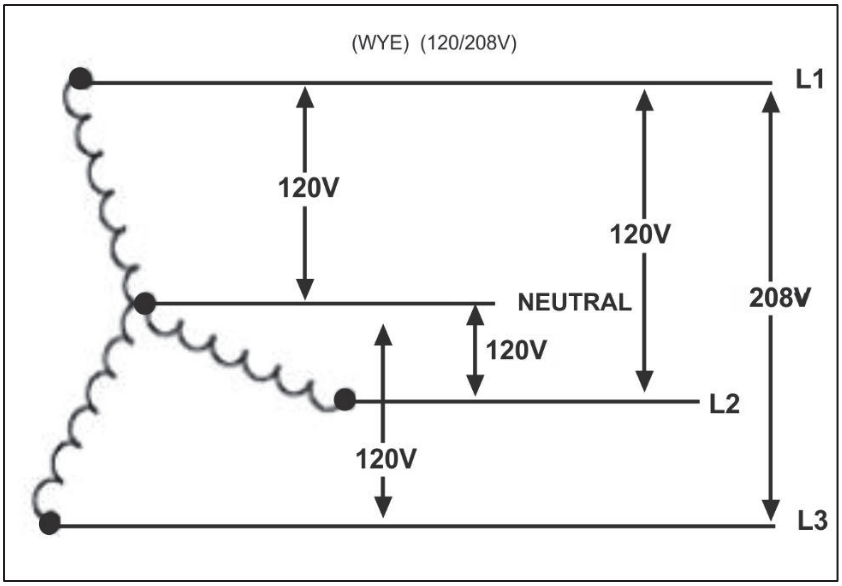

Figure 4-92. Three-phase-four-wire configuration

Service Entry Panel

4-242. Typically, install the service entry panel in the generator room for on-line/off-line switching at facilities with generator backup (see figure 4-93). Terminate both the neutral and ground feeders to the same buss (neutral and protective ground feeder buss). Ground this common buss using a conductor to the facility's earth electrode subsystem. After this, the neutral conductor will be isolated from all ground conductors and elements throughout the facility.

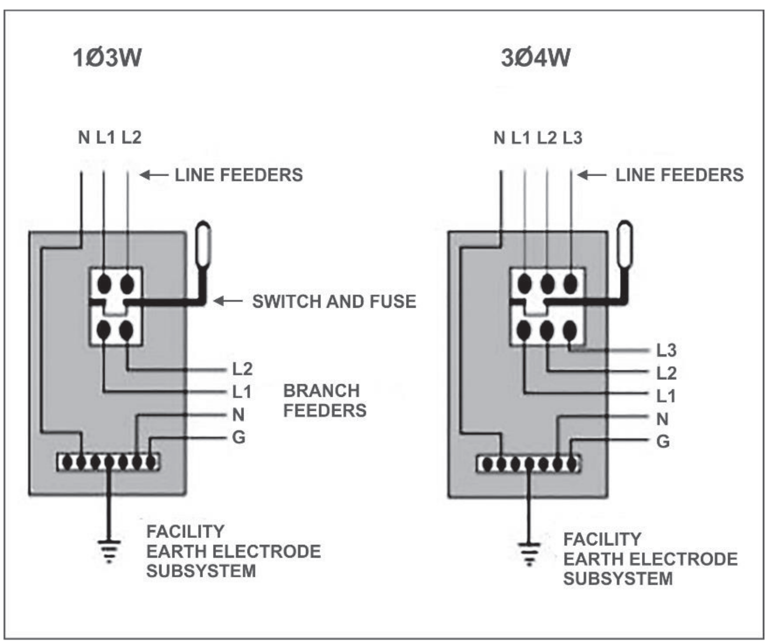

Figure 4-93. Service entry panel configuration

4-243. The protective ground feeder originates at the neutral and protective ground feeder buss on the service entry panel. Keep the protective ground and neutral physically separated after the service entry panel throughout the C&E facility.

Distribution Panel

4-244. The distribution panel distributes power to the branch circuits. It contains the last cutout/branching devices for branch circuits to equipment (power, neutral and ground buss bars). See figure 4-92. Buss bar configuration for 1ø3W and 3ø4W are as follows:

- 1ø3W Distribution panel configuration is as follows—
  - L-1 power buss. Serves circuit breakers. For example 1 and 2, 5 and 6, 9 and 10.
  - L-2 power buss. Serves circuit breakers. For example 3 and 4, 7 and 8, 11 and 12.
- 3ø4W Distribution panel configuration is as follows:
  - L-1 power buss. Serves circuit breakers. For example 1 and 2, 7 and 8, 13 and 14.
  - L-2 power buss. Serves circuit breakers. For example 3 and 4, 9 and 10, 15 and 16.
  - L-3 power buss. Serves circuit breakers. For example 5 and 6, 11 and 12, 17 and 18.

Neutral Buss Bar

4-245. Insulate the neutral buss bar from the panel chassis and protective ground. Mount, when applicable, in a location near the branch feeder entrance to minimize the crossing of hot and neutral feeders with the branch circuit conductors. Count the positions on a buss bar mounted vertically from top to bottom. If mounted horizontally, count the buss bar positions from left to right (see figure 4-94).

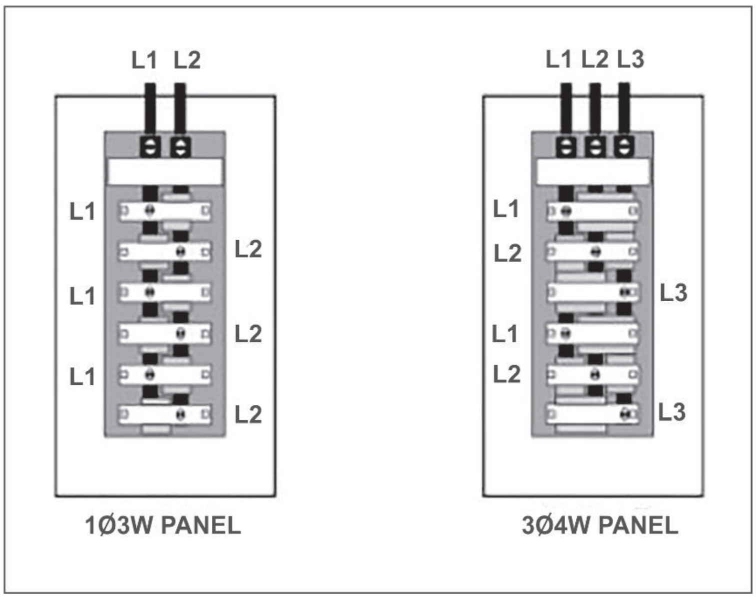

Figure 4-94. Buss bar configurations

Ground Buss Bar

4-246. Properly bond the ground buss bar to the panel chassis. The position count for the ground buss bar is the same as the neutral buss bar (also see figure 4-95 on page 4-74).

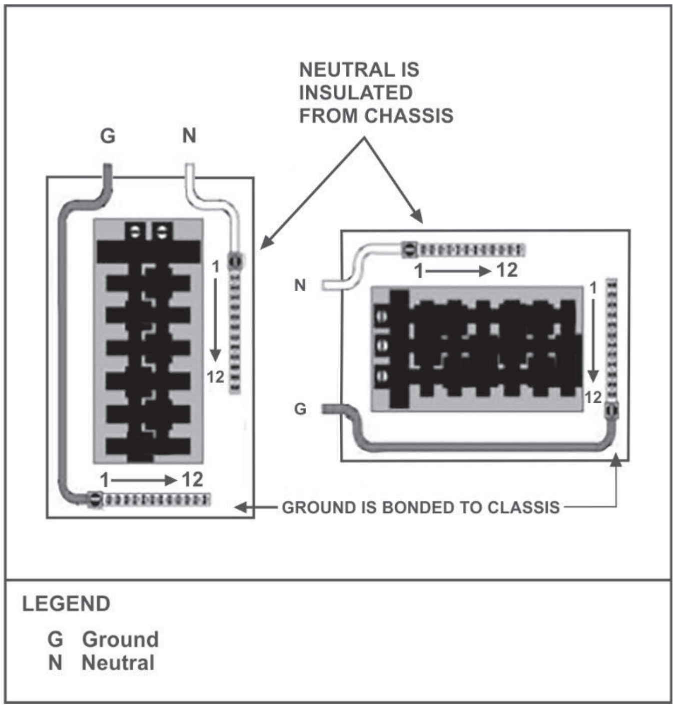

Figure 4-95. Neutral and ground buss bars

Circuit Breakers

4-247. Count circuit breakers for vertically mounted distribution panels (feeders of the power buss bar on the top of the distribution panel) from left to right and top to bottom. Visualize distribution panels mounted vertically or upside down in the vertical position when counting (see figure 4-96 on page 4-75).

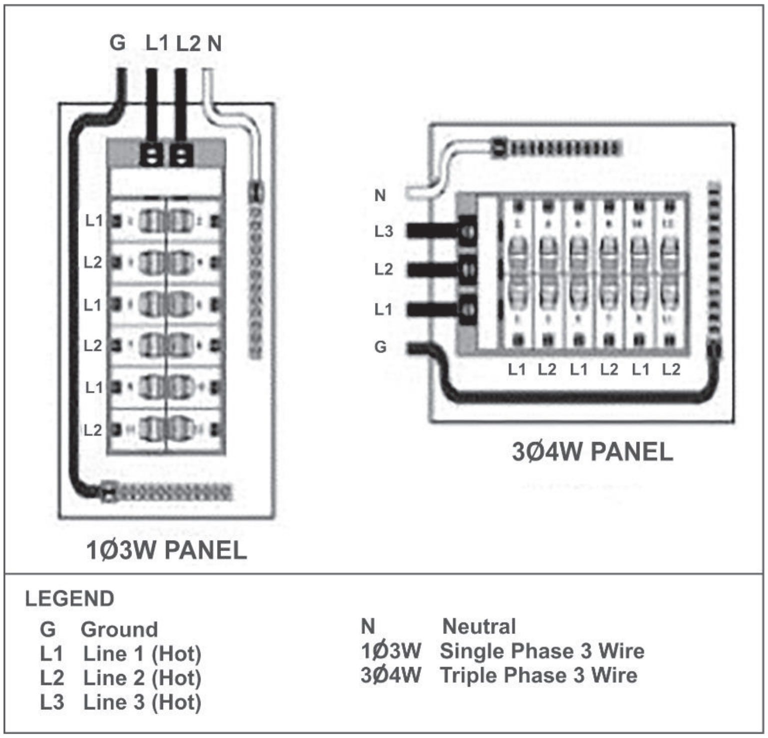

Figure 4-96. Circuit breakers

BRANCH CIRCUITS AND ELECTRICAL DEVICES

4-248. Branch circuits are circuit conductors that run from the distribution panel to the outlet or devices (including light switches, and power outlets). Electrical devices consist of circuit protection devices, receptacles, and general use switches that issue power to electrical appliances. For example, a toaster is an electrical appliance that plugs into an electrical device (a receptacle) in order to receive power to operate.

Branch Circuits

4-249. A branch circuit conductor will not be smaller than 14 AWG. Do not utilize the dedicated conductors within one branch circuit to wire another branch circuit device. Installers can route more than one branch circuit through the same conduit run.

Note. Both the National Electric Code (NEC) and MIL-STD 188-124B(3) specify how many conductors can run in a branch circuit depending on the conductors' size and the size of the conduit being used.

4-250. Branch circuit color codes are shown in table 4-2.

Table 4-2. Branch circuit color codes

Single Phase Alternating Current	*Three Phase Alternating Current*
L-1—Black	L-1—Black
L-2—Black	L-2—Black
Neutral—White or gray	L-3—Blue
Ground—Green	Neutral—White or gray
	Ground—Green

Note. When terminating 240 VAC in a 1ø3W system where the insulated conductors are black, Ensure to identify the L-2 conductor at the terminating location or device by using a tag labeled L-2.

Circuit Protectors and Circuit Breakers

4-251. Circuit protectors and circuit breakers are electrical devices used to protect personnel and appliance from instances when conductors receive more that allowable amperage. This section will discuss the various types of circuit protectors and circuit breakers.

Circuit Protection Devices

4-252. Common circuit protection devices (commonly known as fuses) are as follows—

- Screw and plug fuses have the lowest amperage rating of all the types of fuses (see figure 4-97). They are rated from 0 to 30 amps. There are four types of plug fuses: standard, time delay, S type, and circuit breaker.

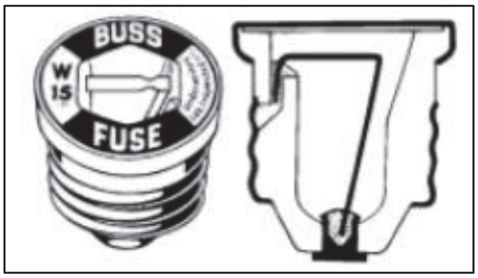

Figure 4-97. Screw and plug fuse (standard)

- Cartridge fuses' length and diameter increases in steps with the amperage rating (see figure 4-98 and 4-99). This does not eliminate the possibility of replacing a fuse with the wrong amperage. The only way to tell if a cartridge fuse is blown is to perform a continuity test. There are two types of cartridge fuses: Ferrule Contact (rated from 30 to 60 amps) and knife blade contact (rated from 60 amps and above).

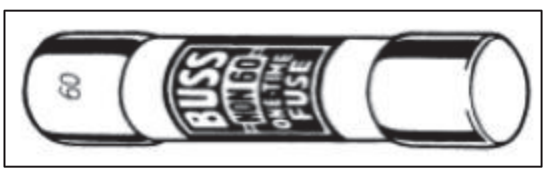

Figure 4-98. Cartridge fuse (ferrule contact)

Figure 4-99. Cartridge fuse (knife blade contact)

Circuit Breakers

4-253. Circuit breakers combine the function as both a disconnect switch and an over-current protection device (see figure 4-100 on page 4-77). By design, they to open a circuit automatically when an over-current condition exists, preventing damage to the equipment and the circuit breaker. Amperage ratings for circuit breakers are 15 thru 200 amps. The size of the circuit breaker increases with the amperage rating.

4-254. Most circuit breakers have a time delay feature, meaning that they can carry 1 1/2 times their rated current for one minute and as much as three times their rated current for five seconds. This time delay allows time for motor driven appliances to reach their operating speed upon initial startup.

4-255. A *circuit breaker pole* is the switch on a circuit breaker. A circuit breaker pole has three positions: on, neutral, and off. The on position is the normal operating position. Neutral happens if the circuit breaker trips due to an overload or over-current conditions, and will cut off the power to that particular branch circuit. To reset from the neutral position, move the switch to the off position and then to the on position. The off position cuts the power off to the circuit breaker's connected branch circuit.

4-256. Circuit breakers can be of a single or multi-poles type (see figure 4-100). A single pole type provides over-current protection for one hot branch circuit. When installed, it taps one hot conductor from the power buss. A multi-pole type (comes in either two or three pole circuit breakers) provides over-current protection from two to three hot branch circuits. When installed they will tap into two or three hot conductors from the power buss, depending on which one you install.

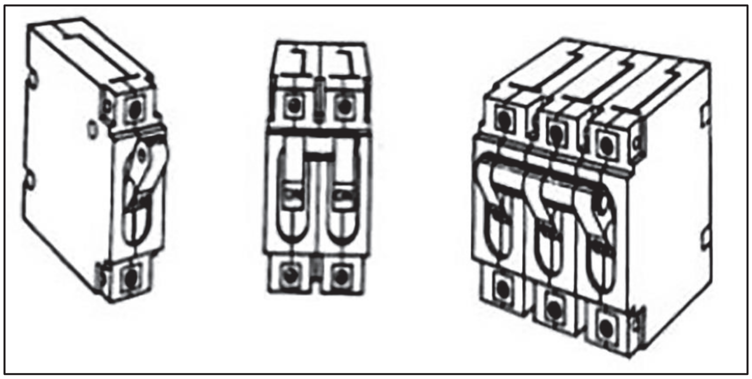

Figure 4-100. Circuit breakers

Ground Fault Circuit Interrupters

4-257. Ground fault circuit interrupters (GFCI) are used where a receptacle is placed within six feet of a water source (including water fountains, sinks, and crawl spaces below grade level). Installers can use one GFCI to control more than one receptacle on the same branch (see figure 4-101).

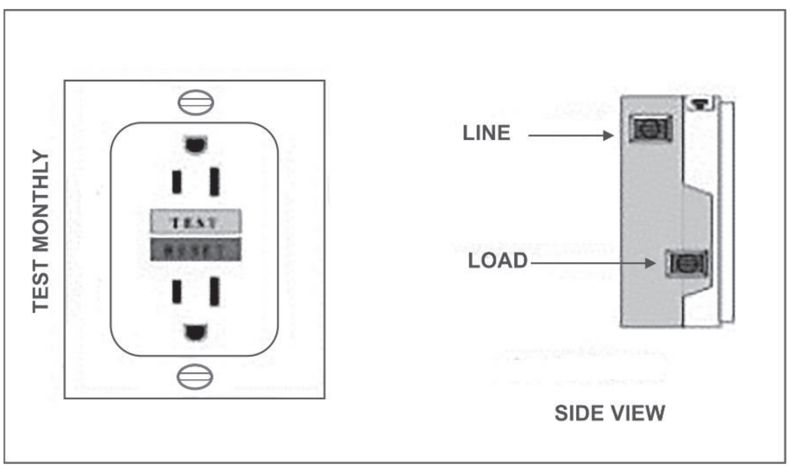

Figure 4-101. Ground fault circuit interrupter

Receptacles and Switches

4-258. Use receptacles and switches to provide electrical power to appliances. This section will discuss various types and configurations of receptacles and switches.

Receptacles

4-259. A receptacle is a contact device installed at the outlet for the connection of a single attachment plug. A receptacle is rated by the amount of voltage or current that it can safely handle. The voltage selections are 125 or 250 VAC. The amperage ratings available are 15, 20, 30, 40, and 50 amps. Mount all receptacles with a ground screw.

Note. As a rule, do not install a receptacle with a lower amperage rating than the connecting branch circuit. For example, a 30 amperes branch circuit must have a circuit breaker, as well as a receptacle rated at 30 amps or above.

4-260. There are three types of receptacles that can be installed—

- Single receptacle. Only has one receptacle on the yoke, thus can only allow one electrical appliance to plugin (see figure 4-102).

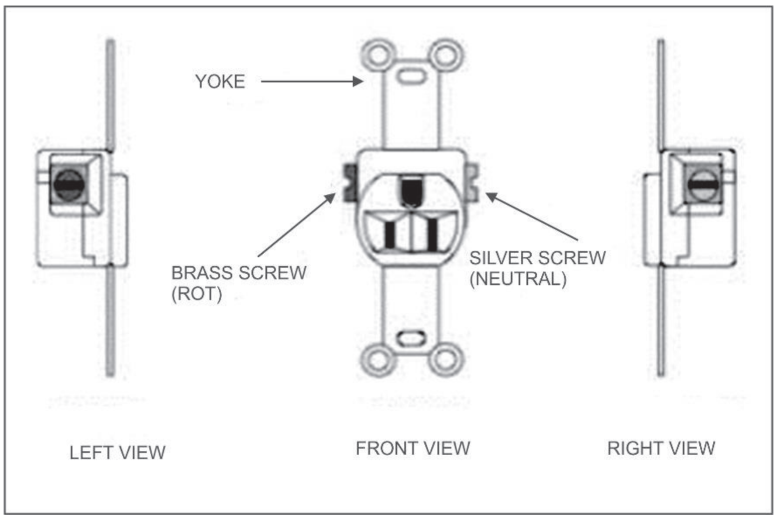

Figure 4-102. Single receptacle

- Multi-receptacle. Has two or more receptacles for the connection of two or more electrical appliances (see figures 4-103 thru 4-105, page 4-79).
- Duplex receptacles are also multi-receptacles. Some duplex receptacles have a combination of two voltages 120/240 volts AC (VAC) (see figures 4-103 and 4-104 on page 4-79).

4-261. Receptacles have a color code as follows (all receptacles have the same color code)—

- Brass-colored screw. Used for attachment of the hot conductor (some duplex receptacles have two hot conductor screws; one for 110 VAC and one for 220 VAC).
- Silver-colored screw. Used for attachment of the neutral conductor.
- Green-colored screw. Used for attachment of the ground conductor.

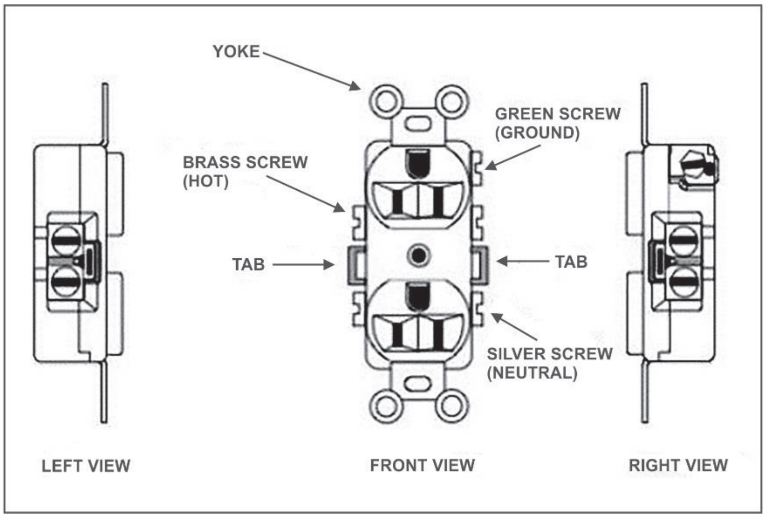

Figure 4-103. 120 VAC duplex receptacle (multi-receptacle)

4-262. Figure 4-104 depicts a 120/240 VAC receptacle. This is also a multi-receptacle.

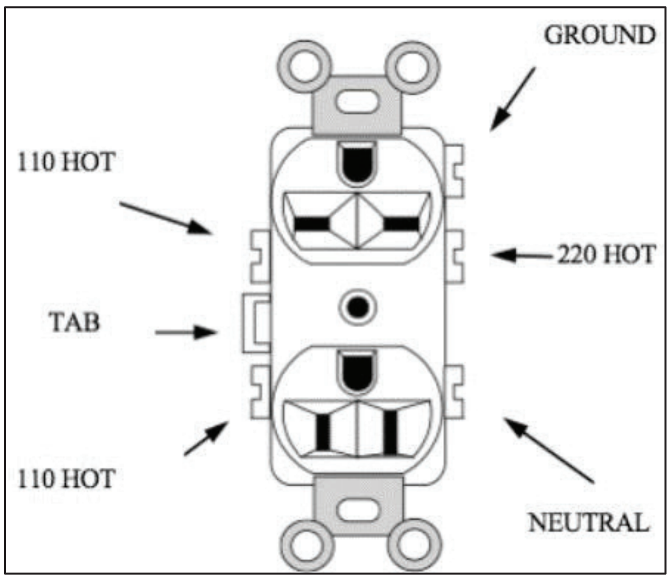

Figure 4-104. 120/240 VAC receptacle (multi-receptacle)

4-263. Figure 4-105 depicts another type of multi-receptacle.

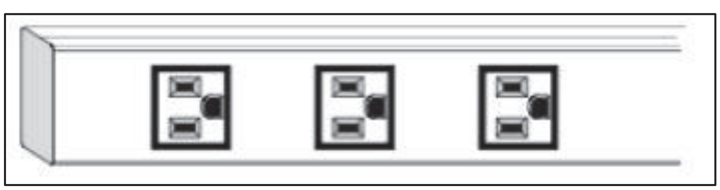

Figure 4-105. Multi-receptacle

General Use Switches

4-264. The intent of general use switches are for general distribution and branch circuits. Measure the current used with general use switches in amperes. General use switches are capable of interrupting its rated current at its rated operating voltage. Do not use switches to disconnect the neutral conductor of a circuit. In special cases, a switch may have a ground terminal screw. There are four types of switches—

- Single-throw switch. Used to control branch circuit devices from on location (see figure 4-106). When mounted in an upright position, the OFF designation is on the upper side of the toggle (the toggle is down). Single-throw switches has two brass screws and is used to open and close one hot conductor path.

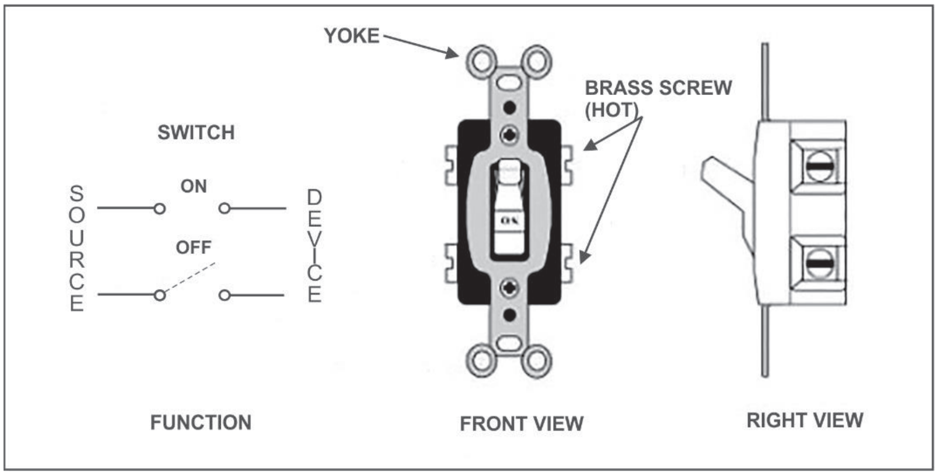

Figure 4-106. Single-throw switch

- Double-throw switch. Used to open and close both the L-1 and L-2 legs at the same time on a 240 VAC circuit from one location (see figure 4-107). Note that this device has four brass screws instead of two.

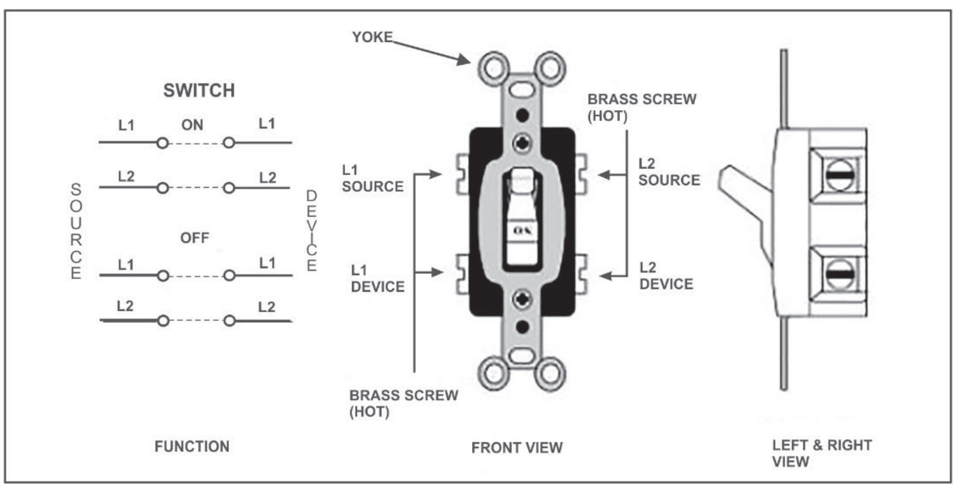

Figure 4-107. Double-throw switch

- Three-way switch. It takes two of these switches, wired correctly, to control an electrical appliance from two locations. These switches have no on/off designations on the toggle. Each switch has three brass screws. One screw, usually black in color, is referred to as the common screw. Traveler screws are the other two screws, usually brass in color. Use the traveler screws to provide a path between the two three-way switches (see figure 4-108).

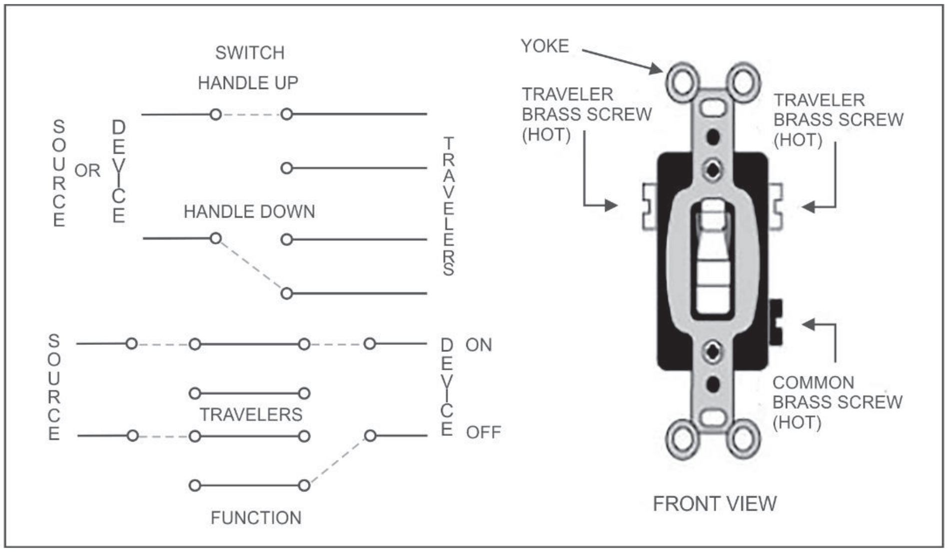

Figure 4-108. Three-way switch

- Use a four-way switch in conjunction with two three-way switches to control a branch circuit from three locations. Each additional four-way switch will give one additional control point. This switch does not have an on/off designation on the toggle and has four brass screws (see figure 4-109).

Note. Double-throw switches look like four-way switches. The only visible difference is that the four-way switch does not have on/off designations on the toggle.

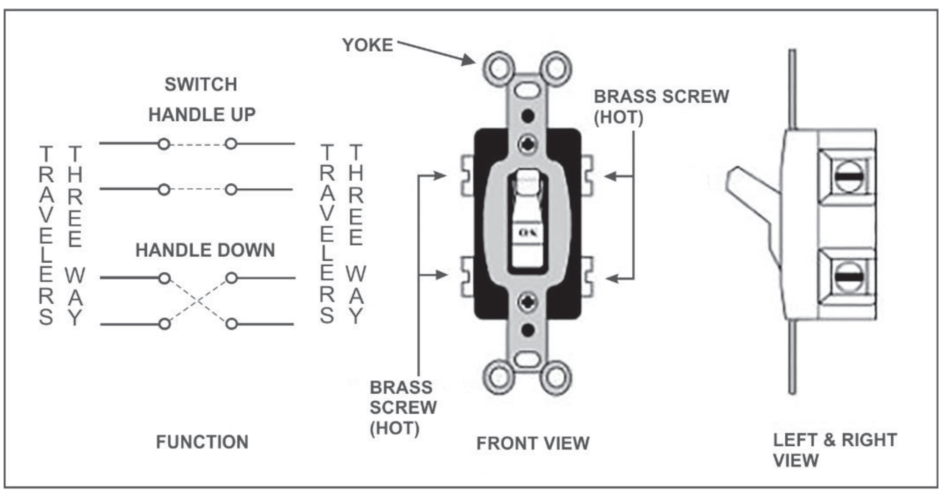

Figure 4-109. Four-way switch

Incandescent Light Fixture

4-265. An incandescent light fixture is a basic light fixture made of porcelain designed to prevent accidental contact with the hot terminals It generally has one brass screw for the hot conductor and one silver screw for the neutral conductor (see figure 4-110 on page 4-82).

Note. If both screws on the incandescent light fixture are the same color, the center screw is the hot conductor.

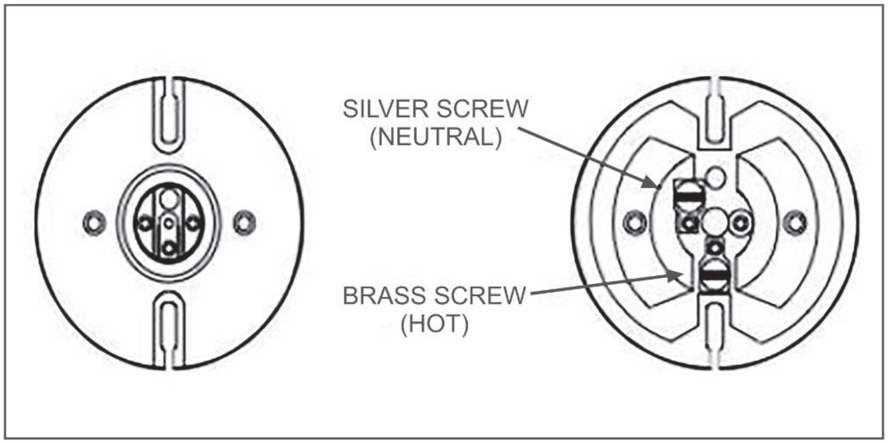

Figure 4-110. Incandescent light fixture (top and rear view)

AC Wire Pulling Techniques

4-266. Before pulling the conductors through conduit, draw each branch circuit on a piece of paper to determine the correct wiring of the branch circuit, as well as the number of conductors needed. This section will discuss short and long runs; pulling conductors; and what to do once the installer has completed pulling the conductors through the conduit.

Short and Long Runs

4-267. When installing a short run, pull the needed conductors lengths off the spool or out of the box and place temporary markings for end-to-end identification. For long runs, temporarily mark the conductor ends out of the box or spool. Pull the needed conductors through the conduit. Before cutting the conductors, mark each conductor for identification.

Pulling the Conductors

4-268. Feed the fish tape through the appropriate conduit run. Strip 12 inches of insulation off each conductor. Use one conductor as a pole. Wrap each individual conductor around the pole and cut off the excess. Start wrapping the first conductor where the insulation ends on the pole conductor. Each conductor will be staggered, creating a tapered effect. Upon attaching the last conductor, take the pole conductor end and create an eyelet by looping the conductor and securing the end with six wraps. Hook the eyelet on the hook of the fish tape (see figure 4-111 on page 4-83). To keep the eyelet on the hook during the pulling phase, place a few wraps of electrical tape over the opening of the hook. Pull all the conductors through the conduit.

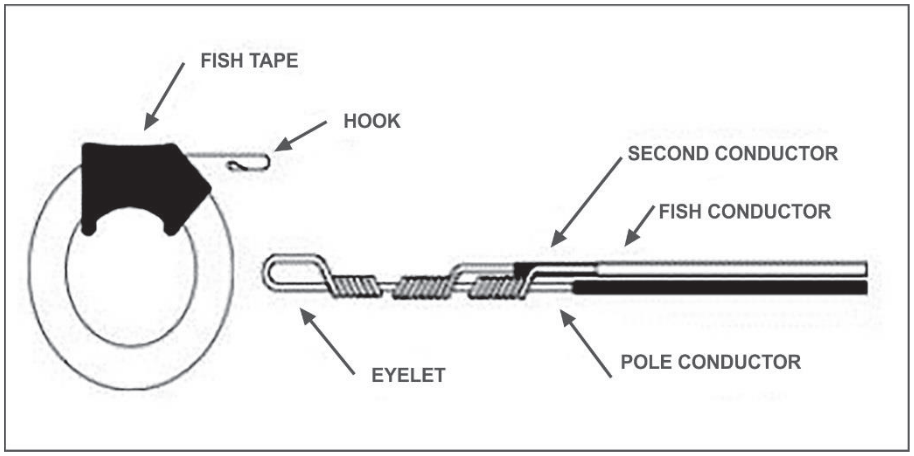

Figure 4-111. Combining conductors to connect to fish tape

Note. If a run terminates at a distribution panel, pull the conductors toward the distribution panel.

4-269. After pulling the conductors through the conduit, cut off the excess, leaving a minimum length of six inches at all outlet boxes and 36 inches for a distribution panel. Use the minimum length for making all necessary terminations and splices.

WIRING BOXES AND ELECTRICAL DEVICES

4-270. This section covers wiring of boxes and electrical devices. It discusses total splices allowed per box, types of splices, and grounding rules.

Total Splices Per Box

4-271. The total splice count per box depends on the box size, depth, number of conductors, and size of the conductors. A general rule for handy and octagon boxes is allow three splices per box with a maximum of four conductors per splice. Allow four splices per box with a maximum of four conductors per splice for 4” X 4” and junction boxes.

Types of Splices

4-272. This section will discuss the various types of splices commonly used during AC power systems installation. They are–in-the-middle splice, stand-alone splice, and jumper splice.

Note. Never solder AC wiring splices because the current could melt the solder.

In-the-Middle Splice

4-273. Use in-the-middle splices in thru box wiring to connect receptacles or lights in series within a branch circuit. Also, use in-the-middle splices when grounding both the box and a device (see figure 4-112 on page 4-84).

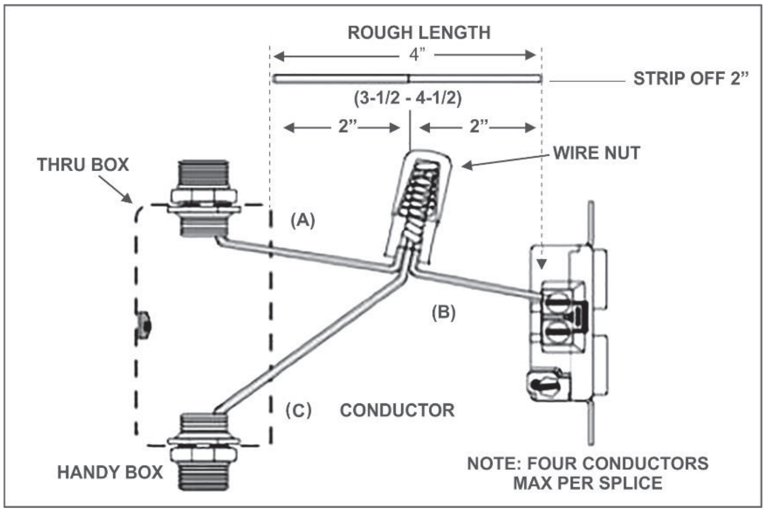

Figure 4-112. In-the-middle splice

4-274. Using figure 5-113, the following procedures are performed—

1. Conductor A and C. Measure and cut off these conductors six inches from the edge of the box. Strip off two inches of insulation.
2. Conductor B. Attach one end of a 6 inch piece of conductor to the device being wired. Strip off two inches of insulation from the other end of the conductor.
3. Splicing conductors. Place conductors A, B, and C side by side and line up the edges of insulation. Hold the insulation line with a pair of needle nose or lineman's pliers. Evenly trim the bare conductor ends to two inches.
4. Grab the ends of the bare conductors with lineman's pliers. Twist the conductors with the lineman's pliers in a clockwise direction. Ensure the twisted bare conductors are free of nicks and the conductors are wrap evenly throughout the splice.
5. Wire nut. Trim the splice to fit the proper size wire nut. There must be at least 1/16 inch of insulation inside the wire nut. No bare conductor can extend beyond the bottom edge of the wire nut. Twist the wire nut clockwise until it tightens firmly around the conductors.

Stand-Alone Splice

4-275. A stand-alone splice is a splice where the conductor does not terminate to a device in the box. Usually used to ground a box or extend the conductors to other devices within a branch circuit (see figure 4-113 on page 4-85).

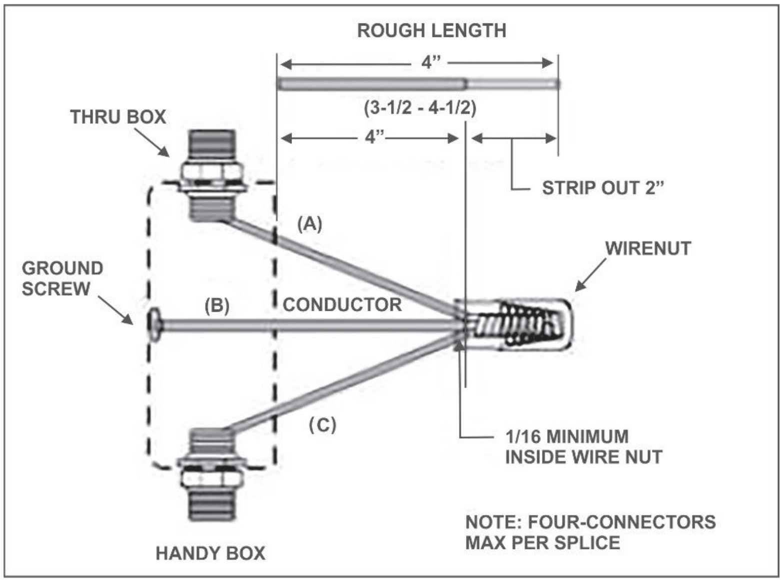

Figure 4-113. Stand-alone splice

4-276. Procedures to splice a stand-alone splice is the same as the in-the-middle splice; however, whereas an in-the-middle splice connects to an electrical device, a stand-alone connects to a ground or an open end conductor that will be used to extend to another device in another box within a branch circuit.

Jumper Splice

4-277. Use jumper splices for distributing a single conductor of a branch circuit (see figure 4-114). Install this splice at junction boxes to allow the branch circuit to go in additional directions.

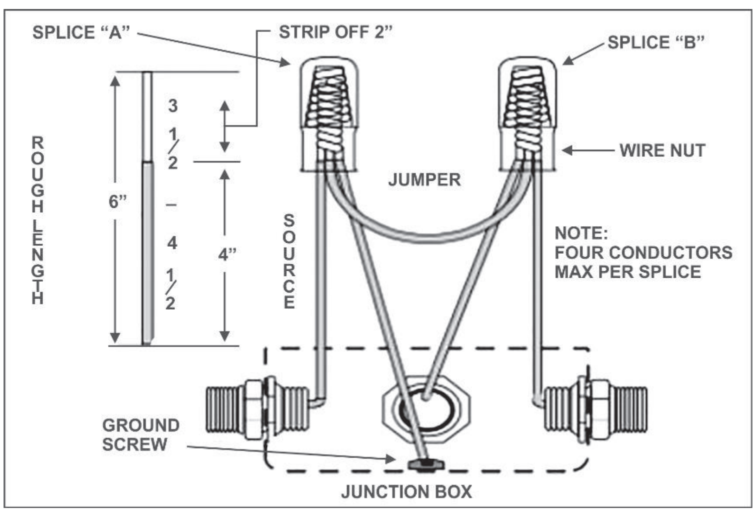

Figure 4-114. Jumper splice

4-278. Using figure 4-114, use the following procedures when installing a jumper splice—

1. Splice A. If a conductor of the A splice terminates to an electrical device, refer to the wiring procedure for an in-the-middle splice. If no conductor terminate to a device, refer to the wiring procedure for stand-alone splice.
2. Jumper length. The conductor must be long enough to allow the wire nut of each splice to be able to reach the opposite sides of the box.

3. Splice B. If a conductor of this splice terminates to a device, refer to the wiring procedure for an in-the-middle splice. If no conductors terminate to a device, refer to the wiring procedure for stand-alone splice.

GROUNDING RULES WHEN TERMINATING CONDUCTORS TO DEVICES

4-279. As a rule, use the grounding conductor to ground electrical equipment, outlets, and boxes. Several factors must be considered when determining how to apply the grounding conductor. This section will discuss the two types of metal box mounting techniques (surface and flush). This section will also discuss how to ground metal boxes and electrical devices.

Surface Mounted Boxes

4-280. A surface mounted box is an electrical box mounted to the surface of a wall (see figure 4-115). Ground any device with a ground screw to the grounding conductor. Ground handy or octagon boxes with electrical devices without grounding screws or with no electrical devices at all by routing the grounding conductor the long way around the box and terminating the ground to the box. Ground all 4” X 4” electrical boxes.

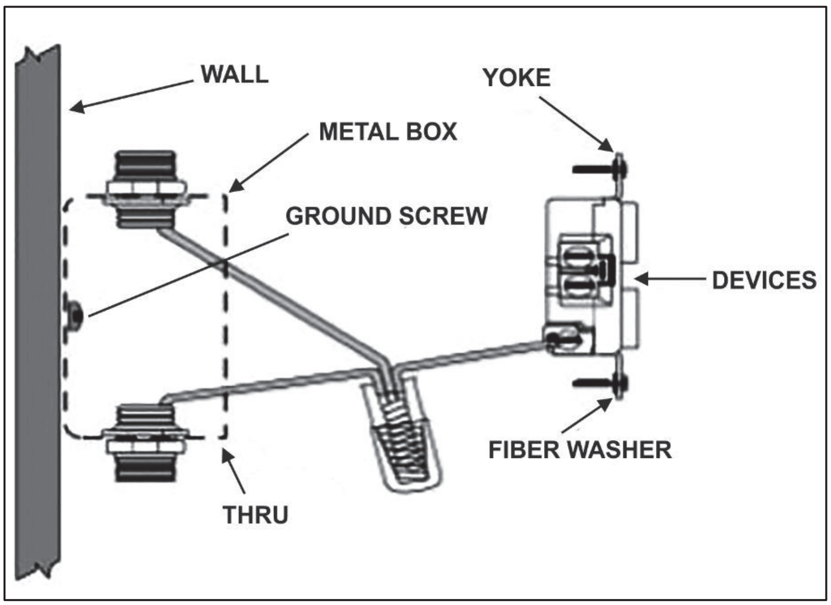

Figure 4-115. Surface mounted box

Flush Mounted Boxes

4-281. Flush mounted boxes are boxes mounted flush with the surface of a wall (see figure 4-116 on page 4-87). Ground all electrical devices. The same grounding procedures apply as with the surface mounted boxes.

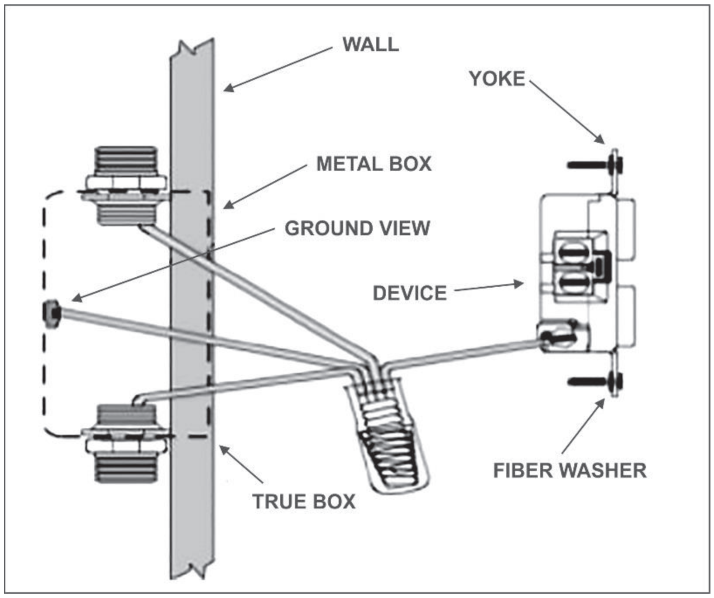

Figure 4-116. Flush mounted box

Terminating a Conductor to a Device

4-282. The following procedures are used to correctly terminate a conductor to an electrical device—

1. Measure and cut off the conductor six inches from the edge of the box. Strip off two inches of insulation.

Note. The final measurement from the edge of the box to the back of the device or wire nut must be between 3 1/2 and 4 1/2 inches.

---

2. Using a pair of needle nose pliers, form a question mark, keeping the inside diameter as close to the screw shaft diameter as possible. Take a pair of diagonal cutters and cut off the conductor at 270 degrees. Do not exceed 360 degrees (see figure 4-117 on page 4-88).

Note. The conductor must wrap clockwise around the screw between 270 and 360 degrees. The end of the conductor cannot stick out from underneath the screw head, more commonly known as a pigtail.

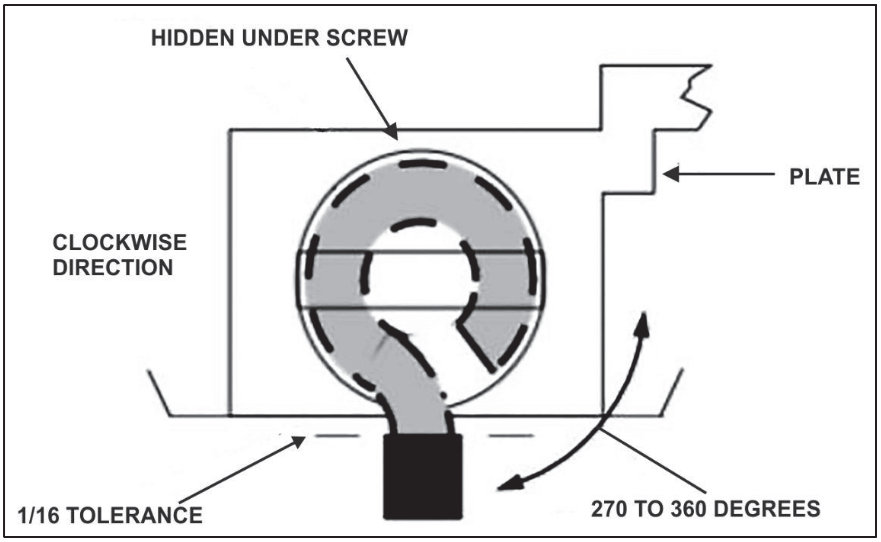

Figure 4-117. 270 degree hook for terminating a conductor to a device

3. Place the conductor under the screw in a clockwise direction. While tightening the screw, ensure the bare conductor remains under the screw head.

Note. The bare conductor must remain under the screw head, to include after setting the electrical device inside the box. Place the device completely to set position, and then remove the device to ensure the bare conductor remains before final setting and securing.

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4. Measure the amount of shiner (exposed bare wire showing from underneath the screw head) from an existing base plate under the head of the screw or, if there is no base plate, measure from the head screw. The tolerance amount of shiner is 1/16 inch (see figure 4-117 above).
5. Conductor insulation cannot be underneath the screw head.
6. Ensure the screw is tight enough so as the screw cannot be turned more than one full turn.

WIRING AC TOGGLE SWITCHES

4-283. This section will cover how to wire the various toggle switch that installers may encounter. These toggle switches include single-throw, double-throw, three-way, and four-way switches. This section will cover connecting the hot conductors, neutral conductors, and grounding conductor for each.

Note. The following illustrations shows the hot, neutral, and ground conductors (panel D) as if they will be ran in different conduits. However, all three conductors are actually ran through the same conduit together. The combination of the hot, neutral, and ground conductors make up the branch circuit. You will see all three of these conduits coming through the same knockout in boxes.

Wiring Single-Throw Switches

4-284. Figure 4-118 on page 4-89 is a visual representation of a single-throw switch wiring schematic.

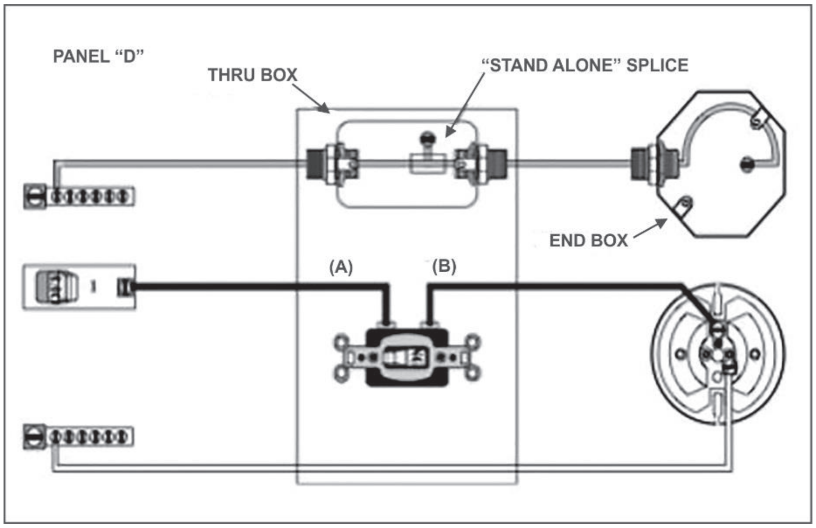


Figure 4-118. Wiring a single-throw switch

4-285. Using figure 4-118, the following are steps on how to wire a single-throw switch—

1. Terminal A is wired to the source (distribution panel).
2. Terminal B is wired to the device(s).
3. Neutral conductor is terminated at the designated position on the neutral buss bar and routed through the conduit the longest way around all through boxes. Connect the neutral conductor directly to the device being installed.
4. The ground conductor is terminated at the designated position on the ground buss, routed through the conduit, and connected to the ground terminal screw on the device. If the device does not have a ground screw (as shown in figure 4-118 above), connect the ground conductor to box that the device will be installed in.

Wiring Double-Throw Switches

4-286. Figure 4-119 depicts a double-throw switch wiring schematic.

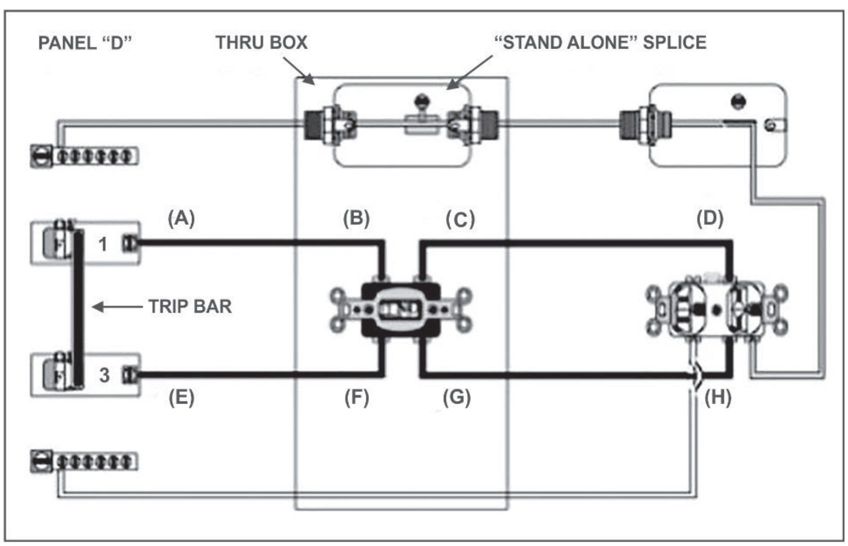


Figure 4-119. Wiring a double-throw switch

4-287. Referring to figure 4-119, the following are steps on how to wire a double-throw switch—

1. Terminal A of the A and B conductor is connected to L-1 on the distribution panel. Terminal B of the A and B conductor is connected to one of the L-1 source screw on the switch.
2. Terminal E of the E and F conductor is connected to L-2 on the distribution panel. Terminal F of the E and F conductor is connected to the L-2 source screw on the switch.
3. Terminal C of the C and D conductor is connected to the L-1 device screw on the switch. Terminal D of the C and D conductor is connected to the L-1 screw on the terminating device (including outlets and lights).
4. Terminal G of the G and H conductor is connected to the L-2 device screw on the switch. Terminal H of the G and H conductor is connected to the L-2 screw on the device.
5. Connect the neutral conductor directly to the device at the devices neutral terminal screw.
6. Ground the ground conductor directly to the device. If the device does not have a ground screw, ground the ground conductor to the box that the device will be installed in.

Wiring a Three-Way Switch Network

4-288. Figure 4-120 depicts three-way switch network wiring schematic.

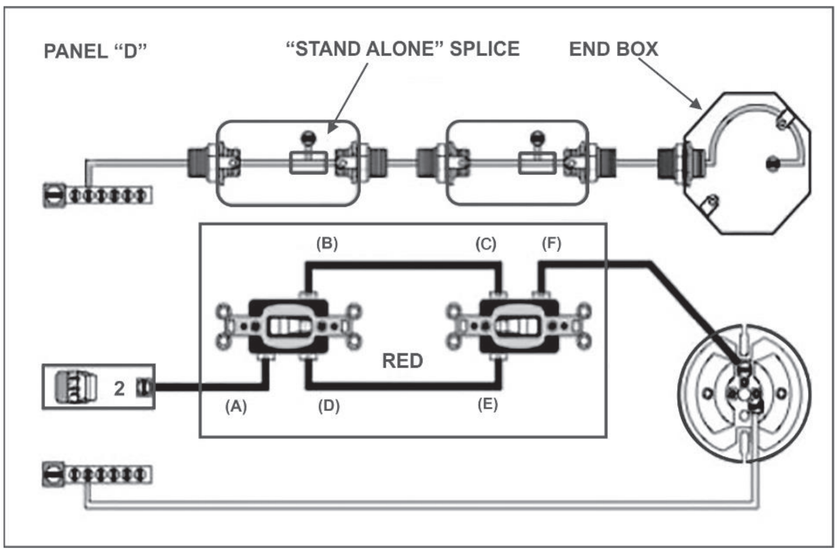


Figure 4-120. Three-way switch network

4-289. Referring to figure 4-120, the following are steps on how to wire a three-way switch network—

1. Conductor A is connected between the distribution panel and the common screw of the first switch.
2. Terminal B of the B and C conductor is connected to the non-common traveler screw on the first switch.

> ***Note.*** The common side of a three-way switch is the side that has the common screw on it.

3. Terminal D of the D and E conductor is connected to the traveler screw on the common side of the first switch.
4. Terminal C of the B and C conductor is connected to the second switches common side traveler screw.
5. Terminal E of the D and E conductor is connected to the non-common traveler screw on the second switch.
6. Conductor F conductor is connected to the common screw of the second switch. The other end of the terminal F conductor terminates on the hot screw of the device (outlet, light, ..).
7. Neutral and grounding conductors follows the same procedures as with single-throw and double-throw switches.

Wiring a Four-Way Switch Network

4-290. Figure 4-121 on page 491 depicts a four-way switch network wiring schematic.

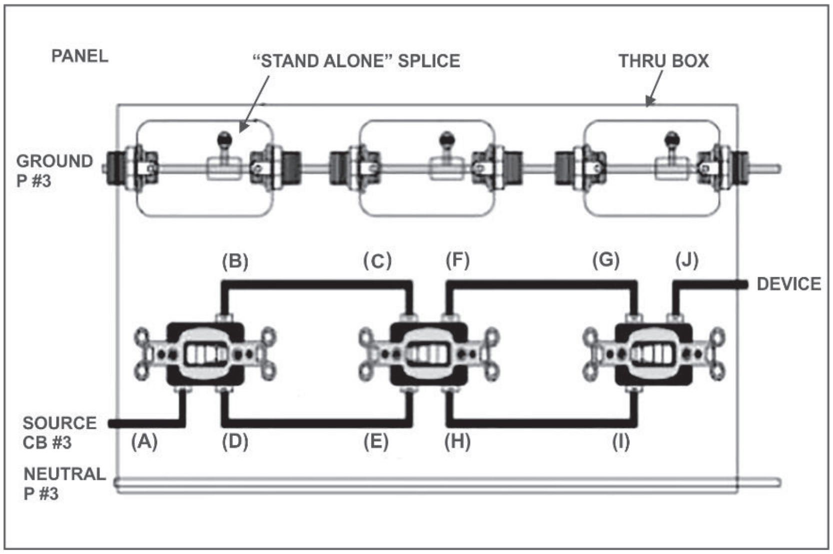


Figure 4-121. Wiring a four-way switch network

4-291. Using figure 4-121, the following are steps on how to wire a four-way switch network—

1. Conductor A is connected between the distribution panel and the common screw of the first three-way switch.
2. Terminal D of conductor D and E is connected to the traveler screw on the common side of the first three-way switch.
3. Terminal B of conductor B and C is connected to the traveler screw on the non-common side of the first three-way switch.
4. Terminal C of conductor B and C is connected to one of the four hot screws on the four-way switch.

Note. All four screws on a four-way screw are hot screws.

5. Terminal E of conductor D and E is connected to the hot screw on the four-way switch adjacent to the hot screw that terminal C is connected to.
6. Terminal H of conductor H and I is connected to the other hot screw on the four-way switch that's on the same side as the hot screw that terminal E is connected to.
7. Terminal F of conductor F and G is connected to the hot screw on the four-way switch that's on the same side as the hot screw that terminal C is connected to.
8. Terminal I of conductor H and I is connected to the traveler screw on the non-common side of the second three-way switch.
9. Terminal G of conductor F and G is connected to the traveler screw on the common side of the second three-way switch.
10. Conductor J is connected between the common screw of the second three-way switch and the device receiving AC power.
11. Neutral and grounding conductors follows the same procedures as with single-throw and double-throw switches.

WIRING RECEPTACLES

4-292. This section will discuss procedures on how to wire receptacles. It will cover how to wire 120 VAC duplex receptacles both switched and unswitched, as well as wiring a 120 VAC duplex receptacle that allows only one of the two receptacles to be switched, while the other remains unswitched.

Note. The following illustrations shows the hot, neutral, and ground conductors (panel D) as if they will be ran in different conduits. However, all three conductors are actually ran through the same conduit. The combination of the hot, neutral, and ground conductors make up the branch circuit. You will see all three of these conduits coming through the same knockout in boxes.

120 VAC Duplex Receptacle Switched and Unswitched

Note. For the 120 VAC, when either wiring switched or with both unswitched, you only have to connect one conductor to either the A or C hot screw (typically it will be the A screw). However, ensure to tighten the unused hot screw so that it has contact to the brass tab (C) that will connect the A and B hot screws.

4-293. Figure 4-122 depicts a 120 VAC duplex receptacle wiring schematic.

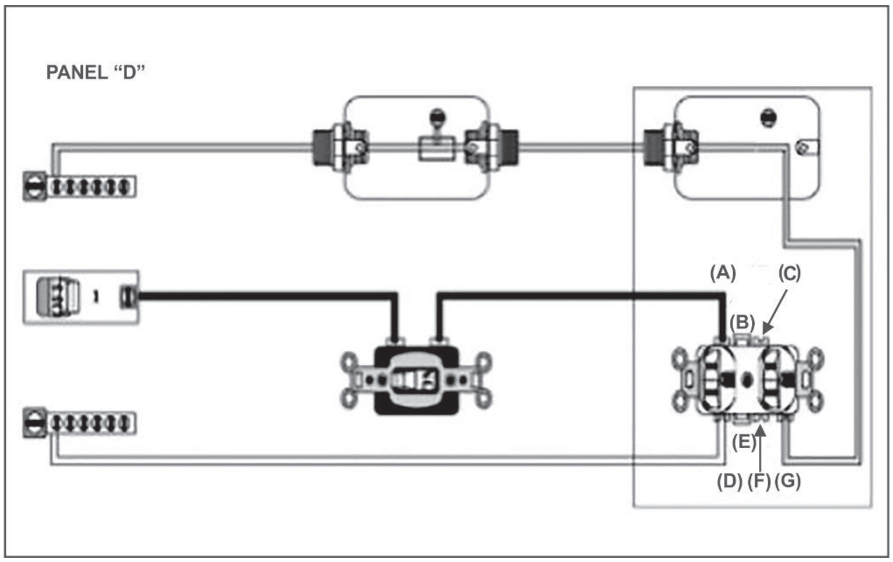


Figure 4-122. Wiring a 120 VAC duplex receptacle (switched)

4-294. Using figure 4-122, the following are steps on how to wire a 120 VAC duplex receptacle switched:

1. Connect the conductor from the distribution panel to the hot source screw on the single-throw switch.

Note. Typically, hot terminals have a brass colored screw. Neutral terminal screws are typically silver colored. Ground terminal screws are typically green colored.

2. Connect the conductor A between the hot device screw on the single-throw switch and the hot screw on the 120 VAC duplex receptacle. Ensure the other hot screw (C)) is tighten so as to maintain contact with the brass tab (B).
3. Connect the neutral conductor (D), that's usually white or gray, from the neutral buss bar to the neutral terminal screw on the 120 VAC duplex receptacle. Ensure the other neutral screw (F) is tighten so as to maintain contact with the silver tab (E).
4. Connect the ground conductor (G), that's typically green, from the ground buss bar to the ground terminal screw on the 120 VAC duplex receptacle.

Note. Ensure to correctly ground and terminate all switches and receptacles. Refer to the Grounding Rules and Terminating Electrical Devices section.

Note. Wiring a 120 VAC duplex receptacle unswitched is very similar to wiring one switched. Simply take the single-throw switch out of the installation and connect the hot conductor directly between the power distribution panel and the hot terminal screw on the receptacle.

120 VAC Duplex Receptacle with One Receptacle Switched

4-295. Figure 4-123 depicts a 120 VAC duplex receptacle wiring schematic

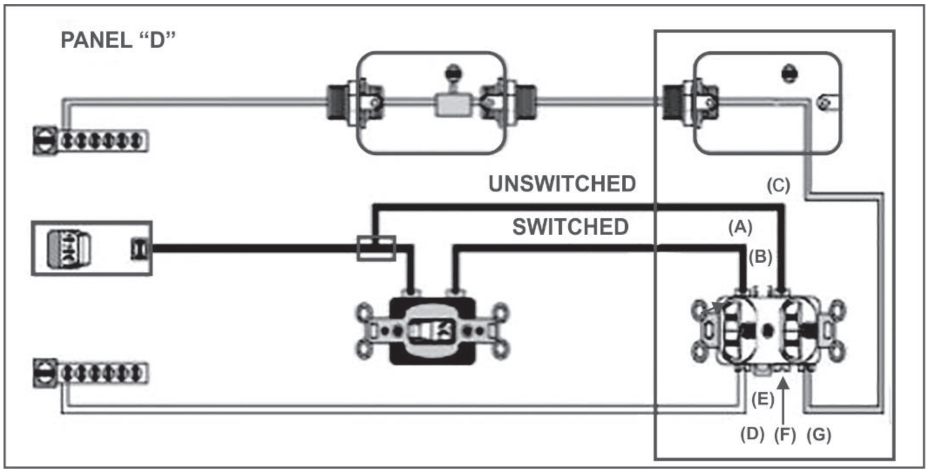


Figure 4-123. Wiring 120 VAC duplex receptacle with one receptacle switched

Note. The hot tab (B) must be broken to make this installation or the switched receptacle will not work properly.

4-296. Using figure 4-123, the following are steps on how to wire a 120 VAC duplex receptacle with one receptacle switched—

1. Break both the hot tab (B) and neutral tab (E) on the 120 VAC duplex receptacle.
2. Connect the conductor from the distribution panel to the hot source screw on the single-throw switch.
3. Connect the conductor A between the hot device screw on the single-throw switch and the hot screw on the 120 VAC duplex receptacle. The receptacle for this screw will be connected to the single-throw switch and can be turned off/on.
4. Splice the conductor C to the second hot screw on the 120 VAC receptacle and splice to the conductor between the distribution panel and the single-throw switch. The receptacle for this hot screw will be unswitched (have continuous power).
5. Neutral and grounding conductors follows the same procedures as with wiring 120 VAC receptacles switched or unswitched.

Wiring a 120/240 Duplex Receptacle Unswitched (One Outlet 120 VAC and the Other Outlet 240 VAC)

Note. Ensure when doing this installation, that you have the correct duplex receptacle. The 120 VAC and 120/240 VAC receptacle are very similar in appearance. The easiest indicator of the differences is that the 120/240 VAC receptacle only has one tab (a hot tab) on the 120 VAC side and does not have a tab on the 220 side. The 120/240 VAC receptacle also only have one neutral screw located on the 220 VAC side.

4-297. Figure 4-124 on page 4-94 depicts a 120/240 VAC duplex receptacle unswitched.

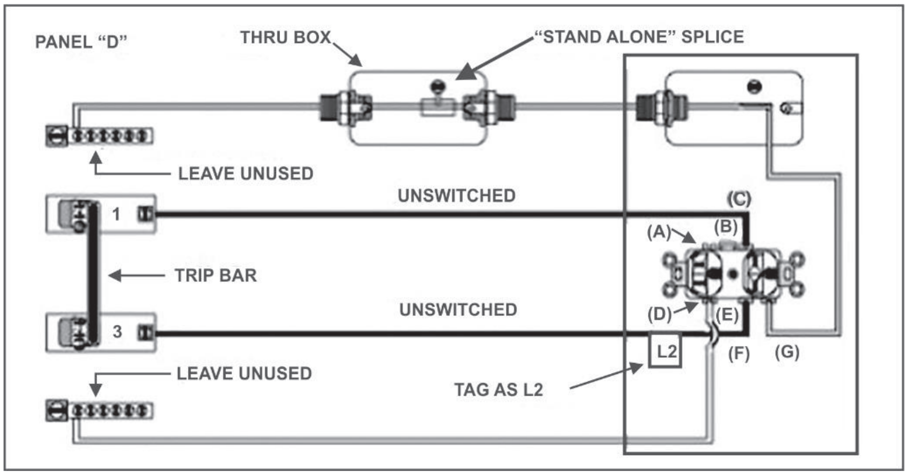


Figure 4-124. Wiring a 120/240 VAC duplex receptacle (unswitched)

4-298. Using figure 4-124, the following are steps on how to install a 120/240 VAC duplex receptacle unswitched—

1. Connect the L-1 conductor (C) from the L-1 circuit breaker at the distribution panel to the hot terminal screw on the 120 VAC side of the 120/240 VAC receptacle. Ensure the other hot terminal tab is screwed tight so as to have a firm connection with the tab (B).
2. Connect the L-2 conductor (F) from the L-2 circuit breaker at the distribution panel to the hot terminal screw on the 240 VAC side of the 120/240 VAC receptacle.
3. Connect the neutral conductor from the neutral buss bar to the neutral terminal screw on the receptacle.
4. Connect the ground conductor from the ground buss bar to the ground terminal screw on the receptacle.

Wiring a 120/240 VAC Receptacle with 120 VAC Receptacle Switched

4-299. Figure 4-125 depicts a 120/240 VAC duplex receptacle with the 120 VAC receptacle switched.

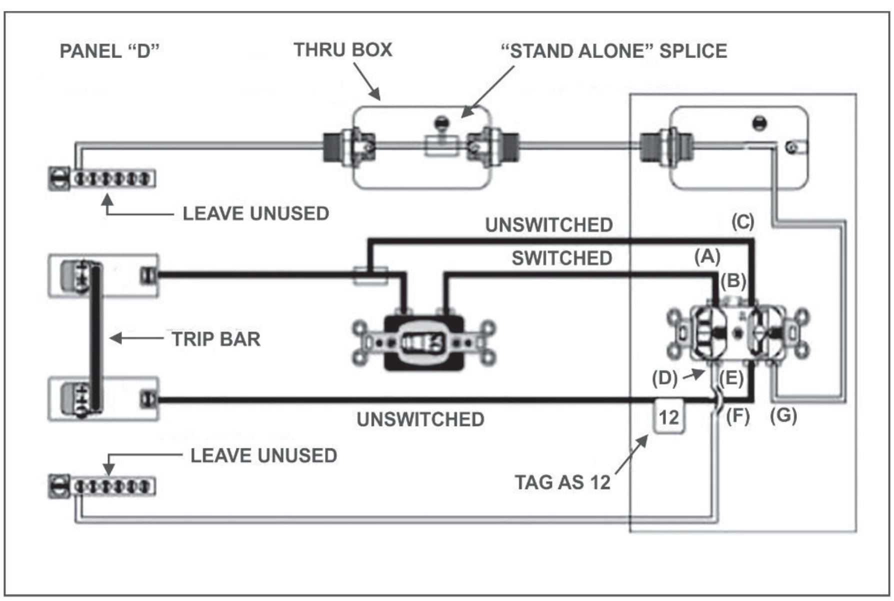


Figure 4-125. Wiring a 120/240 VAC duplex receptacle with the 120 receptacle switched

Note. The hot tab on the 120 VAC side of the 120/240 VAC receptacle must be broken before installation.

4-300. Using figure 4-125, the following are steps on how to install a 120/240 VAC duplex receptacle with the 120 receptacle switched—

1. Break the tab (B) on the 120 VAC side of the 120/240 VAC receptacle.
2. Connect the L-1 conductor from the L-1 circuit breaker at the distribution panel to the source screw on the single-throw switch.
3. Connect the conductor A from the hot device screw on the single-throw switch to the 120 VAC hot terminal screw opposite the neutral screw on the other side of the receptacle.
4. Connect a conductor (C) to the other 120 VAC hot terminal screw and splice to the L-1 conductor between the power distribution panel and the single-throw switch. The 110 receptacle will now be switched (can be turned on/off).
5. Connect the L-2 conductor from the L-2 circuit breaker at the distribution panel to the 220 VAC hot terminal (F) screw on the receptacle. The 240 VAC receptacle is unswitched and receiving 120 from the (C) connection and 120 VAC from the (F) connection, totaling 240 VAC.
6. Connect the ground conductor from the ground buss bar to the ground terminal screw on the receptacle.

Note. Typically, it is not feasible having a 120 VAC and a 240 VAC because appliances with the wrong voltages can easily be plugged into the wrong receptacle. If this installation is required in a particular location, ensure to mark the receptacle to identify the 110 VAC receptacle from the 240 VAC receptacle.

WIRING A 120 VAC BASIC INCANDESCENT LIGHT FIXTURE (SWITCHED OR UNSWITCHED)

4-301. This section will cover wiring of the 120 VAC basic incandescent light fixture. This section will cover how to wire the basic incandescent light fixture both switched (with a single-throw switch) and unswitched.

Wiring a 120 VAC Basic Incandescent Light Fixture Switched

4-302. Figure 4-126 depicts a 120 VAC basic incandescent light fixture with a single-throw switch.

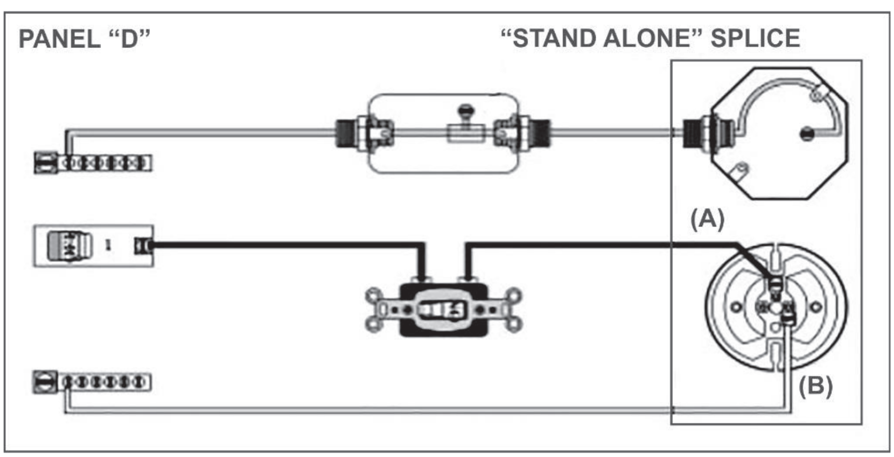


Figure 4-126. Wiring a 120 basic incandescent light fixture switched

4-303. Using figure 4-126, the following are steps on how to install a 120 basic incandescent light fixture switched—

1. Connect the conductor from the distribution panel to the source screw on the single-throw switch.
2. Connect the conductor from the device screw on the single-throw switch to the hot terminal screw on the incandescent light.

3. Connect the neutral conduction from the neutral buss bar to the neutral terminal screw on the incandescent light.
4. The incandescent light typically does not have a ground terminal. Connect the ground conductor from the ground buss bar to the box that the incandescent light will be installed in.

Wiring a 120 VAC Basic Incandescent Light Fixture Unswitched

4-304. Wiring a 120 VAC basic incandescent light fixture unswitched is very similar to installing one switched. Simply take the single-throw switch out of the installation and connect the conductor from the distribution panel directly to the incandescent light fixture. All other connections are exactly as if wiring an incandescent light fixture switched.

WIRING AND LABELING A DISTRIBUTION PANEL

4-305. This section discusses wiring a distribution panel. This section will cover conductor dressing and terminating conductors. It will also discuss how to label a distribution panel correctly. It will close by providing general AC safety practices.

Conductor Dress

4-306. Inside the distribution panel the conductors must be routed the most direct path, taking in consideration the following guidelines—

- Never cross feeder paths with the branch circuit conductors
- Always dress the conductors to the immediate backside of the panel.
- Dress the conductors along the corners to the breakout point, staying tight to the back corners. Bend the conductors 90 degrees, staying tight to the backside of the panel.
- Dress the conductors along the backside working toward the termination point. The conductors must be dressed in a way to prevent them from touching the buss bars before termination.
- When the conductors reach the termination point, bend a 90-degree bend to lift the conductor off the backside of the panel.
- At the level of terminal, bend another 90-degree bend toward the terminal. This allows feeding of the conductor straight into the terminal point.

4-307. Figure 4-127, illustrations a distribution panel that has received a correct conductor dressing.

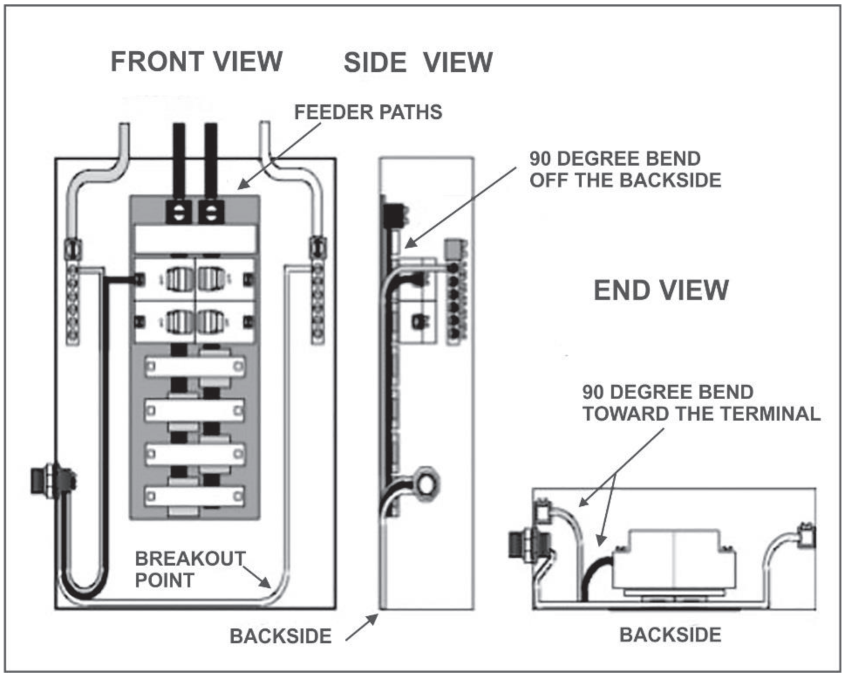


Figure 4-127. Conductor dressing a distribution panel

Terminating Conductors

4-308. Always wire the distribution panel last. The following considerations should take place when terminating conductors—

- Wire all conductors, of each color, in the following order—
  1. Ground-Green insulated conductor.
  2. Neutral-White or gray insulated conductor.
  3. Hot-Black insulated conductor.
- Trim enough excess off to place the conductor in the terminal—.
- To strip, place the conductor in the terminal and mark the insulation. Using the strippers, strip off the insulation to the mark.
- Place the conductor in the terminal and tighten the setscrew (see figure 4-128 on page 4-98). Allow no more than 1/16 inch of shiner between the insulation and the buss bars or circuit breaker terminal.

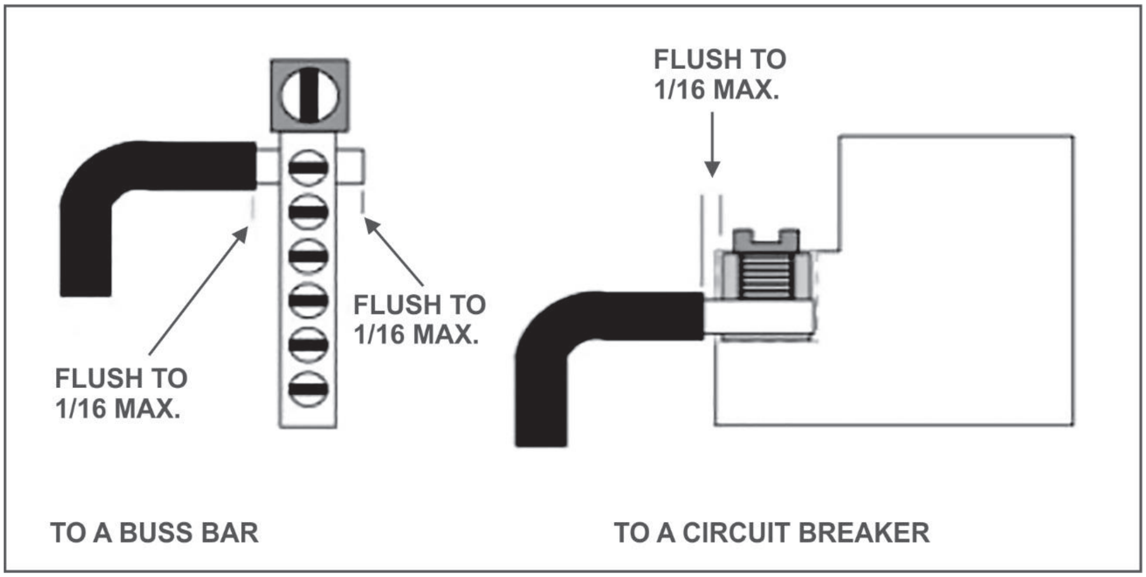


Figure 4-128. Terminating conductors inside the distribution panel

Labeling a Distribution Panel

4-309. This section discusses how to label a distribution panel using floor plan item numbering, group designations, numerical designations, and inner panel designations. This section also gives a brief overview of designation cards.

Floor Plan Item Number

4-310. Label the panel(s) as designated by the site drawings or EIP drawings. Figure 4-129, illustrates a floor plan item number of 4A. The "4" stands for the room that distribution panel is in. The "A" stands for which distribution panel it is in that room. If another distribution panel is in the same room, for example, it would be 4B, and so on. Label the top center portion of both the inner and outer panels with the floor plan item number using 3/4 inch characters.

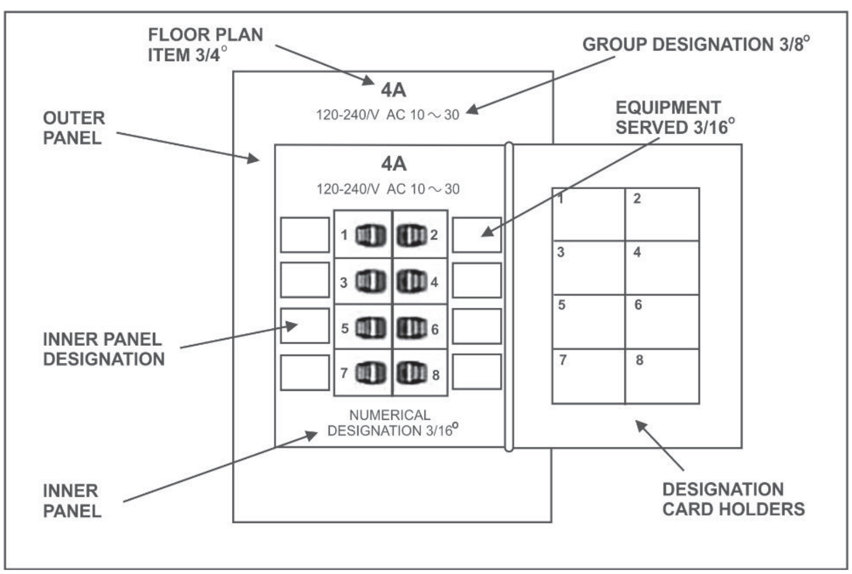


Figure 4-129. Labeling a distribution panel

Group Designation

4-311. The group designations illustrated in figure 4-129 above is 120/240 VAC 60 Hz 3ø. The "V" in 120/240 VAC designates the highest voltage provided by this distribution panel. The "AC" identifies the type of current. 60 Hz identifies the frequency of the power provided by this panel. 3ø identifies the phase relationship within the panel. Label the inner and outer panels, centered and directly below the floor plan item number using 3/8 inch characters.

Numerical Designations

4-312. Manufacturers normally provide numerical designations with the distribution panel or circuit breaker. If not provided, label the circuit breakers using 3/16 inch characters (see figure 5-129 above).

Inner Panel Designations

4-313. Label these designations on the inner panel adjacent to the circuit breakers (see location in figure 4-129 on previous page). Use 3/16 inch characters if designation cardholders are not furnished. Figure 4-130 illustrates how equipment and circuit designations should look.

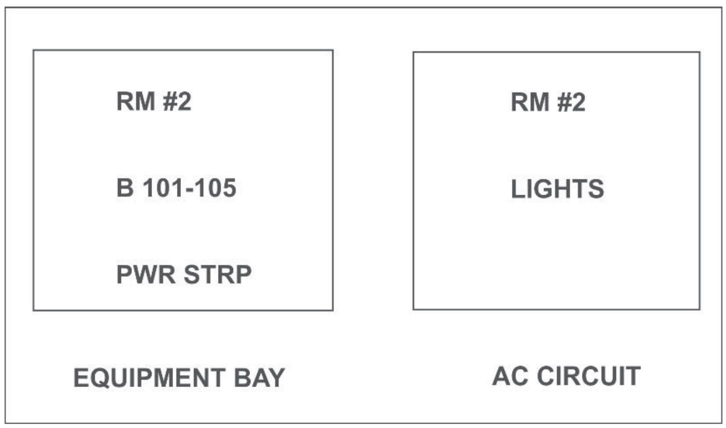


Figure 4-130. Example of inner panel designations

4-314. Inner panel designations can be either equipment bay designations or AC circuit designations for common house or commercial wiring. The following describes each—

- Equipment bay designations—
  - Room number. If the distribution panel is not located in the same room as the bay or equipment.
  - Bay number. The number of the bay or cabinet.
  - Equipment/power strips. Use an abbreviated term for the equipment. If the terms are not common, make an annotation on the site drawings.
  - Common receptacle outlets. The receptacle provided at the front and inner side of each bay. Use abbreviated terms.
- AC circuit designations—
  - Room number. The room number(s) the circuit supplies.
  - Type of device(s). Described as lights or receptacles.
  - Type of equipment. Such as furnace, refrigerator, washer, dryer, and air conditioning unit. When necessary use abbreviated terms. If terms are not common, make annotations on the site drawings.

Designation Card Holders

4-315. Designation cardholders, when available, shows the equipment or circuit designations on the individual cards provided per circuit breaker.

Alternating Current Safety

4-316. The following are some important AC safety practices to consider—

- Avoid putting your heart in the path of current flow.
- Always use rubber soled boots and insulated tools.
- Never work on energized circuits.
- Turn off the power and remove fuses/circuit breakers if possible.
- Post danger signs on the distribution panel.
- Use a light grip on tools.
- Avoid working in damp or wet locations.
- Always do neat work.
- Always use a ground fault interrupter when working outside and inside, whenever possible. A ground fault interrupter has an internal circuitry, which monitors the current. If it detects a difference of five milliamps, it cuts off the circuit in two milliseconds.

WARNING

It takes very little electrical current to kill a person. As little as 100 milliamperes for two seconds can electrocute an individual. The path that the current takes through the body determines the extent of the injury. When working around electrical conductors, equipment, or devices, take extreme caution.

EQUIPMENT MARKING

4-317. It is a requirement that all equipment, groupings of equipment, frameworks, or other assemblies are identified. Installers accomplish this by using identify and mark equipment according to approved installation specifications or drawings. The purpose of ensuring adequate designations is to provide a logical and convenient means of identifying various racks, cabinets, frames, and component parts. The identification facilitates the wiring, testing, operation, and maintenance activities.

Definition of Terms and Color Codes

4-318. This section will discuss terms and color codes used when marking equipment. It defines the common terms used in this process and well as the four colors used for marking equipment.

Definition of Terms

4-319. The following are some common definitions for terms used when marking equipment—

- **Designation**. An identification marking placed upon equipment, unit, part, or accessory to indicate its place in a configuration.
- **Stenciling**. The application of paint or ink through a perforated thin metal, parchment paper, or similar material pattern laid on a solid surface to place an identification designation on an item.
- **Stamping**. The impressing (using a rubber stamp) or imprinting (using a metal die, considered to be permanent) of an identification designation on an item.
- **Decals**. Specially prepared illustrations, designs, or inscriptions, which is sometimes transferrable from a paper backing to an item surface.
- **Self-adhesive vinyl lettering**. Plastic or paper stickers that have an adhesive backing that will adhere to a smooth non-porous surface.
- **Rub-on letters**. Lettering that transfers onto any clean, dry surface.
- **Labeling machine**. An electric labeling device used for printing identifying labels.
- **Equipment**. Frames, racks, and cabinets.

- **Equipment unit**. A group of parts or sub-assemblies, electronically or mechanically connected within a single housing, on a single chassis or framework.
- **Part or component**. An item not normally subject to further disassembly, e.g. resistors, capacitors, or relays.
- **Accessory/auxiliary**. An assembly or parts of a unit that is a support item not permanently affixed or an integral part of the equipment, but contributes to the result, e.g. headset, speakers, patch cord, or portable test equipment.
- **Line-up**. Equipment cabinets or racks aligned, extending between cross aisles.
- **Row**. Number of continuous line-ups, extending across an open section of floor.
- **Front**. Indicates the operation or maintenance side of equipment.
- **Rear**. Indicates the side to terminate wiring.

Color Codes

4-320. There are four different color codes used for marking. They are the following—

- **Black**. Used on light surfaces.
- **White**. Used on dark surfaces.
- **Yellow**. Used to indicate fuse ratings or capacities.
- **Red or vermillion**. Used to indicate notices, restrictions, warnings, or caution.

Designation and Marking Rules and Considerations

4-321. This section discusses designation sizes and rules for marking, as well as three types of identification designations. It will also cover how to install designations on terminal blocks, frame marking, equipment marking, and fuse panel marking.

Designation Sizes

4-322. The installer will use a marking size sufficient to be readable and recognized as a designation. Use abbreviations when unable to mark the designation in the allotted space due to its length. When necessary, reduce the expected size of a stamp due to insufficient space. Reduce the size in 1/16 inch increments until the stamp will fit within the space.

Rules for Marking

4-323. The installer will typically acquire instructions using the marking notes contained within the EIP or drawings. Legibility, accuracy and permanence shall be the primary considerations when applying designations. Designations must be of the proper color and size and placed at the proper location on the equipment. New markings will conform to previous markings.

4-324. All identification designations must coincide to applicable drawings. If an abbreviation other than what a drawing states or other than an approved standard is used, redline the drawing to indicate the deviation. Ensure designations are easily observable. Use the largest stamps that will fit the limited space whenever possible.

4-325. Make each placement of a designation by the use of guides. Use grease pencils, chalk, or string to set up for alignment of stamps. The surface to be marked must be clean and free from oil, dust, and unimpaired. If necessary, paint the surface with a touch-up paint of an approved type and color. Clean and shellac all porous surfaces. After markings are dry, protect with shellac.

Designations on Terminal Blocks

4-326. Place all markings on terminal blocks on the maintenance side. Place group designations on the face/front of the clamping strip and on the side of the fanning strip.

4-327. Place numerical designations on the face or side of the clamping strip, and on the side of the fanning strip. Numerical designations on the face of the clamping strip are required for the first and last circuit on the block.

4-328. Place functional designations on the mounting strips adjacent to the terminal pins to which they apply. When two different types of circuits serve one block they will be separated by a 3/4 inch letter "I" sideways on the clamping and fanning strips. Figures 4-13 depicts the vertical terminal block..

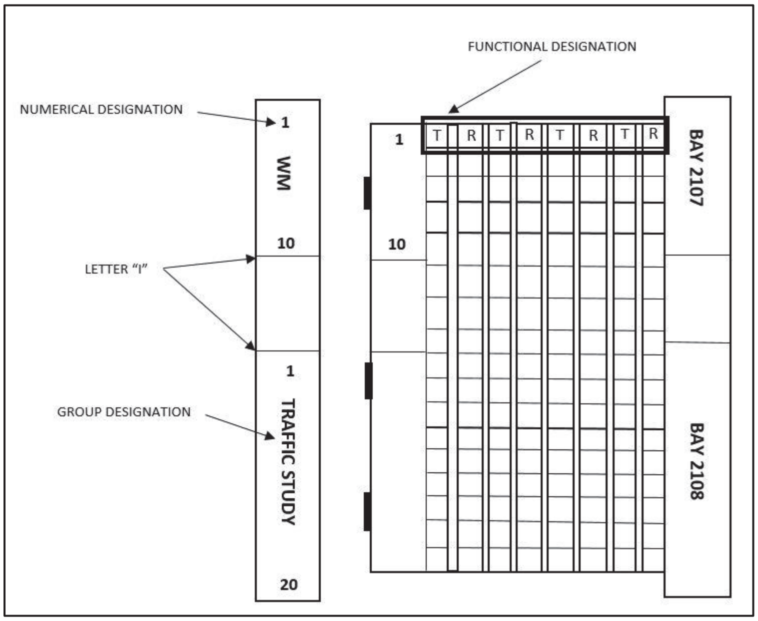


Figure 4-131. Vertical terminal block

4-329. Figure 4-132 depicts a horizontal terminal block configuration.

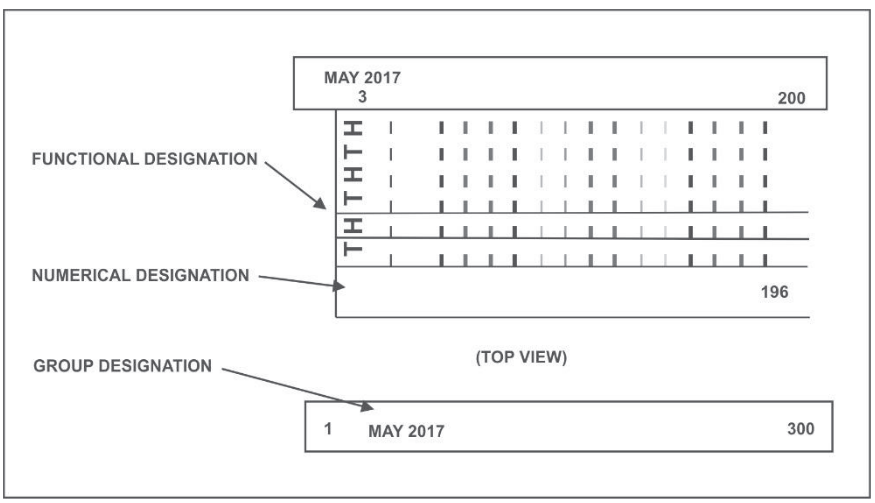


Figure 4-132. Horizontal terminal block

Frame Marking

4-330. Both sides of a frame require marking. Number the vertical members of a combined distribution frame starting where the MDF and IDF divide. The protected side (MDF side) will be marked at the top of each vertical using 3/4 or one-inch numbers and designated as one, 2, 3, or so on. The unprotected side (IDF portion) will be marked at the top of each vertical using 3/4 or one inch numbers and designated as-01, 02, 03,

4-331. Mark the vertical numbers on the fifth terminal block from the floor in the lower right hand corner. Stamp horizontal shelf designations on the end guards from bottom to top using 3/4 or one-inch letters adjacent to the shelves. Mark the shelf letter on each terminal block in the upper left corner on the first, last, and every fifth vertical. Omit when a block, per the drawings, mark the vertical number on the fanning strip below the omitted block. If omitting the block below, the terminal block-mounting clip will be marked.

4-332. The cable number is marked on the protector block using red numbers on a white background. The cable number is marked below the first pair of cables on each vertical. The letter "I" is marked at the fanning hole for each fifth cable pair (see figure 4-133 through 4-136).

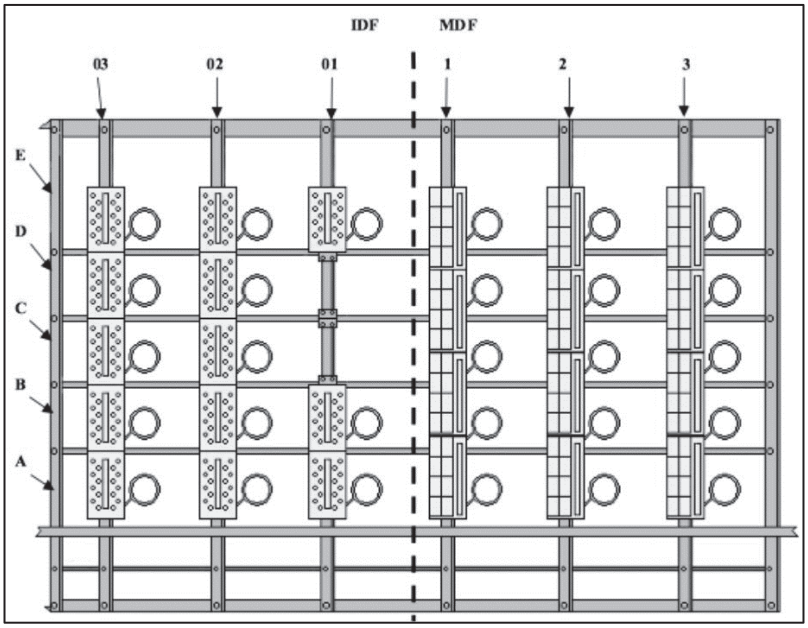


Figure 4-133. Vertical side of a distribution frame

4-333. Figure 4-134 depicts vertical markings on a distribution frame.

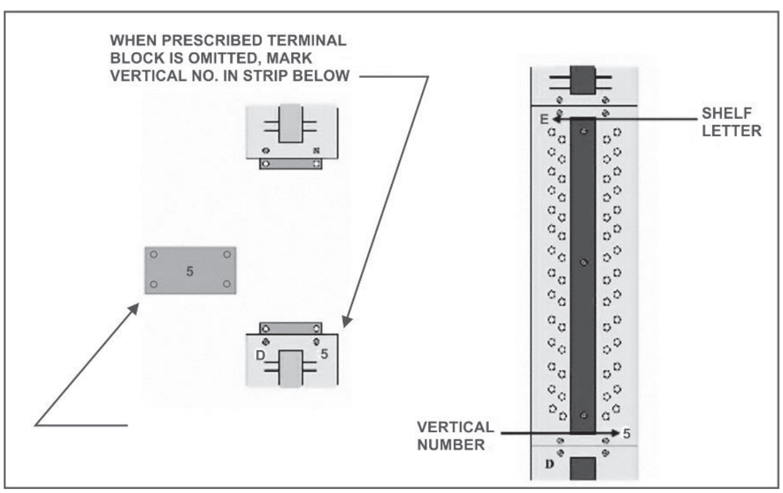


Figure 4-134. Vertical markings on a distribution frame

4-334. Figure 4-135 depicts the horizontal side view of a distribution frame.

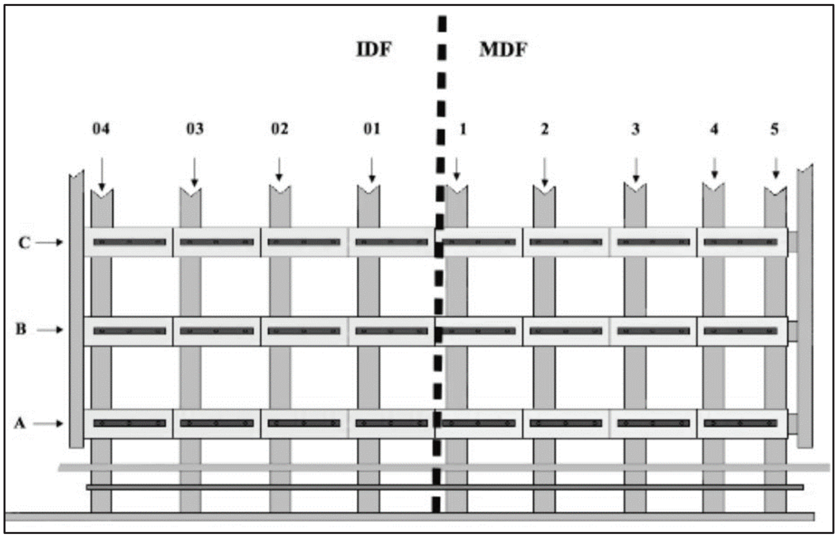


Figure 4-135. Horizontal side of a distribution frame

4-335. Figure 4-136 depicts horizontal markings on a distribution frame.

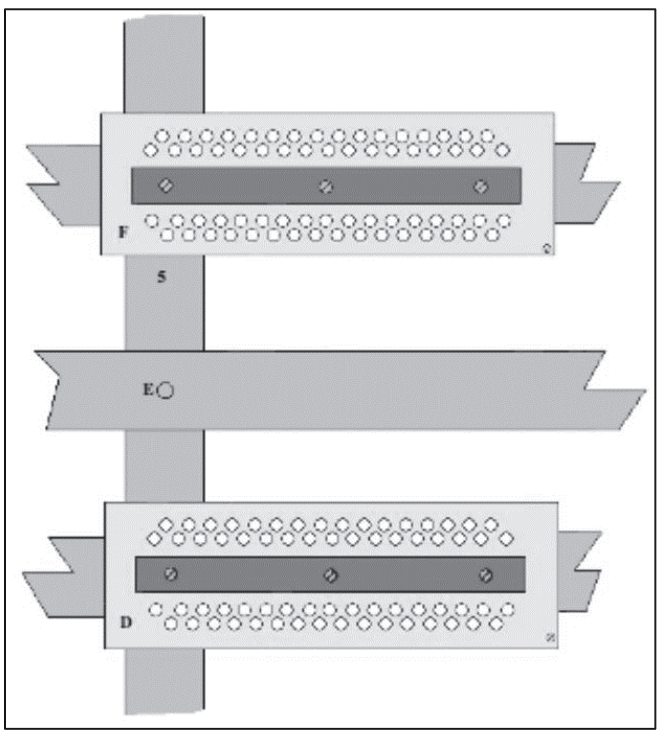


Figure 4-136. Horizontal markings on a distribution frame

Cabinet, Bay and Fuse Panel Marking

4-336. Cabinets or bays. Take applicable designation information from the floor plan layout drawings for identification on cabinets, bays, and panels. Item location designations for equipment cabinets are marked at the top center. Designations for equipment in a cabinet are marked on the lower left corner as viewed from the front.

4-337. Fuse panels. Voltage designations (24 volts DC (VDC), 48 VDC) or type of supply (+ or -) will be marked on the front and rear of all mounting plates and fuse panels where space permits. Designations for capacity and fuse codes will be marked with yellow ink on the front of the fuse panel. Numerical designations will be marked on the front and rear of the fuse panel. Fuses of different capacities, mounted on the same common buss bar, will be separated by a 3/4 inch letter "I" (see figure 4-137).

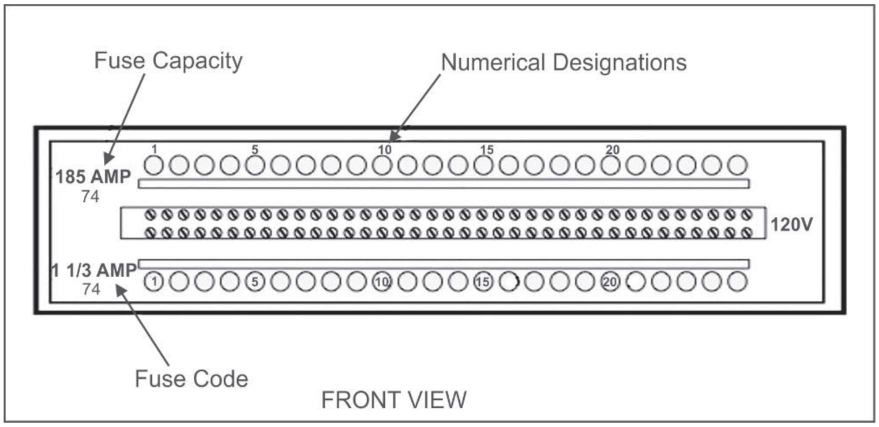


Figure 4-137. Fuse panel markings

Inside Cable Labeling

4-338. Temporarily mark cables for the cable running process, and then replace with permanent labels on terminated cables. Mark cables at both ends with two separate permanent identifications (labels). Do not remove these labels. Label marking steps are—

- Place the first marker (label) "TO" within 12 inches of the connector and indicates the bay, equipment shelf, terminal block, or position as defined in the CRL.
- Place the second marker (label) "FROM" within 2 inches of the first marker and enter the connection information of the opposite end of the cable as defined in the EIP.
- Place cables and labels so they are easy to read.

COMMUNICATIONS SUBSTATIONS

4-339. Communications substations provide data and voice access points to remote subscribers. Communication substations are located outside of the physical dial central office, internet service provider, or telephone exchange. Installers refer to these facilities as communications facilities. A communications substation is a part of a communications distribution and switching system. Communication substations remotely connects to communication facilities through the installation of various cable runs underground via manholes. Communication substations will typically have networking (switches, hubs, routers) and connection points (fiber optics, coaxial, category cables). Install communications equipment in an IDF. Additionally, emplace AC and DC power systems to provide continued and emergency power for all networking equipment at the communications substation. See figure 4-138, page 4-106.

Figure 4-138. Communications substation

Subscriber Data and Voice Access Points

4-340. Subscribers have various access points within communication substation to gain connection to the communications facility for data and voice services. Subscribers can attain data and voice connectivity by using one of the following access points—

- 66 blocks (see paragraph 4-393).
- 110 blocks (see paragraph 4-395).
- Registered jacks -11 (RJ-11) ports.
- Registered Jacks-45 (RJ-45) ports.
- Fiber optics.
- Terminal box (Curb Side and pole mounted).

Cable Tray

4-341. Utilize a cable tray system to support insulated electric cables that provide data and voice services to the subscriber. Use several types of trays in different applications. A solid-bottom tray provides the maximum protection to cables, but requires cutting the tray or using fittings to enter or exit cables. Installers refer to a deep, solid enclosure for cables as a cable channel or cable trough.

4-342. A ventilated tray has openings in the bottom of the tray, allowing some air circulation around the cables, water drainage, and allowing some dust to fall through the tray. Small cables may exit the tray through the ventilation openings, which may be either slots or holes punched in the bottom. A ladder tray has the cables supported by a traverse bar, similar to the rungs of a ladder, at regular intervals. Ladder and ventilated trays may have solid covers to protect cables from falling objects, dust, and water.

TROUBLINGSHOOTING A COMMUNICATIONS SUBSTATION

4-343. Troubleshooting is done systematically and each organization should have written troubleshooting procedures to assist in the training of new Soldiers. Each unit is responsible for training up Soldiers to ensure the Soldiers are capable of preforming their mission in garrison and while deployed.

Categorizing Common Issues

4-344. The causes for troubles in a substation can divided into separate categories. These are—

- Poor electrical connections.
- Bad installation practices.
- Weather.
- Abuse of instruments.
- Carelessness on the part of installers.
- The customer.

Types of Electrical Connection Issues

4-345. Typically, problems discovered with most electrical connection issues are corrected in a relatively short amount of time. Understanding the symptoms and knowing how to resolve the problems make troubleshooting easier to accomplish.

Short

4-346. A short occurs when an electrical connection is an unintentionally connection to ground. This can be through another connector or through the metal around the connector itself. Causes of a short are—

- An electrical connection (caused by metal, scrap wire, water) between two points.
- Poor installation practices.
- Moisture inside the cable.
- To correct a short, create a known open somewhere in the circuit in an effort to eliminate the short. This gives direction in which to troubleshoot, toward the equipment or the telephone. Fix the problem by removing the short, replacing the faulty component, or making the proper connections.

Open

4-347. An open happens when two points should have an electrical connection but do not. This is usually due to a break or cut on one or more conductors. You can usually notice opens when there is a disruption of service. Causes of an open fault are—

- Poor electrical connection.
- Split pair during wire installation.
- Termination of a circuit in the wrong place.
- Broken component or conductor.

4-348. To correct an open, visually check for obvious problems like loose jumpers, screw connections, and installer errors. Use a butt set and tools to verify where the problem is by checking various test points. Find opens between a test point with dial tone and test point without dial tone.

Grounded Contact

4-349. A grounded connection is one or more conductors making electrical contact with ground or a grounded object. Normally, use the term ground when describing the grounded tip or ringside of a central office line. Symptoms of a grounded connector may be the inability to break dial tone, inability to complete a call, or hear a hum over the telephone line. Troubleshooting a ground fault uses the same steps for troubleshooting a short. Correct the ground fault by removing the faulty material or correcting the electrical connection.

Cross Connection

4-350. A cross connection is an abnormal connection between two nodes of an electric circuit intended to be separate. This results in unwanted data or voltage on both circuits and potentially causes circuit damage, overheating, fire or explosion. This type of trouble is also associated primarily with a central office line. Treat possible causes as a short and troubleshoot accordingly. Symptoms of a cross fault are—

- No dial tone.
- Noise on the line.
- Cross talk (another conversation on the line).

4-351. A cross connect is usually caused by a split wire pair or a connection to a wrong termination point. To correct a cross connect, make the correct connection to the indented termination point.

Installer Error

4-352. Installer errors are common. They usually result from the installer not paying attention to the proper installation procedures. Installer errors usually are of three kinds—

- Split pairs results when the installer erroneously connects the tip or ring of one pair to the tip or ring of a different pair.
- Reversal results when an installer incorrectly connect one pair to another pair.
- Improper wiring results from a total disregard for the wiring color code.

Test Equipment

4-353. Many pieces of equipment are available to make troubleshooting easier in a substation. Some of the equipment used for troubleshooting in a substation that will be covered in the following paragraphs are—the telephone test set (butt set), continuity test set, multi-meter, and the Ethernet cable tester.

Telephone Test Set

4-354. A telephone test set, figure 4-139 on page 4-109, is a special type of telephone in use by technicians for installing and testing local loop telephone lines. A typical telephone test set integrates an earpiece, a mouthpiece, a dialing interface, and a set of test leads for connecting to the telephone circuit. Manufacturers design most test sets for use with analog telephone service lines only, and have limited or no function with digital circuits.

Figure 4-139. Telephone test set

4-355. Connect the telephone test set wherever there is a line appearance. Inside the central office, this can be at a main or intermediate distribution frame. For outside plant, this can include any serving area interface, such as a cross-connect box or aerial splice enclosure. At subscriber site, this may be inside or behind the housing of a modular connector, or at the network interface. Use the telephone test set to test for dial tone at connection points and to call for assistance in solving difficult problems.

Continuity Test Set (Toner and Probe Kit)

4-356. A continuity tester as seen in figure 4-140 on page 4-109, is an item of electrical test equipment that will determine if establishment of an electrical path between two points is possible. A continuity test set functions to accomplish the following—

- Check continuity.
- Apply a voltage potential to a line for testing.
- Generate a test tone across a pair to identify use.

Figure 4-140. Continuity tester

4-357. De-energize the circuit under test before connecting the apparatus. Accomplish this by disconnecting both ends of the tested wire before connecting the continuity tester. This prevents false indications on the test set and prevent the possibility of damage to the test set.

Multi-meter

4-358. A multi-meter, figure 4-141, is an electronic measuring instrument that combines several measurement functions in one unit. A typical multi-meter includes features such as the ability to measure voltage, current, and resistance. A multi-meter can be a hand-held device useful for faultfinding and field service work. They can troubleshoot electrical problems in a wide array of devices such as electronic equipment, power supplies, and wiring systems.

Figure 4-141. Multi-meter

Ethernet Cable Tester

4-359. A cable tester, figure 4-142 on page 4-111, is an electronic device that can verify the electrical connections in a cable or other wired assembly. A cable tester can also verify that only the intended connections exist in the tested cable. When an intended connection is missing, it is open. When an unintended connection exists, it is a short. An incorrectly wired connection will go to the wrong place.

Figure 4-142. Cable tester

CABLE

4-360. Installers can identify cables by binder color and/or individual color-codes for each cable pair. This section provides the information to identify cable pairs by numbers and colors, and find the binder color code for each cable pair.

4-361. Cables are an integral part of a network especially a LAN. There are different types of cables that the network communication system utilizes, such as twisted pair cables UTP/STP, coaxial cable, copper wire and fiber optic cables. In the LAN technology, the most popular cable is unshielded twisted pair and twisted pair cable.

4-362. Data travels over a cable via electrical pulses. These electrical pulses are measured positive and negative voltages to form signals. Special encoding schemes, or protocols, translate data from identifiable bit patterns represented by the voltage fluctuations. Fast Ethernet uses a three-level encoding scheme to track data; gigabit Ethernet uses a five-level-encoding scheme. See table 4-2 on page 4-112.

Table 4-2. UTP network compatibility

	Ethernet Thinnet (10Base2)	***Ethernet Thicknet (10Base5)***	***Twisted-Pair (10BaseT)***	***Twisted-Pair (100BaseTX)***	***FDDI***
Media	Thin Coaxial	Thick Coaxial	Unshielded Twisted-Pair	Unshielded Twisted-Pair	Fiber Optic
Max Nodes	30/seg	100/seg	1024	1025	1000/ring
Max Segments	5	5	N/A	N/A	500
Max Cable Length	185m	500m	100m	100m	2000m
Cable Type	RG 58	RG 8	Cat 3, 4, or 5	Cat 5	Fiber
Speed	10 Mbps	10 Mbps	10 Mbps	100 Mbps	100 Mbps
Legend					
Cat: Category			m: Meter(s)		
FDDI: Fiber distribution data interface			RG: Radio guide		
Mbps: Megabits per second			seg: Segment		

4-363. There are five cable types in networks—

- Coaxial.
- Twisted-pair.
- Unshielded twisted-pair.
- Shielded twisted-pair.
- Fiber-optic.

4-364. Twisted pair cabling is the most popular network cable and often used in data networks for short and medium length connections of up to 100 meters or 328 feet.

4-365. Cables that run above ceilings and inside walls use a solid copper core for each conductor, which enables the cable to hold its shape when bent. Patch cables, which connect computers to wall plates, use stranded copper wire so they can flex during their lifetimes.

4-366. Twisted pair cables include—CAT 3 cable, now the minimum requirement by the federal communications commission for every telephone connection; CAT 5e cable, 100 megahertz (MHz) enhanced pairs for running Gigabit Ethernet (1000Base-T); and CAT 6 cable, where each pair runs 250 MHz for improved 1000Base-T performance.

4-367. There are four parts to a cable's composition (see figure 4-143 on page 4-113):

- Sheath.
- Shield.
- Conductors.
- Insulation of cable pairs.

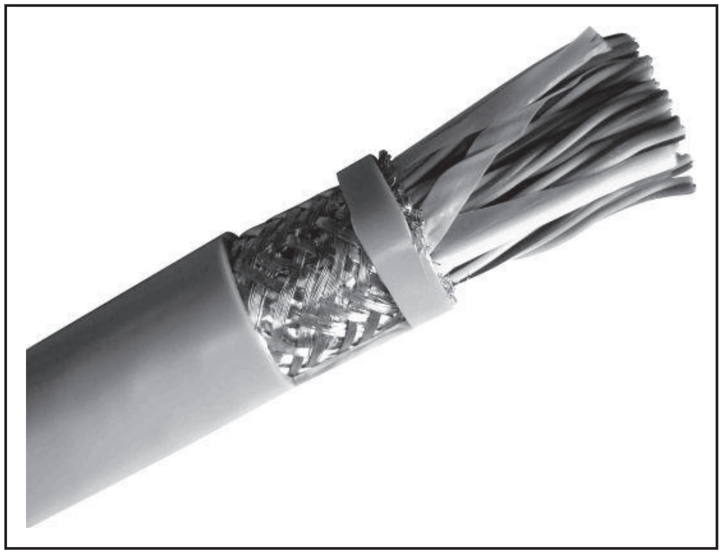


Figure 4-143. Cable composition

CABLE MARKINGS

4-368. Use information markings on the sheath to determine the type of cable, the gauge of the conductors, number of pairs and on some cable the length measurement. The requirements for the exact text and location of the markings, and the method of identification, vary among the different types of wire and cable. Wherever possible, the product is surface marked with information necessary for proper installation. When surface marking is not possible a portion of the marking may be located on a marker tape, or on the tag, reel or the smallest unit container as permitted by the requirements of each product category.

4-369. Single Conductor cables have the manufacturer's name, Underwriters Laboratory (UL) mark, Type of Insulation, wire size and type, and rating. Multi-conductor cables have the manufacturer's name, type, rating, UL mark, type of insulation, number and size of conductors, and length imprinted or painted on the outer insulation jacket of the conductors (see figure 4-144).

Figure 4-144. Cable markings

4-370. Plastic insulated cables are cables that have plastic or polyethylene insulation over the conductors and are the most common type of cable used.

4-371. LAN and WAN systems use CAT 5 and CAT 6 cables for high-speed data. The conductors in CAT 5 and CAT 6 cable have twisted pairs of wires together in a regular spiral pattern. Typically, CAT 5 a, CAT 5 d, and CAT 6 cable is limited to 100 meters for high-speed data and produce 100MHz capabilities.

4-372. UTP is cable that has no metal shielding. Use UTP indoors and comes in a variety of sizes.

CABLE COLOR CODES

4-373. An installer will work with several different color codes within communication facilities; therefore, it is important to know the different color codes. This is because typically designation of pair and conductor colors are not on drawings. The CRL lists conductor pairs by pair-numbers.

4-374. The insulation of conductors in a cable is color coded to facilitate selection of the desired conductors. Using color-coded conductors eliminates the necessity of making continuity tests to identify individual binder groups, pairs or conductors. Color-coding also facilitates the maintenance of equipment served by cables having a large number of pairs of single conductors.

Definitions

4-375. Tip, ring, and sleeve came into use years ago when an operator handled all telephone calls. These common terms, to include tracer, describe the various parts of the operator plug jack:

- Tip or "T" represents positive voltage, which is common.
- Ring or "R" represents negative battery.
- Sleeve or "S" represents ground or "D" for drain on drawings.
- Tracer is a color added to a wire to help identify it from another wire, pair, with the same color. It can be a tic mark, stripe, or spiral (see figure 4-145).

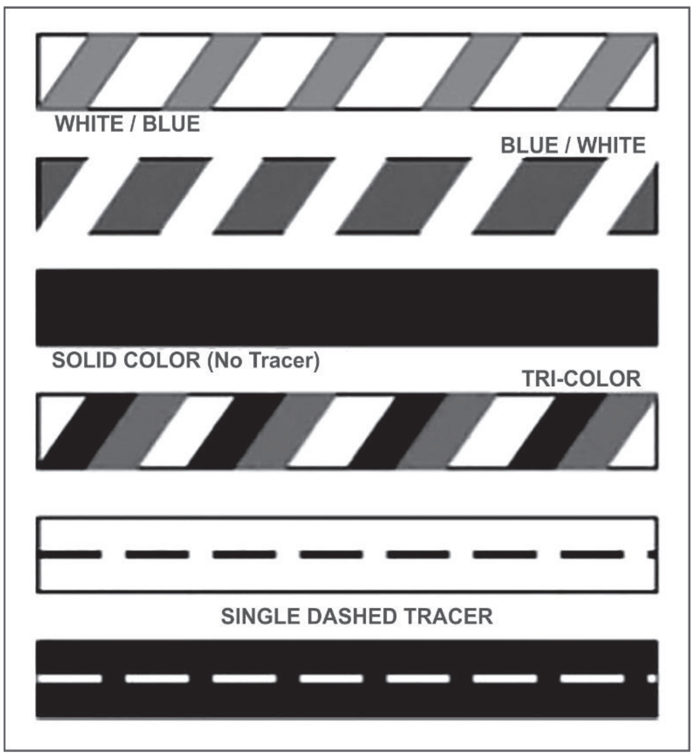


Figure 4-145. Tracer identification

Regular Colors

4-376. *Regular colors* are the colors used to build color code. There are 13 regular colors, of which ten are commonly used. Table 5-3 below depicts a list of the colors and their abbreviations. The ten commonly used colors are blue, orange, green, brown, slate, white, red, black, yellow, and violet. The other regular colors, used primarily in Western Union cables, are pink, tan, and light green.

4-377. The two groups of ring and tip colors are separated into regular colors (see table 4-3 on page 115). Use either a ring color or tip color as tracer with the other color.

Table 4-3. Ring and tip colors

Color	*Abbreviation*
Rings	
Blue	BLU
Orange	ORN
Green	GRN
Slate	SLT
Tips	
White	WHT
Red	RED
Black	BLK
Yellow	YEL
Violet	VIO

4-378. Of the regular colors, the five ring colors, also known as basic or primary colors are–blue, orange, green, brown, and slate. Of the regular colors, the five tip colors, also known as mate colors, are–white, red, black, yellow, and violet. If referring to a binder group, the ring color is used first and the tip color is used last; for example, Blue/White or Green/Red.

Basic 25 Color Code

4-379. The color-coding for single conductors permits the identification of 25 single conductors of a cable. It is used on polyvinyl chloride (PVC) insulated cables. Identify PVC insulation by a lengthwise combination of the basic colors of blue, orange, green, brown, and slate with the mate colors of white, red, black, yellow, and violet. For example, a blue/white conductor will be primarily blue with a tic mark or strip of white. Construct a pair (using blue/white conductor as example) mate a tip conductor (WHT/BLU) with a ring conductor (BLU/WHT). Match the ring colors in order with each of the tips colors through the yellow group for the basic 25-color code without violet and through the violet group for the basic 25-color code with violet.

Binder Groups

4-380. To identify one complete or partial group from another with the same color-coded conductors, employ binder group markers. Color-coded Mylar strips identify each binder group. The binder groups are color coded the same as ring colors of the basic 25-color code and numbered sequentially.

4-381. A complete binder group will contain 20 pairs without violet (figure 4-146 on page 4-116) or a binder group can contain less than 20 or 25 pairs if completion of the cable require fewer pairs. Binder markers around a particular group of pairs still follow the normal color code sequence. Each binder group will always contain the same number of pairs, until the final group of the cable. This final group may be a partial group.

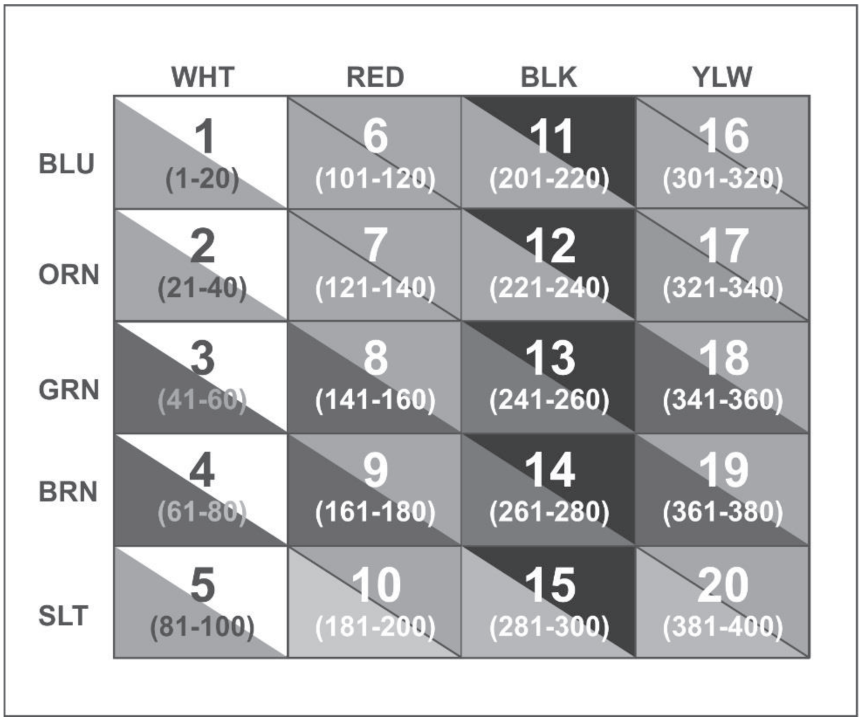


Figure 4-146. Twenty pair binder group color code

4-382. Figure 4-147 is the color code for a 25 pair binder with violet.

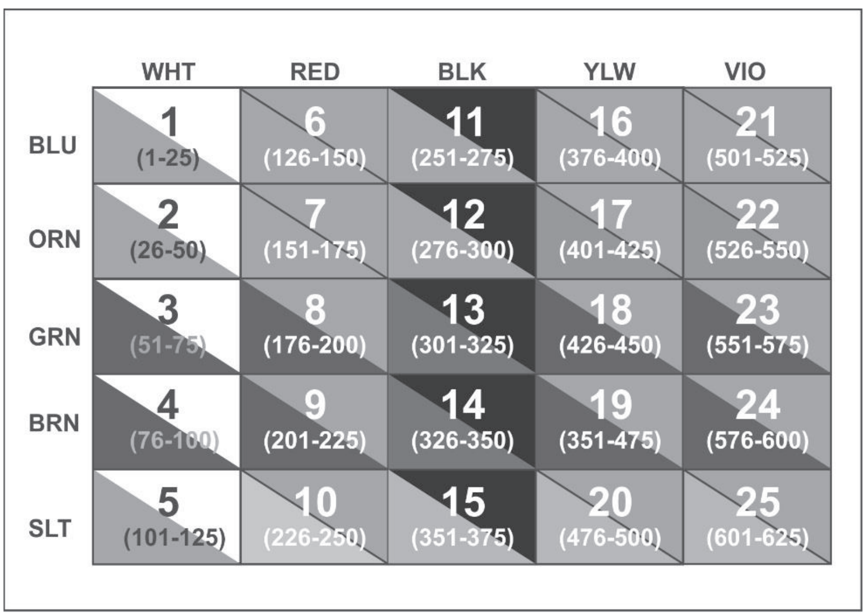
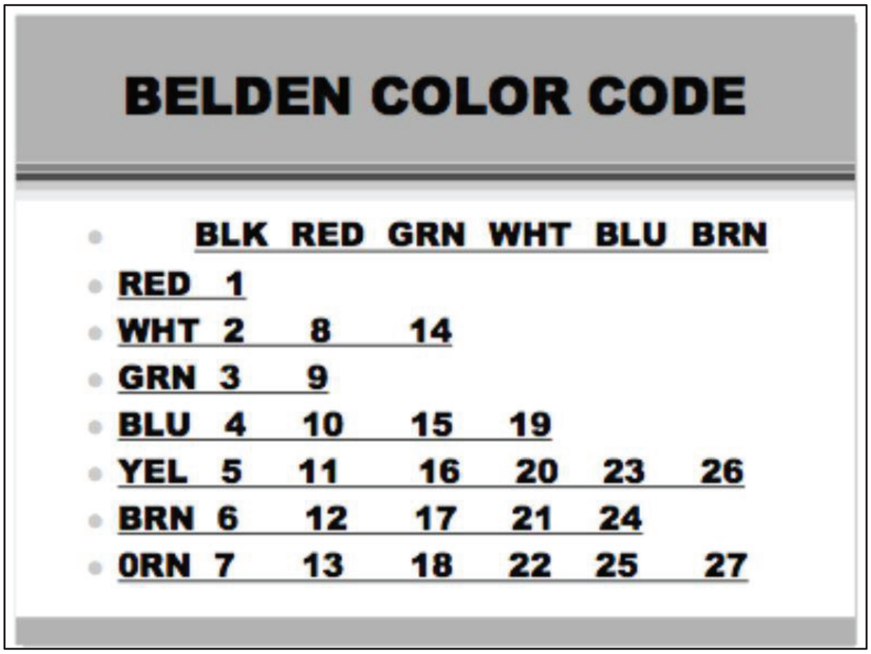


Figure 4-147. Twenty-five pair binder group color code

Belden Color Code

4-383. The Belden or Bedfoil color code, developed by Belden Wire and Cable Company, is used mainly in shielded cable (see figure 4-148 on page 4-117). First, use each color, except black, as a ring color, then as a tip color. Then drop the color from the color code. Only use the color black as a tip color before dropping from the color code as well. In each tip group, the number of pairs is dropped by one as the installer progress through the cable. To build a larger cable, add the colors slate and violet and continue as before.



BELDEN COLOR CODE

	BLK	RED	GRN	WHT	BLU	BRN
RED	1					
WHT	2	8	14			
GRN	3	9				
BLU	4	10	15	19		
YEL	5	11	16	20	23	26
BRN	6	12	17	21	24	
0RN	7	13	18	22	25	27

Figure 4-148. Belden color code

CABLE TERMINATION TYPES

4-384. There is a variety of termination methods for cable. The termination method utilized depends on the system installed, type of cable, and type of connector. The use of the proper termination method allows for good mechanical and electrical integrity. Use the proper tools and materials for the type of termination. For example, using a pair of pliers to crimp the cable might work, but using a crimping tool and the proper die designed for your type of cable and connector is the correct method to termination method.

4-385. There are many different types of termination. The termination type depends on the engineering instruction. The most common termination in use in a substation is insulation displacement and direct connect.

SOLDER

4-386. A solder type connection allows for a strong, solid mechanical and electrical connection. Clean the connection well. For electrical circuits you must use a rosin type flux to clean all connections. Do not use acid flux. Use acid flux for plumbing installation. The acid based flux will cause corrosion and inherently cause intermittent problems with the electrical signal. The choice of solder is also important. Using a solder standard 60/40 formula meets the majority of soldering needs. However, lead-free and high-grade silver solder is available for special applications.

CRIMP

4-387. A crimp type connection allows for quick and simple installation while still maintaining a mechanical and electrical connection fairly close to a solder type termination. Use solid or stranded wire in this type of termination.

4-388. Some of the key points to remember for a good clean connection are as follows:

- Make sure you use the proper size connector for the type of cable you are using.
- Make sure all of your cuts and stripping are clean.

- Avoid nicks as much as possible.
- Use the proper crimp tool; do not try to improvise with pliers,

INSULATION DISPLACEMENT

4-389. Typically, use this type of termination in punch down blocks, wall connectors, and in the back of patch panels. This type of termination eliminates the need for stripping the conductor insulation. When pushing the conductor through the clip, cut the insulation into and the metal clip contact makes contact with the wire.

4-390. The best type of wire to use is a solid conductor. If you use a stranded conductor, the force of the termination may allow the clip to cut some of the strands. In addition, stranded wire will crush somewhat which will not allow for a solid connection.

4-391. Make the connection using a punch down tool. Some patch panel manufacturers supply a termination cap that terminates several wires at once without the use of a tool. Some tools allow use of different bits for use with various terminations (66 block, 110 block). Just like the crimping type termination, it is important to use the correct bit for the type of termination you are doing.

DIRECT CONNECT

4-392. Direct Connect termination uses either solid or stranded conductors. It allows for easy termination as well as quick changing of wire in the future. The main point to remember about a screw connection is to strip back the insulation only to the amount of conductor that wraps around the screw and to place the wire in the same direction as the screw turns when tightening. This will "pull" the wire in tighter as the screw tightens. If you wrap the wire around the screw opposing the tightening rotation of the screw, the wire will pull outward and become unwrapped around the screw.

CABLE TERMINATION PREPARATION

4-393. Cable preparation comprises methods of butting, stripping dressing and fanning the cable. The various types of preparation are—

- Butting is making a circular cut through the sheath of a cable at a predetermined point.
- Stripping is a lengthwise (longitudinal) cut through the sheath to remove the sheath and expose conductors for layering, fanning, forming, and terminating operations.
- Dressing a cable is the treatment of the cable butt to give it a smooth, even appearance. The butt should be square as possible on the cable and not have gashes or marks from the cutting procedure.
- Fanning is the routing of the individual conductors from the cable butt to the terminating equipment.

BUTTING

4-394. The butt location on a cable varies depending on the equipment design and the location of cable supports. All butts are located as near as possible to the point of termination.

4-395. When butting a cable you must consider the following—

- Location of the last cable support.
- Type of conductor fanning device.
- Cable and conductor bending radius.
- Routing of conductors from the butt to the point of termination.

4-396. When utilizing a 66 block not mounted on standoff brackets, the butt of the cable should be flush with the top or bottom of the block.

4-397. On all cable, ensure that the butt cut is straight, smooth and square. Before removing Mylar markers and cords, pull the sheathing back towards the secured end of the cable (called *milking*). Leave sheathing in this position until all layering is completed.

4-398. To dress the cable(s), pull on the Mylar binder markers and other paper, foil, or plastic and snip it off with scissors. Push the ends back under the sheath, pulling on the wrappings before cutting causes them to snap under the sheathing. Installers can treat cable butts with shrink tubing, lacing twine, tape, or other materials as called out by the engineers.

LAYERING

4-399. Cable layering enables the installer to identify one tip group from another and prepares the cable for fanning and termination. The following are requirements when cable layering:

- Cables will be separated first into binder groups (20 or 25 pair) and then into tip groups (groups of five).
- Layer cables in normal color code sequence starting at the butt of the cable.
- Always tie the conductors into binder groups immediately after removing the sheathing to prevent unraveling pairs.

4-400. Refer to communications equipment as wired tip or ring common. With wired tip common equipment, the tip conductor wires to the odd numbered pin or the first pin of the circuit. The ring conductor wires to the even numbered or second pin of the circuit.

4-401. After layering identified binder groups in sequence, layer the cable conductors into tip groups, as shown in figure 4-149. Layering eliminates crossing and bunching of wires at the cable butt and allows for the first wires being fanned leaving the cable on the side nearest the fanning strip. Pair #1 should be opposite to the last pair in the cable.

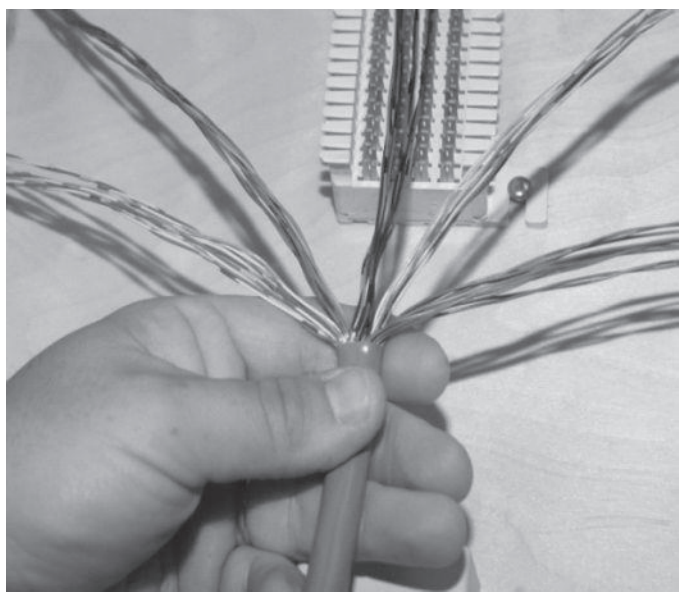


Figure 4-149. Separating group pairs

4-402. When the cable conductors are in layers, pull the sheathing back towards the secured end of the cable (known as milking) to predetermined point and permanently secure the cable.

FANNING

4-403. Fanning is the separation and routing of cable conductors from the butt of the cable to the point of termination (see figure 4-150 on page 4-120). Before fanning, ensure that the conductors are capable of reaching the farthest termination point on the block. Fan the conductors to the permanent side of terminal blocks (the left hand side).

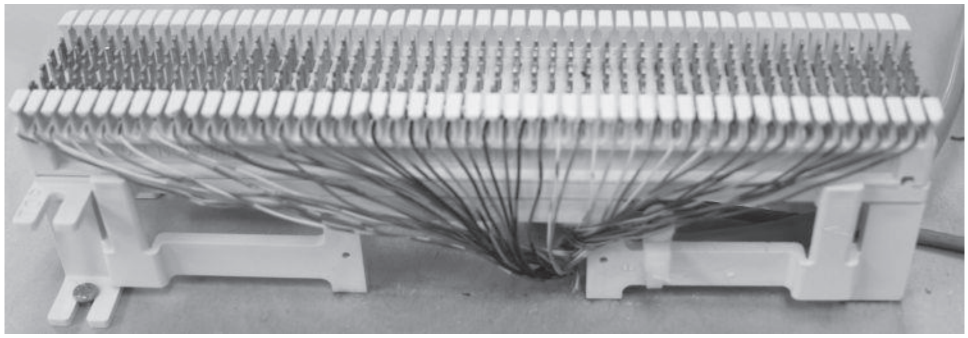


Figure 4-150. Fanning

4-404. Make sure there is no slack in the fanned conductors and the factory twist remains in a pair until it reaches the final fanning device. Layer the conductors in sequence of termination and are routed straight from the butt to their termination point.

4-405. Remove conductors from the terminal clips with a pair of needle nose pliers or a spudger. Exercise rare to prevent damage to the clips. Do not use clips that are bent or misaligned until straightened. Repair a bent clip with long nose pliers, but replace a spread clip.

PUNCH DOWN BLOCKS

4-406. A punch down block is a type of electrical connection often used in telephony. The name punch down block comes from the solid copper wires punched down into short open-ended slots, which are a type of insulation-displacement connectors. These slots, usually cut crosswise across an insulating plastic bar, contain two sharp metal blades that cut through the wire's insulation when punched down. These blades hold the wire in position and make the electrical contact with the wire as well.

4-407. Punch down blocks are a very quick and easy way to connect wiring, as there is no stripping of insulation and no screws to loosen and tighten. Punch down blocks are often used as patch panels, or as breakout boxes for Private Branch Exchange or other similar key phone systems with a 50-pin RJ-21 (Amphenol) connector.

66 Block

4-408. A 66 block, figure 4-151 on page 4-121, is a type of punch down block for connecting sets of wires in a telephone system. 66-blocks enable termination of 18 through 26 American wire gage solid copper wires. The 25-pair standard non-split 66 block contains 50 rows; each row has four columns of clips that are electrically bonded. Each row contains four clips, but the left two clips are electrically isolated from the right two clips.

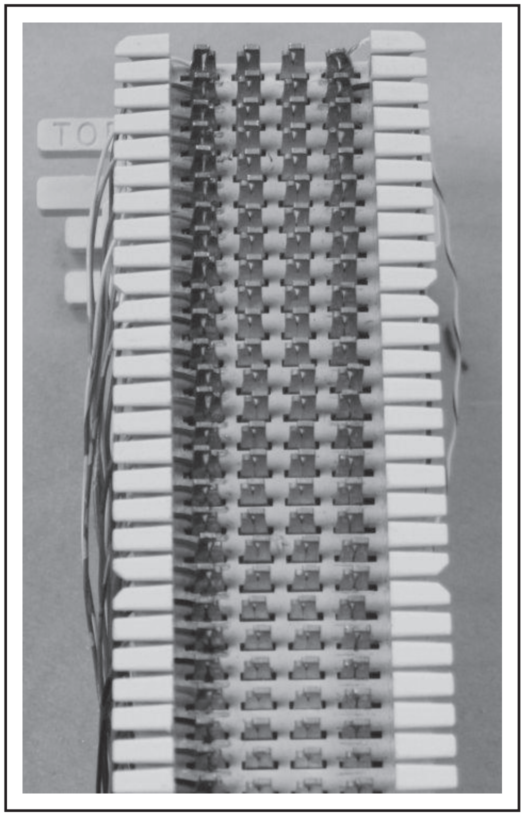


Figure 4-151. Sixty-six block

4-409. There are several sizes of 66 type connector blocks available. MI-25 accommodates 25 pair; MI-50 accommodates 50 pair.

110 Block

4-410. A 110 block, figure 4-152 is a type of punch block for terminating twisted pair cables and uses a similar punch-down tool as the older 66 block. The 110 Connector system has rapidly become the connective hardware of choice by the tele-communications and data industries. This miniature quick-connect terminating system supports both analog and high-rate bit digital transmissions, provided via UTP.

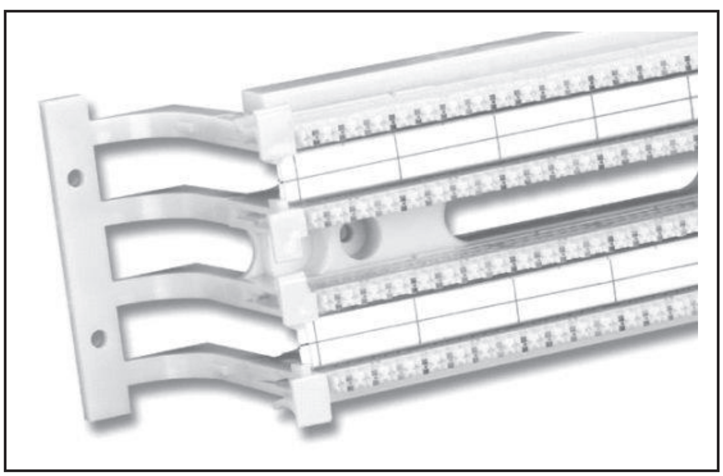


Figure 4-152. One hundred-ten block

4-411. The 110-block connector can terminate 22, 24, or 26 gauge plastic insulated conductors. The color code on the high teeth is provides for pair identification during installation. The 110 block also has a clear, fire retardant plastic part that snaps onto notches located between alternate row of the wiring block, providing protection and support for replaceable paper labels.

MODULAR SPLICING SYSTEM

4-412. The Modular Splicing System (MS2) connects and cuts off up to 25 pairs of conductors at one time, without the need to strip insulation. The system accepts 22-28 AWG (0.6 - 0.32 mm) solid copper conductors insulated with PIC, pulp or paper with a maximum insulation outer diameter of .065 inches (1.7 mm).

USING THE MODULAR SPLICING SYSTEM

4-413. The following are steps on how to use the MS2:

1. Attach the 4046 support tube to the cables to be spliced with appropriate splice opening.
2. Attach buckle strap and tighten to secure the tube to the cable (figure 4-153).

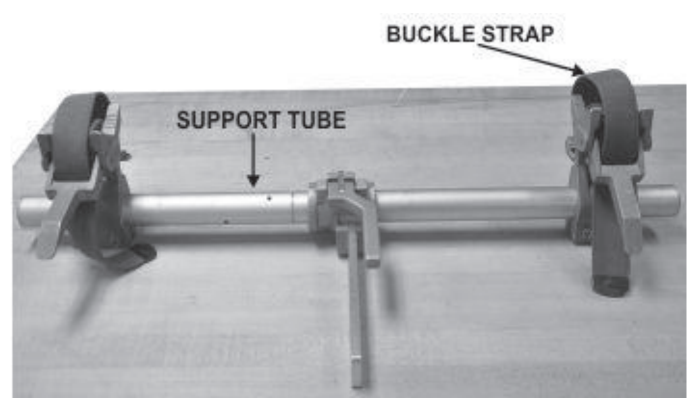


Figure 4-153. Support tube and buckle strap

3. Attach the traverse clamp assembly, slide the head clamp on the traverse bar to align with splicing, insert the pedestal with splice head or heads into the pedestal (see figure 4-154).

Note. Splice head should be higher than the spliced group.

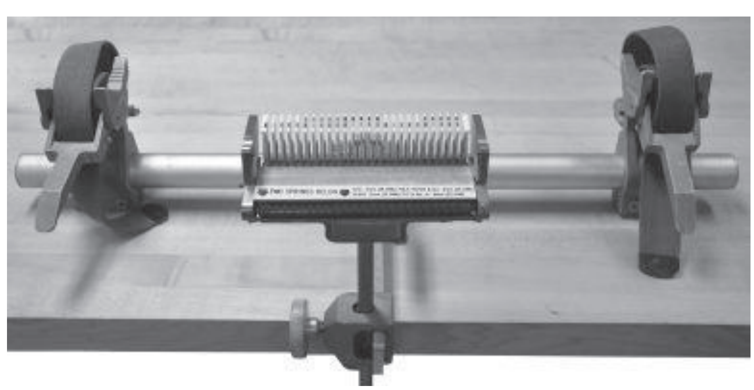


Figure 4-154. Traverse clamp and head assembly

4. Set retainer spring to wire gauge of splice.
5. Install module bottom and then select a 25-pair group and place wires in module.

6. Draw the wires snug into wire channels in module and secure in the retainer springs. Make sure all wires are lying flat in module channel (see figure 4-155).

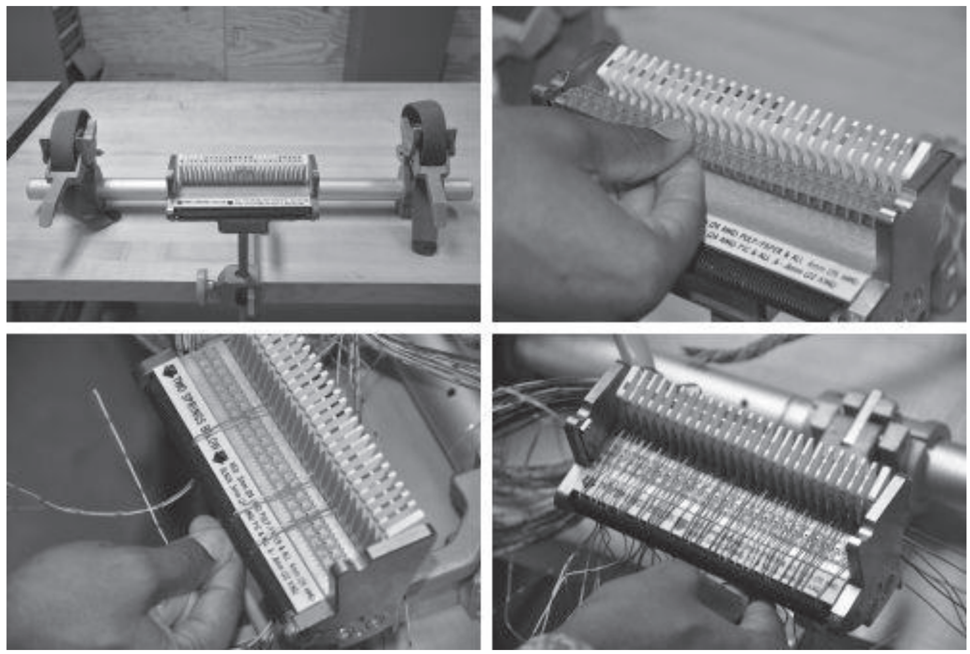


Figure 4-155. Pair installation

7. Follow the color code according to the white wire guides. Wire pair to right side of corresponding color-coded wire guide.
8. Separate pair over pair separator, tip is placed to the left and the ring is placed to the right.
9. Look for empty channels, two wires in one channel, or reversed pairs with the check comb.
10. Slide the check comb left, only the tip wires should show.
11. Slide the check comb right, only the ring wires should show.
12. Install next module component and place pairs from corresponding group.
13. Follow the same procedures as with installing the first 25-pair group.
14. Check for correct wire placement using the orange check comb.
15. Install module cover. See figure 4-156 on page 4-124.

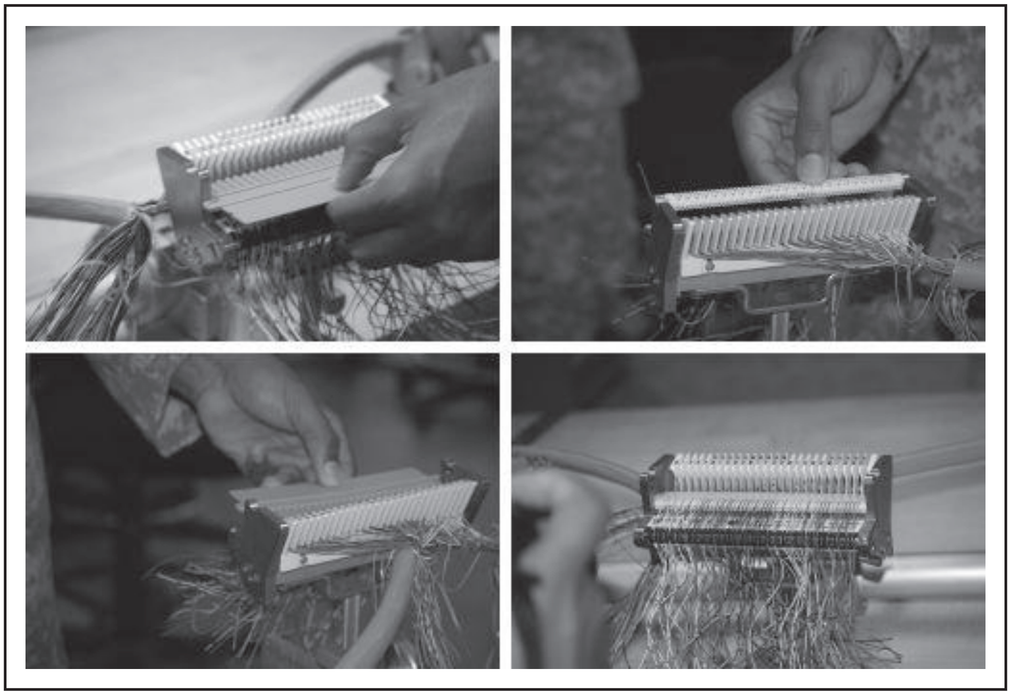


Figure 4-156. Check comb and second pair installation

MODULAR SPLICING SYSTEM CRIMPER

4-414. The modular splicing system (MS2) crimper, figure 4-157 on page 4-125, is a self-contained, pistol-gripped crimper designed for MS2 splicing and pluggable modules. The crimper is comprised of—

- Rapid advance lever.
- Fixed handle.
- Moveable handle.
- Release trigger.
- Press bar.
- Ball plungers.

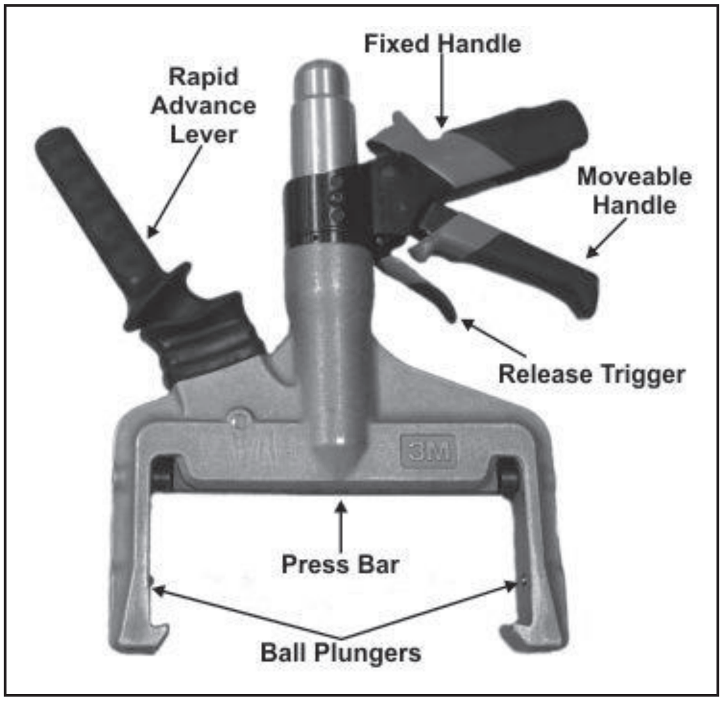


Figure 4-157. Modular splicing system crimper

Using the Modular Splicing System Crimper

4-415. The following are steps on how to use the MS2 crimper—

1. Place crimper rockers into yoke of splice head.
2. Rotate crimper until it locks into upright position.
3. Adjust ball plungers in or out with standard screwdriver if necessary to allow rotation and locking.
4. Using the rapid advance lever, advance press bar until it presses down firmly on the module.
5. Pump the handle until the pressure bypass operates, indicating module is fully crimped. See figure 4-158.

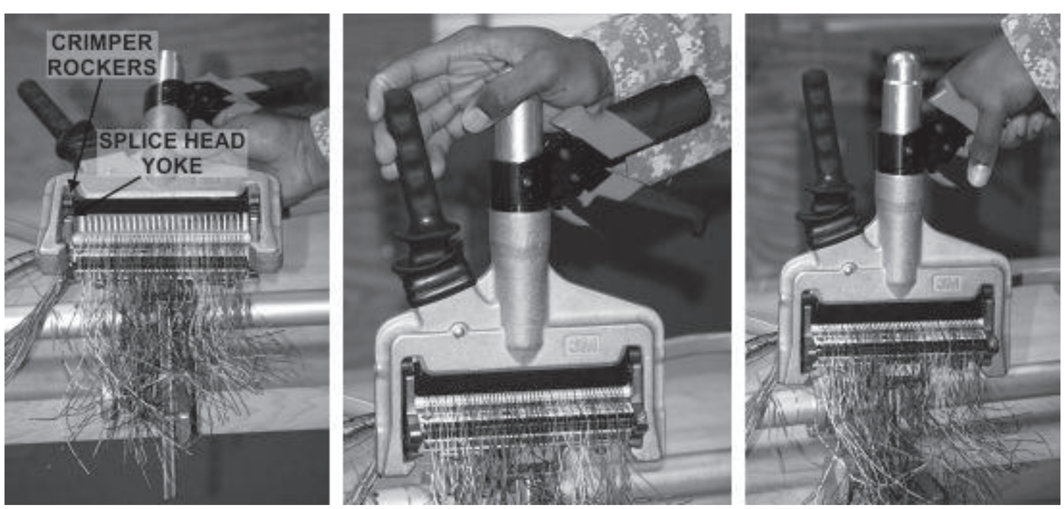


Figure 4-158. Crimper installation

6. Remove the cut off conductors by lifting straight up from retainer spring and pulling gently.

7. Pull release trigger to reset press bar.
8. Remove crimper by reversing rotation described above.
9. Remove the module from splice head (see figure 4-159).

Figure 4-159. Completed splice module

Chapter 5

Local Area and Wide Area Networks

This chapter introduces the various types of IP base networks. It provides an overview to assist the reader with distinguishing the difference between local area networks, wide area networks, virtual local area networks, and virtual private networks. Additionally, this chapter discusses the different network topologies used to engineer various networks that suits the users' requirements. This chapter will also discuss Ethernet protocols and the various networking layers that create the open source interconnect model. Finally, this chapter provides information on the various networking devices used to connect computers to one another, thus creating a network, as well as devices used for voice over internet protocol service.

INTERNET PROTOCOL NETWORK TYPES

5-1. The term network in computing system means a system of computers and other devices (such as printers) that connect to each other. Computer networks consists of many standards and technologies. Based on these standards, several protocols, topologies, cables and devices are also part of a computer network.

LOCAL AREA NETWORK

5-2. The definition of a Local Area Network (LAN) is a data communications system that (a) lies within a limited spatial area, (b) has a specific user group, (c) has a specific topology, and (d) is not a public switched telecommunications network, but may be connected to one (American National Standard T1-523-2011).

WIDE AREA NETWORK

5-3. A Wide Area Network (WAN) is a physical or logical network that provides data communications to a larger number of independent users than are usually served by a LAN and is usually spread over a larger geographic area than that of a LAN one (American National Standard T1-523-2011).

VIRTUAL LOCAL AREA NETWORK

5-4. A virtual local area network (VLAN) is a way of creating multiple distinct broadcast domains that are isolated so that information can only pass between them via one or more router. Achieving this requires a switch or router device.

5-5. Grouping hosts with a common set of requirements regardless of their physical location by VLAN can greatly simplify network design. A VLAN has the same attributes as a physical LAN, but allows for end stations to be grouped together more easily even if they are not on the same network switch, see figure 5-1, on page 5-2.

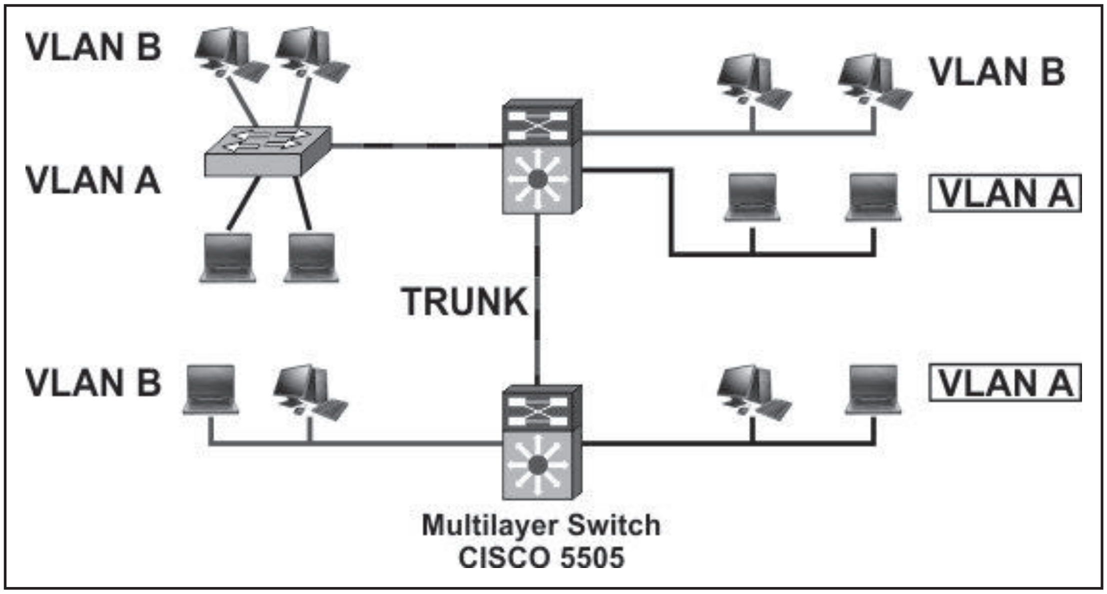


Figure 5-1. Virtual Local Area Network

5-6. VLANs provide the following benefits—

- VLANs reduce traffic to unnecessary destinations. Routers require more processing of incoming traffic than switches. As the volume of traffic through the routers increases, so does the latency, which results in a reduction in performance. The use of VLANs reduces the requirement in the number of routers. It is common to find cross-functional teams with members from different departments. To contain broadcasts and multicasts within the workgroup, a VLAN can be set up. With VLANs, it is easier to place members of a workgroup together.
- The task of adding, moving, and changing the users in the network is simplified with VLANs. Accomplish this simplicity by having to configure the VLAN only and not the entire network.
- VLANs use can include the creation of broadcast domains, which eliminate the need for expensive routers.
- Users can broadcast sensitive data on a network; however, in such cases, placing only those users who require access to that data on a VLAN can reduce the chances of an outsider gaining access to the data. VLANs are also be used to control broadcast domains.

VIRTUAL PRIVATE NETWORK

5-7. A virtual private network extends a private local network or LAN across a WAN. It enables a host computer to send and receive data across the WAN as if they are an integral part of the originating LAN with all the functionality, security and management policies of the private network. To accomplish this, establish a virtual point-to-point connection using dedicated connections, encryption, or a combination of the two. The intent of the VPN is to run a LAN over the internet.

NETWORK TOPOLOGY

5-8. In Computer networking, topology refers to the layout or design of the connected devices. Network topologies can be physical or logical. Physical topology means the physical design of a network including the devices, location and cable installation. Logical topology refers to how data actually transfers in a network as opposed to its design.

5-9. Computer network topology categories include—

- Bus.
- Star.

- Ring.
- Mesh.
- Tree.

5-10. Hybrid networks are complex networks, which can be built of two or more above-mentioned topologies.

BUS TOPOLOGY

5-11. Bus topology, figure 5-2, uses a common backbone to connect all the network devices in a network in a linear shape. A single cable shares the communication medium for all the devices attached with this cable with an interface connector. The device that wants to communicate sends a broadcast message to all the devices attached to the shared cable but only the intended recipient accepts and processes the message.

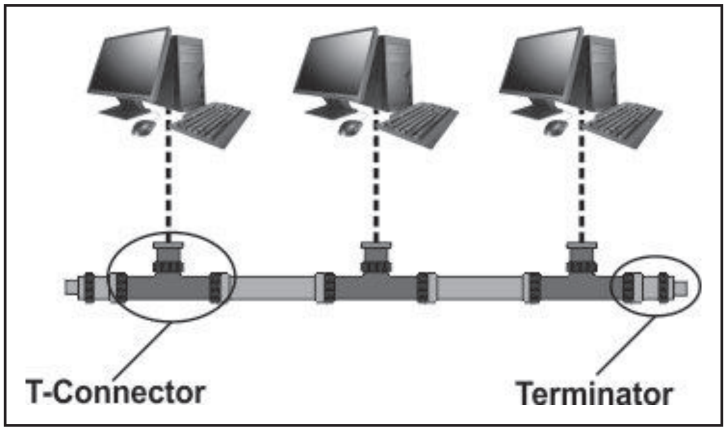


Figure 5-2. Bus topology

5-12. Ethernet bus topologies are easy to install and do not require much cabling and only a main shared cable is used for network communication. 10Base-2 and 10BaseT are two popular types of the Ethernet cables in the Bus topology.

5-13. Bus networks work with very limited devices. Performance issues are likely to occur in the Bus topology if adding more than 12-15 computers in a bus network.

5-14. In the event that the Backbone cable fails then the entire network becomes useless, as no communications are available among all the computers.

5-15. A linear bus topology consists of a main run of cable with a terminator at each end. All nodes connect to the linear cable. Ethernet and LocalTalk networks use a linear bus topology.

5-16. Bus topologies are easy to connect a computer or peripheral to and require less cable length than a star topology.

5-17. Disadvantages of a linear bus topology are—

- Entire network shuts down if there is a break in the main cable.
- Terminators are required at both ends of the backbone cable.
- Difficult to identify the problem if the entire network shuts down.
- Functions poorly as a stand-alone solution in a large building.

5-18. The bus cable carries the transmitted message along the cable. As the message arrives at each workstation, the workstation checks the destination address to see if it matches its own. If the address does not match, the workstation does nothing more. If its address matches that contained in the message, the workstation processes the message. Transmit the message along the cable and is visible to all computers connected to that cable.

RING TOPOLOGY

5-19. In Ring networks, every computer, or device, has two adjacent neighbors for communication. In a ring network, all the communication messages travel in the same directory whether clockwise or counter-clockwise. Any damage of the cable or device can result in the breakdown of the whole network. Ring topology now is almost obsolete.

STAR TOPOLOGY

5-20. When networking computers, the most common topology in LAN is the star topology, shown in figure 5-3. All the computers in the star topologies connect to a central device like a hub, switch or router. The functionality of all these devices is different.

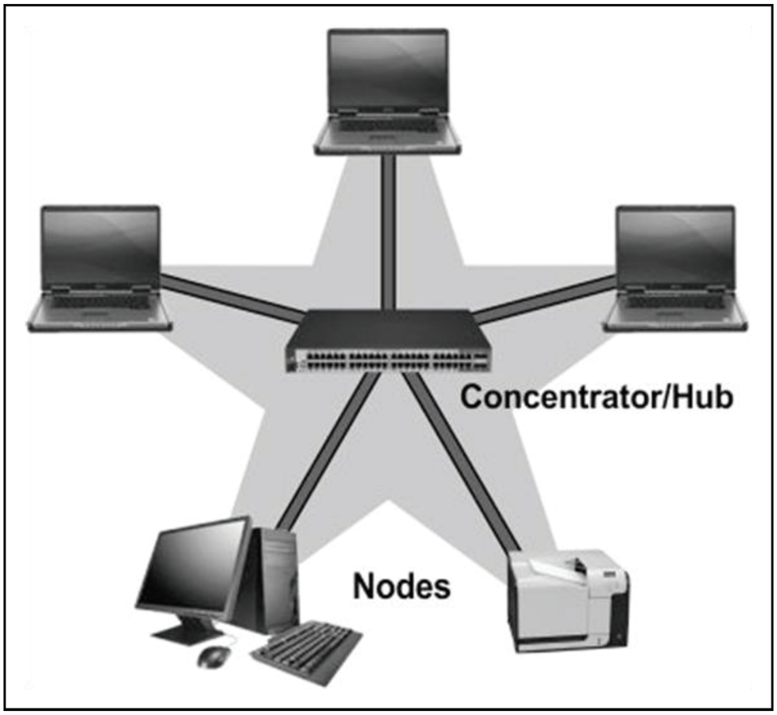


Figure 5-3. Star topology

5-21. As compared to the Bus topology, a Star network requires more devices & cables to complete a network. The failure of each node or cable in a Star network will not affect the entire network as in the Bus topology. If the central connecting devices such as hub, switch or router fail due to any reason, then ultimately the entire network can fail.

5-22. A Star topology design connects each node directly to a central network device. Data on a Star network passes through this device before continuing to its destination.

5-23. Advantages of a star topology are—

- Easy to install and less wire.
- No disruptions to the network when connecting or removing devices.
- Easy to detect faults and to remove parts.

5-24. Disadvantages of a star topology are—

- Requires more cable length than a linear topology.
- If the hub or concentrator fails, associated nodes will fail.
- More expensive than linear bus topologies due to the cost of concentrators.

TREE TOPOLOGY

5-25. Tree topologies (see figure 5-4), consist of the multiple Star topologies on a bus. Only the hub devices can connect directly with the tree bus and each Hub functions as a root of a tree of the network devices. This bus/star/hybrid combination supports future expandability of the computer networks, much better than a bus or star.

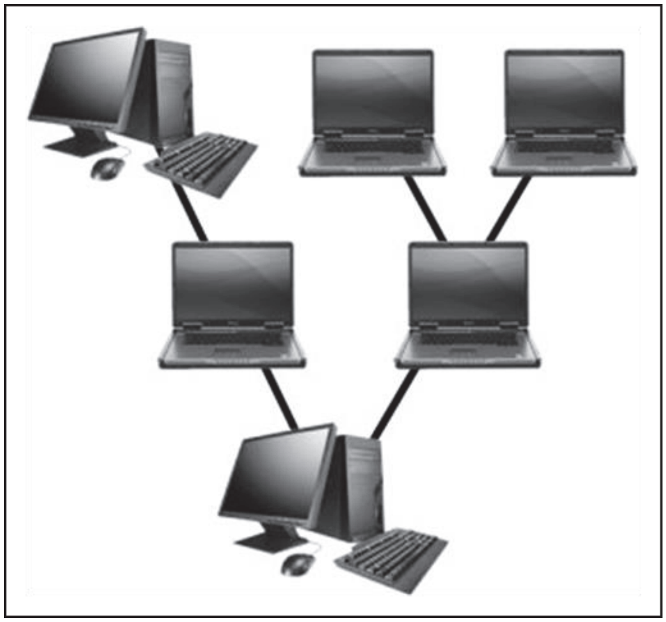


Figure 5-4. Tree topology

5-26. Advantages of a tree topology are—

- It is scalable; secondary nodes allow more devices to connect to a central node.
- Provides for point-to-point connection of devices.
- Having different levels of the network makes it more manageable.
- Easier fault identification and isolation.

5-27. Disadvantages of a tree topology are—

- Maintenance of the network may be an issue when the network spans a great area.
- Since it is a variation of bus topology, if the backbone fails, the entire network is crippled.

MESH TOPOLOGY

5-28. Mesh topology (see figure 5-5 on page 5-6), works on the concept of routes. In Mesh topology, messages travel to the destination by any of the possible shortest, easiest route to reach its destination. In the star and bus topologies, usually broadcasted messages go to every computer on the network, especially in bus topology. Similarly, in the Ring topology messages can travel in only one direction, clockwise or counterclockwise.

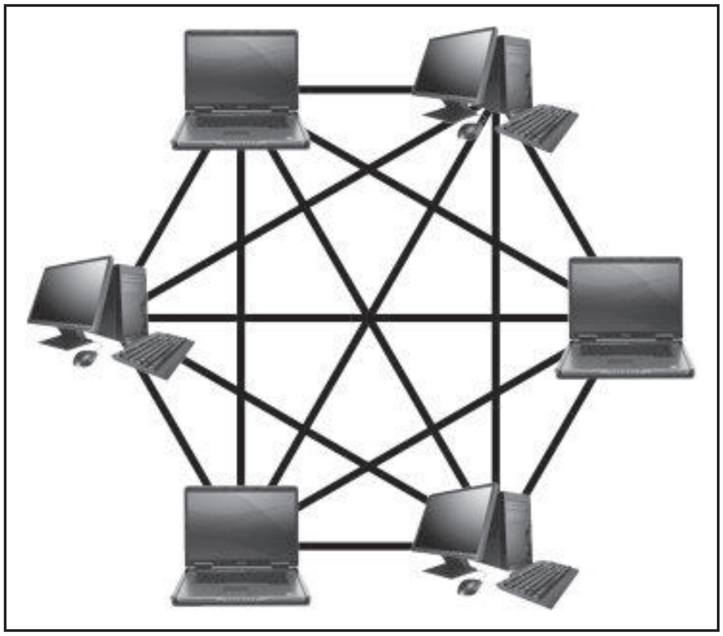


Figure 5-5. Mesh topology

ETHERNET PROTOCOLS

5-29. Protocols are the agreed upon ways, communication language and a set of rules, which both the networking computers understand and communicate with each other. Protocols by default come with the operating systems and computers use them to communicate with each other.

5-30. Ethernet is a LAN standard for network communication. Ethernet is a development by the Xerox system. The Digital Equipment Corporation, Intel Corporation, and the Xerox Corporation joined forces to develop and release the actual Ethernet Specification, version 2. In 1983, the Institute of Electrical and Electronics Engineers approved an Ethernet protocol standard of 802.3.

5-31. Ethernet works with carrier sense multiple access with collision detection technology. This is a system where each computer listens to the cable before sending anything through the network. If the network is clear, the computer will transmit. If some other node is already transmitting on the cable, the computer will wait and try again when the line is clear.

5-32. To increase transmission speed, the Ethernet protocol now supports 100 Mbps (commonly called *Fast Ethernet*). Fast Ethernet requires different, more expensive network concentrators/hubs and network interface cards. In addition, CAT 5 or fiber optic cable is necessary. Recently wired schools commonly have Fast Ethernet.

5-33. The most recent development in the Ethernet standard is a protocol demonstrating a transmission speed of one Gbps. Utilization of Gigabit Ethernet is primary use for backbones on a network at this time. It is compatible for use with both fiber optic cabling and copper. The use of 1000BaseTX, the copper cable for gigabit Ethernet, will likely become the formal standard.

THE OPEN SYSTEM INTERCONNECT MODEL

5-34. The open system interconnect (OSI) model layer is the logical layers, which assist in understanding the complete communication system. The ISO (International organization for standardization) developed several logical layers. These layers prescribe similar communication functions grouped into each logical layer. A layer serves the layer above it and is served by the layer below it. OSI has two major components: an abstract model of networking, called the basic reference model or seven-layer model, and a set of specific protocols.

5-35. This model divides a networking system into layers. Within each layer, one or more entities implement its functionality. Each entity interacts directly only with the layer immediately beneath it, and provides facilities for use by the layer above it. Protocols enable the layer of one host computer to communicate with the same layer of another computer.

DESCRIPTION OF THE OPEN SYSTEM INTERCONNECT LAYERS

5-36. There are seven layers, labeled 1 to 7, with layer 1 at the bottom (see figure 5-7). Each layer has its own service data unit that is a set of data sent by a user of the services of a given layer, and transmitted semantically unchanged to a peer service user. The service data unit is also a specific unit of data passed down from an OSI layer to a lower layer. The lower layer encapsulates the service data unit of a higher layer into the protocol of its own layer to form the protocol data unit that is a set of data sent by a user of the services of a given layer, and transmitted semantically unchanged to a peer service user.

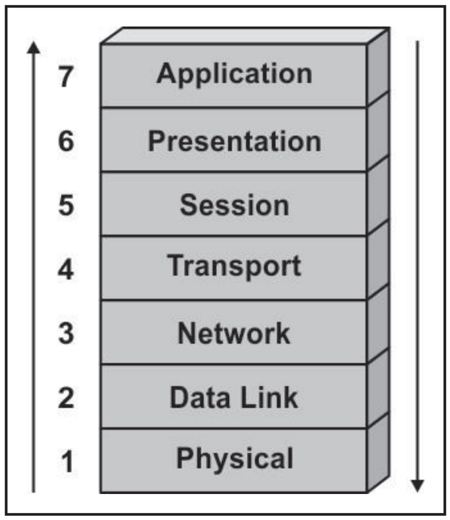


Figure 5-7. Open System Interconnect model

PURPOSE AND FUNCTIONS OF THE OPEN SERVICE INTERNET LAYERS

5-37. The purpose of each layer is to provide services to the next higher layer and shield the upper layer from the details of how to implement the services. This layering provides the following advantages:

- It divides interrelated aspects of network operation into less complex elements.
- It defines standard interfaces for plug and play compatibility and multi-vendor integration.
- It enables engineers to specialize design and promote symmetry in the different internetwork modular functions so that they can operate.
- Prevents changes in one area from affecting other areas so each area can evolve quickly.
- Divides the complexity of internetworking into discrete, more easily learned operations.

5-38. The host layer and media layer are two functional areas that group the seven layers. The host layer consists of the upper four layers because they provide for the accurate delivery of data between computers on the network. The lower three layers control the physical delivery of messages over the network. See figure 5-8 on page 5-8.

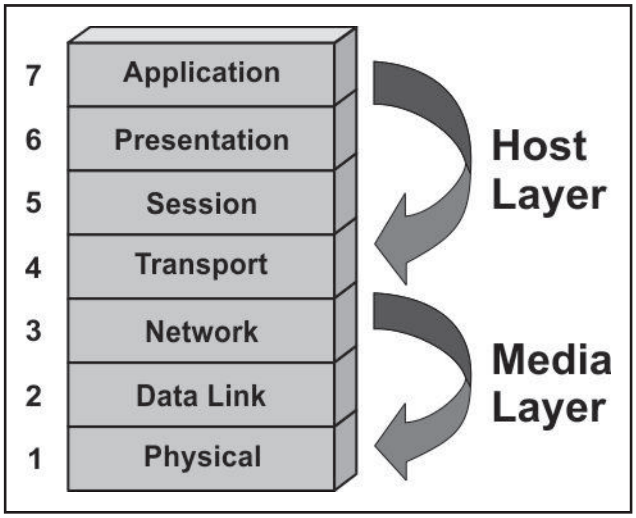


Figure 5-8. OSI host and media layers

Layer 1-Physical Layer

5-39. The physical layer defines electrical and physical specifications for devices. It defines the relationship between a device and a transmission medium, such as a copper or fiber optical cable. This includes the layout of pins, voltages, line impedance, cable specifications, signal timing, data rates, transmission distance, hubs, repeaters, network adapters, host bus adapters and more. The physical layer also performs the establishment and termination of a connection to a communications medium, contention resolution and flow control, and modulation.

Layer 2-Data Link Layer

5-40. The data link layer provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that may occur in the physical layer.

5-41. Both WAN and LAN service arrange bits from the physical layer into logical sequences called frames. The functions of data link layer are—

- Framing.
- Physical addressing.
- Flow control.
- Error control.
- Access control.
- Media access control

Layer 3-Network Layer

5-42. The network layer provides the functional and procedural means of transferring variable length data sequences from a source host on one network to a destination host on a different network, while maintaining the quality of service requested by the transport layer. The network layer performs network routing functions, and might also perform fragmentation and reassembly, and report delivery errors. Routers operate at this layer, sending data throughout the extended network and making the Internet possible.

5-43. This layer, also called the communication subnet layer, controls operation of subnets by determining how data packets are to be routed between networks. A number of layer-management protocols, a function defined in the management annex, ISO 7498/4, belong to the network layer. These include routing protocols, multicast group management, network-layer information and error, and network-layer address assignment.

Layer 4-Transport Layer

5-44. The transport layer provides transparent transfer of data between end users, providing reliable data transfer services to the upper layers. The transport layer controls the reliability of a given link through flow control, segmentation/de-segmentation, and error control. This means that the transport layer can keep track of the segments and retransmit those that fail. The transport layer also provides the acknowledgement of the successful data transmission and sends the next data if no errors occurred.

Layer 5-Session Layer

5-45. The session layer establishes, manages and terminates the connections between the local and remote application. It provides for full duplex, half-duplex, or simplex operation. The OSI model made this layer responsible for the close of sessions, which is a property of the transmission control protocol.

Layer 6-Presentation Layer

5-46. The presentation layer establishes context between application layer entities, in which the higher layer entities may use different syntax and semantics if the presentation service provides a mapping between them. The presentation layer transforms data into the form that the application accepts. This layer formats and encrypts data sent across a network.

Layer 7-Application Layer

5-47. The application layer is the OSI layer closest to the end user, which means that both the OSI application layer and the user interact directly with the software application. Application layer functions typically include identifying communication partners, determining resource availability, and synchronizing communication.

NETWORK DEVICES AND PROTOCOLS

5-48. Several network devices are part of a computer network such as hub, switch, router, NIC adapter, gateway device, modems, wireless access points and many other devices. Every device performs a different function. This section details these devices.

NETWORK INTERFACE CONTROLLER

5-49. The network interface card (NIC), figure 5-9 on page 5-10, is a device that provides connectivity that enables workstations, servers, printers, or other nodes to receive and transmit data over network media. The NIC usually contains a data transceiver and belongs to both the Physical and Data Link layers. The NIC will—

- Apply data signals to wire.
- Assemble and disassemble data frames.
- Interpret physical addressing information.
- Determine which node has the right to transmit data at any given instant.

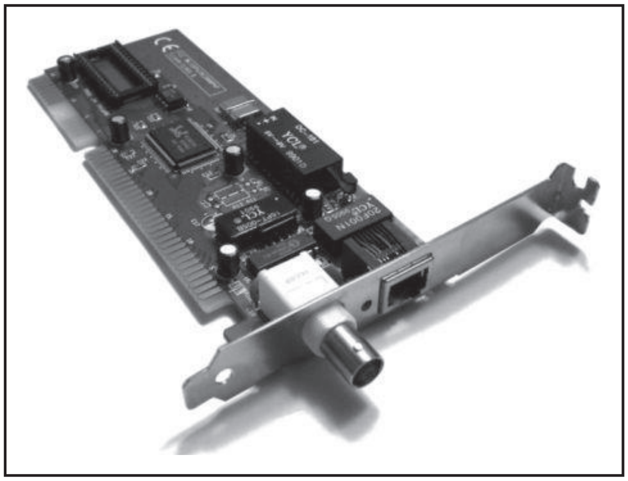


Figure 5-9. Network interface card

5-50. NIC cards control the information flow between the computer and the network. NICs carry on an electronic dialogue with other NICs on the network so that both cards agree on the following:

- Maximum size of the groups of data sent.
- The amount of data sent before confirmation.
- The time intervals between sending data chunks.
- The amount of time to wait before confirmation sent.
- The amount of data each card can hold before it overflows.
- The speed of the data transmission.

5-51. NIC cards are able to confirm and keep track of who they are in communications with because each has a unique address or media access control (MAC) address. A MAC address is a unique identifier assigned to network interfaces for communications on the physical network segment. Multiple network technologies use MAC addresses and most IEEE 802 network technologies, including Ethernet.

5-52. Every NIC has a unique MAC address given by the manufacture. This address is in a hexadecimal value.

5-53. MAC addresses are separate from internet protocol (IP) addresses. A MAC address is unique to the specific communications device and travels with that device. When a NIC moves from one computer into another computer, the MAC moves also.

5-54. A NIC can have one or more LED indicators. These LEDs are identified as and used to determine—

- ACT: if blinking, indicates that NIC is transmitting or receiving data, if solid, heavy network traffic volume.
- LNK: if lit, the NIC is functional. In some models, if blinking, the NIC detects a network but cannot communicate with it.
- TX: if blinking, the NIC is functional and transmitting frames.
- RX: if blinking, the NIC is functional and receiving frames.

REPEATERS

5-55. Repeaters are the simplest type of connectivity devices. Their function is to regenerate a digital signal applied to them. The repeater operates in physical layer and regenerates the applied signal over the entire segment. The repeater cannot improve or correct bad or erroneous signal. A repeater has only one input port and one output port and is suited only to bus topology networks.

HUBS

5-56. A hub, figure 5-10, is a device for connecting multiple devices together and making them act as a single network segment. It has multiple input/output ports, in which a signal introduced at the input of any port appears at the output of every port except the original incoming. A hub works at the physical layer of the OSI model. The device is a form of multiport repeater. Repeater hubs also participate in collision detection, forwarding a jam signal to all ports if it detects a collision.

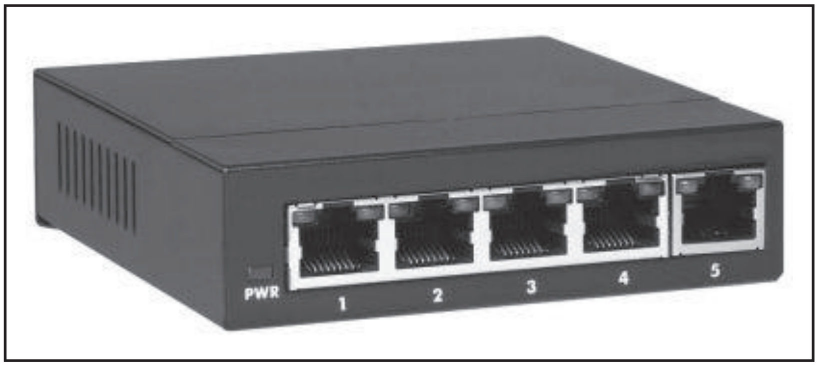


Figure 5-10. Hub

5-57. A hub does not examine or manage any of the traffic that comes through it. Any packet entering any port on a hub rebroadcasts on all other ports. Effectively, it is barely aware of frames or packets and mostly operates on raw bits or symbols. Consequently, due to the larger collision domains, packet collisions are more frequent in networks connected using hubs than in networks connected using devices that are more sophisticated.

SWITCHES

5-58. A network switch is a computer networking device that links network segments or network devices. The term commonly refers to a multi-port network bridge that processes and routes data at the data link layer of the OSI model. Layer-3 switches or multilayer switches are switches that additionally process data at the network layer and above.

5-59. A switch is a telecommunication device that receives a message from any device connected to it and then transmits the message only to the intended device. This makes the switch a more intelligent device than a hub. The network switch plays an integral part in most LANs. Mid-to-large sized LANs contain a number of linked managed switches.

5-60. A network switch manages the sharing of multiple computers or networks on the same data connection. A network switch can support 10/100 megabits per second (Mbit/s) or 10/100/1000 Mbit/s port transfer rates. It is possible to have multiple network switches operating at different speeds on the same network. However, this type of setup lends itself to bottlenecks and restricts the possible routes available for the flow of data.

5-61. A network switch is critical in the management of a computer network. The network switch functions as the traffic management system within the network, directing data packets to the correct destination. These devices connect peripheral devices to the network and ensure maximum cost effectiveness and the ability to share resources.

5-62. A typical setup of a network switch is two computers, one printer, and a wireless router. These devices connect to the network switch, and each clearly identified with connection rules created.

5-63. Once the setup is complete, any computer on the network can use the same printer. All computers can transfer files to each other and anyone with a wireless card can access the network, print and transfer files. The network switch design allows the sharing of resources to without reducing performance.

ROUTERS

5-64. A router is a multiport device that forwards data packets between computer networks. A router connects to two or more data lines from different networks, integrating either LANs or WANs. When a data packet comes in one of the lines, the router reads the address information in the packet to determine its ultimate destination. Then, using information in its routing table or routing policy, it directs the packet to the next network on its journey. Typically, a data packet forwards from one router to another through the networks that constitute the internetwork until it reaches its destination node.

5-65. When using multiple routers in interconnected networks, the routers exchange information about destination addresses using a dynamic routing protocol. Each router builds up a table listing the preferred routes between any two systems on the interconnected networks. A router contains firmware for different networking communications protocol standards. Each network interface uses this specialized computer software to enable data packets forwarded from one protocol transmission system to another. See Figure 5-11.

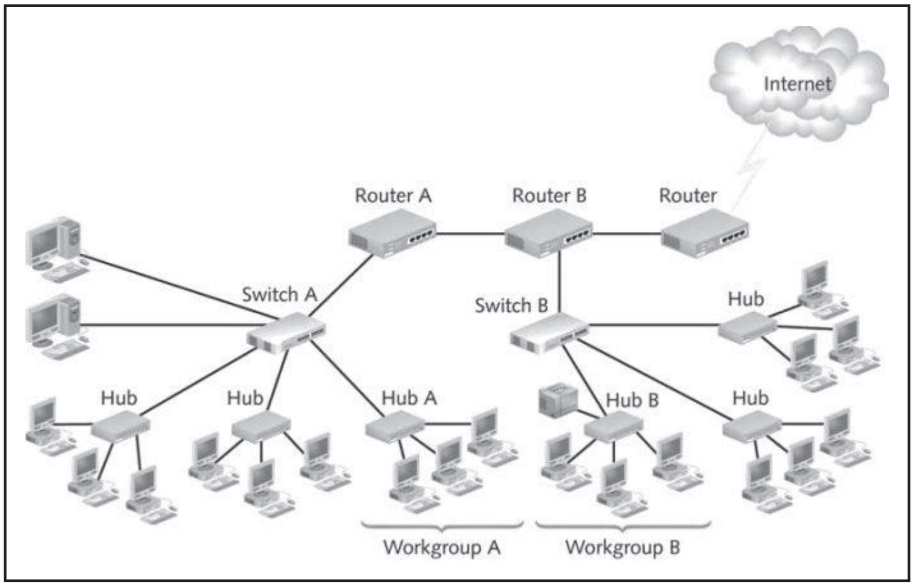


Figure 5-11. Routed network

VOICE OVER INTERNET PROTOCOL

5-66. This section provides an understanding of Voice over Internet Protocol (VoIP) technology. This section will also discuss how to deploy VoIP in a network. To understand VoIP technology, an understanding of the previous telephony techniques is essential. This helps to understand the connections made from one type of network to another, to include how to implement them.

VOIP NETWORK COMPONENTS

5-67. Many devices require employment at various places to have a functional VoIP network. These devices range from telephone systems to call agents or call managers.

Call Agent

5-68. In a telecommunications system, a call agent is a Media Gateway Controller when used in the context of Media Gateway Control Protocol (MGCP). Its primary concern is the handling of specific services to users. MGCP is a server client protocol developed by Cisco, to meet industry standard. MGCP is the only server-client voice communication protocol in existence. Other protocols like session initiation protocol (SIP) and H.323 are peer-to-peer protocols.

5-69. A Call agent controls the signaling communication between phones, Media gateways like routers, Analog extensions and Analog trunks. The Call agent is responsible to register the end devices like phones and media gateways.

5-70. Call agents handle—

- Phone numbers switching logic.
- Call control.
- Agent/Endpoint registration.
- Bandwidth management (This is a function of Gatekeeper also).
- Quality of Service (QOS) management (this is a function of Gatekeeper also).
- Centralized configuration.

Unified Communications Manager (Call Manager)

5-71. A call manager is a software application that manages a group of devices. Call managers provide services such as-routing, auto registration, and music on hold, call waiting, caller identification, and conferencing. The most important job of the call manager is to act as a skinny protocol interface to the H.323 proxy.

Unified Communications Manager Express

5-72. Unified communications manager express (UCME) is a Cisco internet operating system based internet protocol private branch exchange for small and medium offices. It provides a rich set of call control and voice application features. It supports VoIP phones using skinny client control protocol and session initiation protocol. Call manager express also provides a rich set of traditional public switch telephone network (PSTN) connectivity options using both digital and analog lines.

Voice over Internet Protocol Gateway

5-73. VoIP Gateways connect two dissimilar networks. A typical VoIP gateway has interfaces to both IP networks and PSTN or plain old telephone service (POTS) telephone services. The Gateway performs layer 3 routing of voice packets between other voice network transport technologies and the internet protocol (IP) network. The gateway may be configured to use these in several ways, including—

- An internal telephone instrument or private automatic branch exchange, with external connectivity through VoIP via the Internet.
- The PSTN interface to a telephone network, with IP connectivity to an in-house VoIP phone system.
- Both PSTN and VoIP interfaces externally, sometimes to offer a connection at local call charges to a remote call center.

5-74. The PSTN interface is often either duplicated as a connection for both a foreign exchange station and a foreign exchange office. It can also act as a connection for both a foreign exchange station and a foreign exchange office. A foreign exchange station interface connects to foreign exchange office devices, such as local analogue telephone handsets or the exchange side of a PABX. The foreign exchange office interface connects to foreign exchange station devices, such as the PSTN. Some examples of gateways include routers, voice switches, and gateway appliances.

Digital Signal Processor

5-75. The digital signal processor (DSP) is a separate circuit board that installers can install on a router's T1/E1 interface. The DSP provides the circuitry that segments voice signals into frames and changes voice stream codecs to be compatible between the PSTN, other gateways, endpoints, or services.

VoIP Gatekeeper

5-76. A Gatekeeper, also called an H.323 Gatekeeper, serves the purpose of call admission control and translation services from E.164 (commonly a phone number) to IP addresses in an H.323 telephony network.

Gatekeepers combine with a gateway function to proxy H.323 calls. A gatekeeper can also deny access or limit the number of simultaneous connections to prevent network congestion.

5-77. The gatekeeper provides specific services including—

- Admission control.
- Bandwidth management.
- Address translation.
- Zone management.

Multipoint Control Unit

5-78. The multipoint control unit (MCU) connects multiple H.323 endpoints together to participate in a voice or video teleconference.

Voice over Internet Protocol Phone

5-79. A VoIP phone allows telephone calls over an IP network such as the Internet instead of the ordinary PSTN system. Calls can traverse the Internet or a private IP network. The phones use control protocols such as SIP, skinny call control protocol (SCCP) or one of various proprietary protocols. See figure 5-12.

Figure 5-12. VoIP phone

VOIP TELEPHONE CONFIGURATIONS

5-80. This section covers procedures to configure VoIP phones. It consist of implementation of manual setup of a VoIP phone,

Implement Manual VoIP Phone Setup

5-81. VoIP phones use trivial file transfer protocol (TFTP) to download configuration files. Download these files from the TFTP server (Cisco Call Manager (CCM) or (Call Manager Enterprise (CME) router). There are two methods to configure IP phones for TFTP. They are—

- Dynamic host configuration protocol (DHCP).
- Manual network configuration.

VoIP Phone Soft Reset

5-82. Press Settings Feature Button, then **#** on the keypad. This Recycles the VoIP phone through normal startup procedures without unplugging the Ethernet cable.

Manual VoIP Phone Configuration

5-83. The phone is set using the IP phone settings feature button and the network configuration menu. Select the Option 3 or navigation button then the select soft key (see figure 5-13).

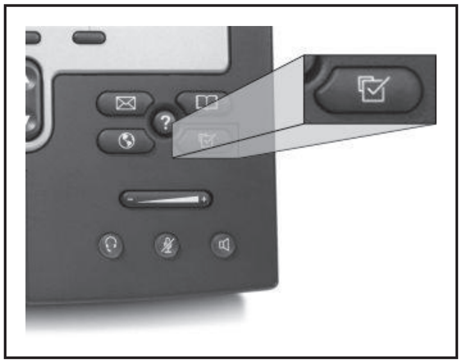


Figure 5-13. Features button

Unlocking the Network Configuration Menu

5-84. After entering the network configuration menu enter **#.

5-85. The locked icon in the top right-hand corner of the VoIP phone display.

5-86. Window will change to the unlocked icon .

Note. **# immediately followed by another **# will soft reset the VoIP phone by accident.

Disabling DHCP on a VoIP Phone

5-87. First, configure DHCP address released setting to “Yes”.

5-88. Then configure DHCP enabled setting to “No”.

5-89. Save the configuration.

5-90. The following parameters that must be set on a phone—

- IP address.
- Subnet mask.
- TFTP server.
- Default router.

TROUBLESHOOT VOICE OVER IP PHONE CONNECTIONS

5-91. Often the establishment of a connection for a VoIP phone can be faulty. This can be for a number of reasons. The following are steps to troubleshoot a VoIP connection.

Verify VoIP Telephone Power

5-92. The first step in verifying a VoIP connection is to check the phone for power. If the phone does not have power, steps to correct are—

- Check to make sure phone is connected to an Ethernet port.
- Physically check connections on phone.
- Test Ethernet cable with an Ethernet cable tester (see Chapter 3).

Verify IP Configuration

5-93. After verifying the power, check for dial tone on the VoIP phone. If the phone does not have dial tone, follow these steps—

1. Verify that phone has IP address, subnet mask, TFTP server, and fault gateway. The procedure for completing these tasks require the following steps—
    1. Press settings, then select network configuration and select IPv4 configuration.
    2. To view IP address, subnet mask, the default router, and TFTP server, use navigation button.
2. Rest the phone. If phone does not have an IP address, first perform the VoIP phone soft reset. When not using DHCP perform the manual VoIP phone configuration.
3. Verify the Ethernet connection. Check cable form phone to computer to make ensure cable connection to the personal computer port on the phone and to the NIC card is present.
4. Check LEDs. Make sure the LEDs on NIC card are on. If lights are not on, test the cable from the phone to the computer with an Ethernet cable tester. If cable is bad, replace it.
5. Verify network configuration on associated computer. To verify the network configuration on an associated computer the following steps must be performed—
    1. Log onto the computer and enter the username and password.
    2. Press start menu icon, click RUN and type “CMD” in space.
6. To manage IP configuration, do the following—
    1. Type “IPCONFIG”, then press enter.
    2. Type “PING (space)” then your default gateway IP address.
    3. There should be a reply from the default gateway IP address.
7. If ping states “timed out” or “destination unreachable”, the connection to the switch is not working.

Appendix A

Safety

This appendix discusses various safety considerations when performing wire and cable installation. It describes the dangers of electrical equipment malfunctions, safety precautions to prevent electrical shock, and recommended procedures and care for electrical shock victims. This appendix will also discuss ladder safety, potential hazards when working in confined spaces, as well as safety procedures to consider when working in confined spaces. Additionally, this appendix will discuss some safety precautions when working with power supplies.

OVERVIEW

A-1. Current is the flow of electricity. The passage of even a very small amount of current through a vital part of the human body can kill. Currents of 100 mill amperes, or 0.1 ampere, can result in a fatal shock if it lasts for one second or more. Fatalities have resulted from voltages as low as 30 volts.

A-2. Wet conditions add to the chance of receiving an electrical shock. Perspiration or damp clothing may reduce the bodies resistance to a point that the chance of shock is significantly higher when working with electricity and encountering a metal structure. Personnel must be aware when electrical shock hazards exist.

A-3. Accidentally placing or dropping a metal tool, ruler, flashlight case, or other conducting article across an energized terminal may cause a short circuit. The resulting arc and fire, even on a relatively low-voltage circuit, may extensively damage equipment and seriously injure personnel. Touching one conductor of an ungrounded electrical system while the body is in contact with a metal surface can be fatal.

WARNING

Treat all energized electrical circuits as potential hazards at all times.

DANGER SIGNS OF EQUIPMENT MALFUNCTION

A-4. Be alert for any signs that indicate a malfunction of electrical equipment. When danger signals are noted, report them to the noncommissioned officer in charge or the officer in charge. The following are examples of danger signals—

- Fire, smoke, sparks, arcing, or an unusual sound from an electric motor.
- Frayed and damaged cords, wires, cables, or plugs.
- Receptacles, plugs, wires, cables, and cords that feels warm to the touch.
- Slight shocks felt when handling electrical equipment or wiring.
- Unusually hot running electric motors and other electrical equipment.
- An odor of burning or overheated insulation.
- Electrical equipment that either fails to operate or operates irregularly.
- Electrical equipment that produces excessive vibration.

A-5. For information regarding safety requirements for maintenance of electrical and electronic equipment refer to TB 385-4.

> **WARNING**
>
> **Do not operate faulty equipment. Stand clear of any suspected hazard and instruct others to do likewise.**

ELECTRICAL SHOCK

A-6. Electrical shock is a sudden stimulation of the nerves and convulsive contraction of the muscles caused by the discharge of electricity through the body (Webster's dictionary). An electrical shock may result in little to no external evidence or visible burns that may range from minor to severe. Victims usually feel a violent shake or jolt. Significant voltage and current can result in unconsciousness, muscle, nerve, and tissue damage, or cardiac arrest. Muscular spasms may cause the hands to clasp the apparatus or wire, making it impossible to let go.

RESCUE AND CARE OF SHOCK VICTIMS

Note. See TC 4-02.1, *First Aid*, for complete coverage of cardiopulmonary resuscitation (CPR) and treatment of burn and shock victims.

A-7. The following procedures are recommended for the rescue and care of electrical shock victims—

- Remove the victim from electrical contact at once, without endangering yourself. Touching a shock victim who is still in contact with the energized circuit will create another shock victim. De-energize the affected circuit. Use a dry stick, rope, belt, coat, blanket, shirt, or any other nonconductor of electricity to drag or push the victim to safety.
- Check the victim's airway, breathing, and pulse. Start cardiopulmonary resuscitation (CPR) if respiration or circulation is absent. After stabilizing the individual, continue first aid for any additional injuries. If there is no chest or head injury, lay the victim face up in a prone position with the feet about 12 inches higher than the head. If the victim has chest or head injuries, elevate the head slightly. If there is vomiting or if there are facial injuries that are causing bleeding into the throat, place the victim on stomach with the head turned to one side. The head should be 6 to 12 inches lower than the feet.
- Keep the victim warm. Conserve body heat by covering the victim with one or more blankets, depending on the weather and the individual's exposure to the elements. Avoid artificial means of warming, such as hot water bottles.
- Do not give drugs, food, or liquids if medical attention will be available within a short time. If it is necessary to administer liquids, use small amounts of water, tea, or coffee. Never give alcohol, opiates, or other depressant substances.
- Send for medical personnel at once. Do not leave the victim until medical help arrives.

SAFETY PRECAUTIONS TO PREVENT ELECTRICAL SHOCK

A-8. Observe the following safety precautions when working on electrical equipment—

- When working in the immediate vicinity of electrical equipment, check with the non-commissioned officer in charge responsible for maintaining the equipment to avoid any potential hazards. Stand clear of operating radar and navigational equipment.
- Never work alone. Another person could save your life if you receive an electrical shock.
- Keep the covers of all fuse boxes, junction boxes, switch boxes, and wiring accessories closed. Report any cover that is not closed or that is missing to the non-commissioned officer in charge responsible for its maintenance. Failure to do so may result in injury to personnel or damage to equipment if a person accidentally makes contact with exposed live circuits.

- Discharge capacitors before working on de-energized equipment. Take special care to discharge capacitors properly. Injuries to personnel or damage to equipment could result from the use of improper procedures.
- If possible, de-energize equipment before hooking up or removing test equipment.
- Work on energized circuits only when necessary. In the event a circuit cannot be de-energized, teams will conduct a thorough verification of safety procedures and safety equipment before starting any work. When working on energized circuits, teams will—
  - Tag the power source at the nearest source of electricity when servicing the component.
  - Stand on a rubber mat to prevent grounding yourself.
  - Wear approved electrical insulating rubber gloves, and cover as much of your body as practical with an insulating material. This is especially important when working in a warm space where you may perspire.
  - Work with only one hand inside the equipment. Keep the other hand clear of all conductive materials that may provide a path for current flow.
  - Wear safety goggles. Sparks could damage your eyes. The sulfuric acid contained in batteries and the oils in electrical components can cause blindness.
  - Adequately insulate all tools when working on energized electrical equipment.
- Never work on electrical equipment while wearing rings, watches, identification tags, or other jewelry.
- Never work on electrical equipment while wearing loose-fitting clothing. Be careful of loose sleeves and uniform shirttails.
- Ensure that there are protective guards on all rotating and reciprocating parts of the electric motors.
- Remain calm and consider the possible consequences before performing any action.

WARNING

To avoid injury and to prevent damage to equipment, keep liquids away from electrical equipment.

A-9. Use carbon dioxide extinguishers for fighting electrical fires. It has a nonconductive extinguishing agent and does not damage equipment. However, the ice that forms on the horn of the extinguisher will conduct electricity.

LADDER SAFETY

A-10. To reduce the chance of accidental injury, follow these general safety precautions during placement of ladders to ensure safe climbing procedures—

- Choose the appropriate ladder for the task.
- Be certain the ladder is sufficient for weight needed for the job.
- Place the ladder on a firm, level surface.
- Check the condition of the ladder.
- Never use a ladder in a strong wind.
- Never use a ladder in front of a door without first locking, blocking, or placing a guard.
- Inspect ladders for potential dangers before using.
- Keep your body centered between the rails of the ladder.
- Never carry tools or materials in your hand when going up or down a ladder.
- Only one person should be on a ladder at a time.
- When working near power lines, always use a wooden or fiberglass ladder.

WARNING

Never work with a metal ladder around power lines.

A-11. For every four feet of rise the base of the ladder should be one foot away from the object that the top of the ladder is resting. See figure A-1, page A-4 for an example of the distances required when using a ladder.

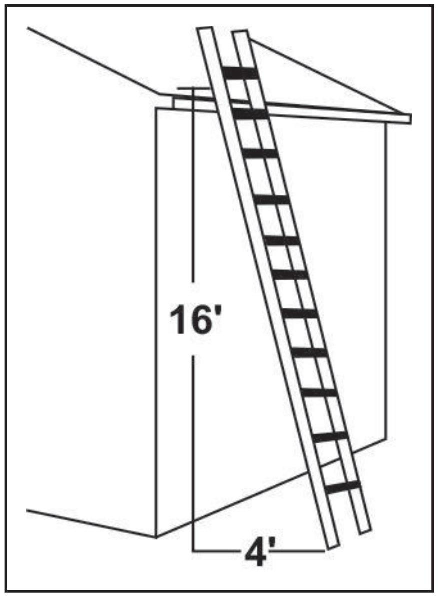


Figure A-1. Ladder rise

CONFINED SPACES

A-12. Confined spaces present potential risks that include hazardous atmospheres. A hazardous atmosphere is one in which flammable gas or vapor, combustible dust, toxic gases, or lack of sufficient oxygen are present and places the individual at risk. The Occupational Safety and Health Administration under the Occupational Safety and Health Administration 29 Code of Federal Regulations 1910.146 governs working in confined spaces.

WARNING

DO NOT enter confined spaces as you are putting yourself at risk of serious injury or death.

Know how to identify a confined space.

When in doubt, never enter an area that could be a confined space without first speaking with a supervisor or safety representative.

DO NOT rely on your senses to determine if a confined space has no hazards. A number of hazardous gases are both colorless and odorless.

NEVER enter a confined space to try to rescue another worker.

A-13. A confined space is a space large enough for authorized personnel to enter and perform work, but has a limited or restricted means of entry or exit; and not designed for continuous occupancy. Examples of a confined space are—

- Sewers.
- Tunnels.
- Manholes.
- Boilers.
- Tank cars.
- Cisterns.
- Pits.
- Silos.
- Storage bins.

NON-PERMIT REQUIRED CONFINED SPACE

A-14. A non-permit confined space is a space that does not contain or have the potential to contain hazards capable of causing death or serious physical harm. While Soldiers are not required to attain a permit to operate in these spaces, they should use caution when entering into, working in, and exiting any confined space.

PERMIT REQUIRED CONFINED SPACE

A-15. A permit required confined space is one that contains or has the potential to contain serious safety or health hazards. Examples of hazards include engulfment, toxic atmosphere, heat or cold stress, slipping hazards, flammable atmosphere, and oxygen deficiency. Sewers, tanks, vessels, and wells are examples of permit required confined spaces.

CONFINED SPACE HAZARDS-MAJOR FATALITY FACTORS

A-16. Failure to recognize and control the hazards associated with a permit required confined space is the main cause of casualties. The three main threats are atmospheric hazards, physical hazards, and inadequate or incorrect emergency response. An incorrect emergency response includes personnel entering the confined space to rescue the victim and becoming an additional casualty. A majority of the fatalities in combined spaces are due to inadequate or incorrect emergency response.

Potential Hazards

A-17. The following hazards may be encountered in confined spaces—

- Oxygen deficiency results from inadequate ventilation, consumption of oxygen from welding (acceptable oxygen limits 19.5-23.5%). Oxygen displacement occurs when simple asphyxiates, like nitrogen or carbon dioxide, replace oxygen.
- Flammable atmospheres from gases, vaporized solvents, enriched oxygen.
- Toxic gases develop from decomposition of organic matter, which generates hydrogen sulfide. Other toxic gases are carbon monoxide from welding, or chlorine from bleach.

Flammability Hazards

A-18. Flammable gases can accumulate quickly within a closed space. These gases or fumes are often highly combustible and come from liquid chemicals (including paint, paint remover, and fuel) stored in containers. These gases are very dangers and have the potential of igniting and causing a fire or explosion. Ignition of such gases can occur by something as simple as static electricity or two metal objectives such as tools or metal cans creating a spark due to contact. Many of these gases are odorless and non-detectable without proper detection equipment.

Physical Hazards

A-19. Physical hazards within confined spaces include—

- Engulfment, the collapse of material trapping the Soldier in the confined space.
- Electrocution by activation of electrical equipment.
- Falling objects.
- Slick surfaces.
- Injuries from extreme temperatures that include heat exhaustion, heat stroke, or frostbite.

PROCEDURES

A-20. Conduct a pre-entry brief before entering any confined space. Pre-entry briefing includes reviewing the risk assessment and material safety data sheets. Supervisor must complete entry permits identifying who is the entrant, attendant, and supervisor. Supervisors will also—

- Conduct initial monitoring with gas detector and fill out results on permit.
- Check sensors and calibration dates. Calibration must be current and within a 12 months period of inspection date.

A-21. Identify and eliminate potential hazards that could enter the space, including atmospheric and physical hazards. Use forced air ventilation and perform lock out, tag out procedures if needed. Keep gas engines a safe distance away for the work area.

A-22. The use of a full body harness for a permit required confined space is mandatory along with a retrieval unit and the use of a two-way communications system. Notify designated emergency personnel before entry into a confined space.

Duties of the Authorized Entrant

A-23. Personnel entering a confined space must know the hazards that they may face during entry. Entrants will wear appropriate personal protective equipment and maintain communication with an attendant who is not in the confined space. Entrants will recognize signs of overexposure and evacuate the space at once if signs of overexposure are noticed, when given an order, or upon detection of unsafe condition.

Duties of the Attendant

A-24. Confined space attendants will maintain a position outside the entrance at all times while entrants are in a confined space. Attendants are responsible to recognize signs and symptoms of overexposure. Attendants will prevent unauthorized access into the confined space. They will maintain communication with entrants at all times and initiate emergency response when required.

Duties of the Entry Supervisor

A-25. Supervisors will conduct a risk assessment and a pre-briefing to ensure all personnel are aware of any hazards. Supervisors will implement required hazard control procedures to reduce risk. The supervisor will also—

- Contact post fire department.
- Coordinate initial testing of space.
- Complete and maintain entry permit.

EMERGENCY PROCEDURES

A-26. In the event of an emergency, entrants leave the space at once. The attendant will contact emergency personnel if the entrant becomes injured, or shows signs of illness. The use of approved retrieval equipment to remove incapacitated entrant is necessary.

POWER SUPPLIES

A-27. Most of the portable communication equipment described in this chapter requires a power source. In some instances, this power source might be a battery pack—in others, a generator, or a centralized power source.

A-28. When the communication equipment requires battery power, be sure to check the equipment manual for the proper battery. When the specific battery or batteries are not available, consider the following factors before selecting a substitute—

- Voltages required.
- Minimum power requirements (the equipment current drain affects battery life).
- Physical size of battery in relation to space available in the equipment battery compartment.
- Type of battery connections on the equipment.
- Equipment requiring a steady power supply over a long period usually uses a centralized power source or a generator.
- The equipment load must not exceed the capabilities of the power source.
- Before attempting to connect any equipment, check the power output of the power source against the required power input of the equipment.

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Appendix B
Individual and Collective Tasks

This appendix provides tables for individual and collective critical tasks for cable systems installer/maintainer, military occupational specialty (MOS) 25L. The tables will provide required individual and collective critical tasks from skill level one through skill level three.

B-1. Table B-1 shows the collective tasks for MOS 25L (cable systems installer/maintainer. Collective tasks are activities, actions, or events that requires the organized team or unit performance and leads to accomplishment of a mission or function.

Table B-1. MOS 25L (cable systems installer/maintainer) collective tasks

Task Number	*Task Title*	*Location of Critical Task*
11-CW-7038	Install Network cable/wire	All operational domains
11-CW-7039	Recover network cable/wire	All operational domains
11-CW-7292	Maintain network cable/wire	All operational domains
11-CO-9080	Provide cable support to theater operations	TIN-E only
11-CW-7148	Conduct tactical installation & networking-enhanced company quality control activities	TIN-E only
11-CW-7149	Install an information system network	TIN-E only
11-CW-7150	Install a local area network	TIN-E only
11-CW-7152	Conduct light/heavy outside communications plant activities	TIN-E only
11-CW-7153	Conduct heavy outside communications plant activities	TIN-E only
11-CW-7154	Conduct inside communications plant activities	TIN-E only
11-CW-7155	Conduct light/heavy communication system restoration	TIN-E only

B-2. Table B-2 shows the individual critical tasks for MOS 25L (cable systems installer/maintainer), skill level 1 (PV-2 through SPC). Individual tasks are the lowest level task performed in a job or duty and should support a collective task. Additionally, a critical task is a task performed in order for a unit or organization to accomplish their mission and duties.

Table B-2. MOS 25L (cable systems installer/maintainer) individual critical tasks skill level-1

Task Number	*Task Title*	*Training Domain*	*Sustainment Training Frequency*
113-600-1012	Install telephone Set TA-312/PT	Operational	Semi-annual
113-574-9004	Perform field level maintenance on fiber optic test set	Institutional	Semi-annual
113-580-9005	Modify active directory	Institutional	Annual
113-583-1002	Install cable rack and wire way	Institutional	Annual
113-583-1003	Install distribution frames	Institutional	Annual
113-583-1004	Install anchoring devices	Institutional	Annual

Table B-2. MOS 25L (cable systems installer/maintainer) individual critical tasks skill level-1 (continued)

Task Number	*Task Title*	*Training Domain*	*Sustainment Training Frequency*
113-583-1007	Interpret engineering installation packet	Institutional	Semi-annual
113-583-1008	Perform marking site layout	Institutional	Annual
113-583-1010	Install conduit	Institutional	Annual
113-583-2001	Operate hand and power tools	Institutional	Annual
113-583-9017	Install local/wide area network connectivity	Institutional	Semi-annual
113-583-9018	Perform helpdesk functions and desktop services	Institutional	Semi-annual
113-588-0021	Locate cable faults using a time domain reflectometer/optical time domain reflectometer test set	Institutional	Annual
113-588-1002	Set poles	Operational	Annual
113-588-1107	Install underground cable system	Institutional	Annual
113-588-1108	Install a CAD-6 buried distribution terminal	Institutional	Annual
113-588-2002	Perform cable marking procedures	Institutional	Annual
113-588-2004	Perform a splice on a plastic sheath, plastic insulated cable	Institutional	Annual
113-588-2005	Install AC/DC power source for communications equipment	Institutional	Annual
113-588-2006	Install cable/wire systems	Institutional	Semi-annual
113-588-2007	Operate telephone maintenance truck	Operational	Semi-annual
113-588-2010	Recover cable/wire system	Institutional	Semi-annual
113-588-6008	Maintain a communications systems installation record	Institutional	Semi-annual
113-588-9009	Troubleshoot telephone cable	Operational	Annual
113-588-9010	Install connectors on radio frequency (RF) cable	Institutional	Annual
113-588-9011	Perform aerial rescue operation	Institutional	Annual
113-588-9014	Determine cable depth using a cable finder or fault locator	Institutional	Annual
113-588-9018	Troubleshooting local/wide area network connectivity	Institutional	Annual
113-600-1001	Install secure digital telephone STU III/STE	Institutional	Semi-annual
113-600-7047	Perform field level maintenance on telephone set TA-312/PT	Operational	Quarterly
113-600-7048	Troubleshoot NIPR/SIPR voice communication	Operational	Semi-annual
113-600-7050	Perform call manager operations as part of NIPR/SIPR network	Institutional	Annual

Table B-2. MOS 25L (cable systems installer/maintainer) individual critical tasks skill level-1 (continued)

Task Number	*Task Title*	*Training Domain*	*Sustainment Training Frequency*
113-609-7002	Install encryption device	Operational	Semi-annual
113-609-7003	Operate encryption device	Operational	Semi-annual
113-609-7004	Maintain encryption device	Operational	Semi-annual
113-628-1001	Install voice over internet protocol telephone	Institutional	Semi-annual
113-632-4002	Splice commercial fiber optic cable	Institutional	Semi-annual
113-632-5002	Troubleshoot commercial fiber optic cable	Institutional	Semi-annual
113-632-9012	Install commercial fiber optic connectors	Institutional	Annual
113-632-9013	Troubleshoot tactical fiber optic cable	Institutional	Semi-annual

B-3. Tables B-3 shows the individual critical tasks for MOS 25L (cable systems installer/maintainer), skill level 2 (SGT).

Table B-3. MOS 25L (cable systems installer/maintainer) individual critical tasks-skill level-2

Task Name	*Task Title*	*Task Domain*	*Sustainment Training Frequency*
113-574-9005	Supervise field maintenance on test sets	Operational	Semi-annual
113-580-9006	Supervise modification of active directory	Operational	Semi-annual
113-583-9020	Supervise helpdesk functions and desktop services	Operational	Semi-annual
113-588-7005	Supervise recovery of cable/wire systems	Operational	Semi-annual
113-588-7006	Supervise troubleshooting of cable/wire systems	Operational	Semi-annual
113-588-7012	Supervise installation of cable/wire systems	Operational	Semi-annual
113-588-9019	Supervise installation of local/wide area network connectivity	Operational	Semi-annual
113-588-9020	Supervise troubleshooting of local/wide area network connectivity	Operational	Semi-annual
113-600-7049	Supervise troubleshooting of NIPR/SIPR voice communications	Operational	Semi-annual
113-600-7051	Supervise call manager operations as part of NIPR/SIPR network	Operational	Semi-annual
113-632-9014	Supervise splicing of commercial fiber optic cable	Operational	Semi-annual

B-4. Table B-4 shows the individual critical tasks for MOS 25L (cable systems installer/maintainer), skill level 3 (SSG).

Table B-4. MOS 25L (cable systems installer/maintainer) individual critical tasks skill level-3

Task Name	*Task Title*	*Task Domain*	*Sustainment Training Frequency*
113-574-9006	Inspect field level maintenance on test sets	Institutional	Annual
113-583-9019	Manage helpdesk functions and desktop services	Institutional	Annual
113-588-5007	Plan a telephone cable line	Institutional	Annual
113-588-6001	Inspect existing cable lines	Institutional	Annual
113-588-6007	Prepare a detailed cable route map	Institutional	Annual
113-588-7001	Inspect installation of AC/DC power source for communications equipment	Operational	Annual
113-588-7008	Inspect installation of cable/wire systems	Institutional	Annual
113-588-7009	Inspect recovery of cable/wire systems	Institutional	Annual
113-588-7011	Inspect troubleshooting of cable/wire systems	Institutional	Annual
113-588-7108	Inspect preventive maintenance checks and services of telephone maintenance truck	Operational	Annual
113-588-9021	Direct basic safety in cable systems installation	Institutional	Annual
113-593-1040	Establish site layout for transmission systems	Operational	Annual
113-611-6006	Lead restoration of transmission link within a network	Institutional	Annual
113-613-4003	Verify engineering installation package	Operational	Annual
113-632-9009	Inspect operation of fiber optic cable test set	Institutional	Annual
113-632-9011	Inspect splicing of commercial fiber cable	Institutional	Annual
113-632-9015	Inspect splicing of tactical fiber cable	Institutional	Annual
113-632-9016	Inspect repair of tactical fiber cable	Institutional	Annual
113-632-9018	Inspect troubleshooting of local/wide area network connectivity	Institutional	Annual
113-632-9019	Inspect installation of local/wide area network connectivity	Institutional	Annual

Appendix C
Additional Training

This appendix discusses additional installer training provided to Soldiers. Soldiers that attend these courses receive either a skill qualification identifier or additional skill identifier that indicates their advanced skill set. The basic installer course focuses on non-tactical installation training required for installing AC/DC power, communications and electronic equipment, and cable and wiring for power distribution and IP networking in communications facilities. The communications cable and antenna installation course provides training on the fundamentals of antenna installation, to include tower training, and fault detection and splicing techniques for communications cable.

BASIC INSTALLERS COURSE

C-1. The basic installer course provides training on non-tactical communications-electronics equipment installation. The course provides instructions on general cabling practices, RF and electrical cabling practices, signal cable termination, and equipment placement. This course instructs Soldiers in the proper techniques and procedures for installing communication-electronics equipment to support DOD and Department of the Army communications programs and projects. I provides a basic knowledge of inside installation of communications-electronics facilities, fiber optics connectors, fiber optics splicing, and an overview of local area networks. Upon successful completion of this course, the Soldier will be awarded the "I" skill qualification identifier (SQI).

COMMUNICATIONS CABLE AND ANTENNA INSTALLATION COURSE

C-2. The communication cable and antenna installation course provides training in cable and antenna fundamentals; antenna systems fundamentals, antenna principles, rotatable log periodic and microwave antennas. This course also provide training in antenna support towers; aerial, buried, and transmission lines installation and principles; splicing and sealing communications cables; pressure systems and termination procedures; underground splicing procedures; testing coaxial and copper core cables; cable fault location; fiber optic splicing procedures; local and wide area network distribution systems. Upon completion of this course, the Soldier attain the J2 additional skill identifier (ASI).

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Appendix D
Electrical Cable and Wire Standards

This appendix discusses the various standards established to standardize cable and wire installation, both nationally and internationally. This appendix also identifies national and global standards for LANs and WANs. Many of these associations and programs also indicate standardization of manufactured electronic equipment and devices.

GLOBALLY RECOGNIZED STANDARDS

D-1. The Institute of Electrical and Electronics Engineering undertook Project 802. Named for the year and month ('80 Feb) of its inception, Project 802 defines a family of low-level protocol standards for the architectural development of local area networks (LANs). The American National Standards Institute (ANSI) subsequently adopted project 802 in 1985.

D-2. American National Standards Institute engages in accrediting programs that assess conformance to standards-including globally recognized cross-sector programs such as the International Organization for Standardization (ISO) 9000 (quality) and ISO 14000 (environmental) management systems.

D-3. ISO is an international standard-setting body composed of representatives from various national standards organizations. Founded on February 23, 1947, the organization promotes worldwide proprietary, industrial, and commercial standards.

D-4. The International Electro-technical Commission (IEC) is a non-profit, non-governmental international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies. IEC standards cover a vast range of technologies from power generation, transmission, and distribution to semiconductors, fiber optics and batteries as well as many others.

D-5. The Telecommunications Industry Association (TIA) is a full service, non-profit trade association, providing support to companies involved in enterprise communications products and services, across terminal and application equipment and the supporting cabling and wireless infrastructure systems.

D-6. The Electronic Industries Alliance (EIA) is a national trade organization that includes the full spectrum of U.S. manufacturers. EIA comprises nearly 1,300 member companies whose products and services range from the smallest electronic components to the most complex systems in use by defense, space and industry, including the full range of consumer electronic products.

CABLE STANDARDS/TELECOMMUNICATIONS

D-7. International standard ISO/IEC 11801 specifies general-purpose telecommunication cabling systems (structured cabling) that are suitable for a wide range of applications. It covers both balanced copper cabling and optical fiber cabling. The standard optimized for premises that span up to 3 km, up to 1 km^2 office space, with between 50 and 50,000 persons, but can also be applied for installations outside this range. A corresponding standard for small-office/home-office environments is ISO/IEC 15018, which also covers 1.2 GHz links for cable and satellite TV applications.

D-8. The ANSI-TIA-EIA standards specify and address commercial building cabling for telecommunications products and services. The best-known feature of TIA/EIA-568-B.1-2001 is the pin/pair assignments for eight-conductor 100-ohm balanced twisted pair cabling. These assignments are T568-A and T568-B and called TIA/EIA-568-A and TIA/EIA-568-B. ANSI-TIA-EIA-568-B.2 was set forth for CAT 6 copper cabling and application standards. The following applies to CAT 6 cable:

- Backward compatibility to categories 5e, 5, and 3.
- Open standard that allows products from different vendors to work together.

- Patch cord plug and jack interoperability for modular (RJ45 type) connections.
- Full system specification including testing of components, patch cords, channels and permanent links.
- Twice the bandwidth and less near end cross talk of CAT 5e.
- Ratio up to 200 megahertz (MHz).
- Test all specifications for components and cabling to 250 MHz.

D-9. The majority of Army networks use CAT 5 and 5e. CAT 6 is the standard for use with fiber optic switches and gigabyte Ethernets.

Appendix E

Conduit Measurement Formula and Shrinkage Table

This appendix provides the formula to measure the amount of conduit required to install a cable run for inside plant operations. These measurements accounts for shrinkage that occurs during conduit bends when installing a conduit run. Bend conduits to conform to walls and other stationary obstacles. Additionally, this appendix provides a table that calculate the amount of spacing and shrinking that occurs due to conduit bends.

E-1. The following formula is used to measure the amount of conduit needed for a conduit run:

Rough Horizontal Length
+ Rough Vertical Length
= Total Rough Length
+ Shrinkage
- Gain
= Final Length

Figure E-1. Formula for measuring conduit run

Note. All conduit measurements are made on the outside of the conduit run.

E-2. Table E-1 on page E-2 provides the amount of shrinkage resulting from bending conduit. It also discuss the amount of inches between the first bend mark and second bend mark (known as spacing).

Table E-2. Bend spacing and shrink table

Bend spacing and shrink table			
1	***2***	***3***	***4***
Bend (degrees)	***Offset depth (inches)***	***Place Second Mark (inches from the first mark)***	***Conduit shrinks (inches)***
11	Less than 1”	3	0
22	1	3	3/16
	2	5–1/4	3/8
	3	7 3/4	9/16
	4	10–1/2	3/4
	5	13	15/16
	6	15–1/2	1–1/8
	7	18–1/4	1–15/16
	8	20–3/4	1–1/2
	9	23–1/2	1–3/4
	10	26	1–7/8
30	3	6	3/4
	4	8	1
	5	10	1–1/4
	6	12	1–1/2
	7	14	1–3/4
	8	16	2
	9	18	2–1/4
	10	20	2–1/2
	11	22	2–3/4
	12	24	3
45	5	7	1–7/8
	6	8–1/2	2–1/4
	7	9–3/4	2–5/8
	8	11–1/4	3
	9	12–1/2	3–3/8
	10	14	3–3/4
	11	15–1/2	4–1/8
	12	16–3/4	4–1/2
	13	18–1/4	4–7/8
	14	19–3/4	5–1/4
	15	21	5–5/8

Table E-2. Bend spacing and shrink table (continued).

Bend spacing and shrink table			
1	2	3	4
Bend **(degrees)**	***Offset depth*** **(inches)**	***Place Second Mark*** **(inches from the first mark)**	***Conduit shrinks*** **(inches)**
60	10	12	5
	11	13–1/4	5–1/2
	12	14–1/2	6
	13	15–1/2	6–1/2
	14	16–3/4	7
	15	18	7–1/2
	16	19–1/4	8
	17	20–1/2	8–1/2
	18	21–1/2	9
	19	22–3/4	9–1/2
	20	24	10

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Glossary

The glossary lists acronyms and terms with Army, ANSI, EIA, IEC, and ISO definitions.

SECTION I—ACRONYMS AND ABBREVIATIONS

AC	alternating current
ANSI	American National Standards Institute
AT&T	American Telephone & Telegraph
ASI	Additional skill identifier
AWG	American Wire Gauge
BIC	Basic Installers Course
BNC	Bayonet Neil-Concelman
BOM	bill of material
CAT	category
C&E	communications & electronics
CB	common battery
CCM	Cisco call manager
CDF	combined distribution frame
CEMF	counter electromotive force
CFS II	compact fusion set II
CME	call manager express
CMO	configuration management officer
COT	commercial-off-the shelf
CPR	cardiopulmonary resuscitation
CRL	cable running list
dB	decibel
dBm	decibel millwatts
DC	direct current
DHCP	dynamic host configuration protocol
DODIN	Department of Defense information network
DODIN-A	Departiment of Defense information network-Army
DSP	digital Signal processor
DTMF	dual tone multi-frequency
EIA	Electronic Industries Association
EIP	Engineer Installation Package
EMI	electromagnetic interference
EMT	electrical magnetic protection
ESCON	enterprise systems connection
FC	fix connector
FDDI	fiber distributed data interface
FTP	foil twisted pair

GFCI	ground fault circuit interrupter
GOTS	government-off-the shelf
Gbps	gigabytes per second
HF	high frequency
Hz	hertz
IBM	International Business Machine
IDF	intermediate distribution frame
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineering
IP	Internet Protocol
IPv4	Internet Protocaol version 4
IPv6	Internet Protocaol version 6
ISDN	integrated services digital network
ISO	International Organization for Standardization
km	kilometer
LAN	local area network
LB	local battery
LC	little connector
LCD	liquid crystal display
LED	light emitting diode
LTF	liquid tight flexible
MAC	media access control
Mbps	megabytes per second
MCU	multipoint control unit
MDF	main distribution frame
MGCP	media gateway control protocol
MHz	megahertz
MIL-Spec	military specification
MIL-Std	military standard
mm	millimeter
MMF	multimode fiber optic
MS2	modular splicing system
MT-RJ	mechanical transfer registered jack connector
NA	numerical aperture
NEC	National Electric Code
NIC	network interface controller
NF	national fine
nm	nanometer
OLS	optical light source
OPM	optical power meter
OSI	open source interconnect

OTDR	optical time domain reflectometer
PABX	Private Automatic Branch Exchange
PBX	Private Branch Exchange
PCM	pulse code modulation
POTS	plain old telephone service
PSTN	public switch telephone network
PVC	polyvinyl chloride
QOS	Quality of Service
RCA	Radio Corporatoin of America
RF	radio frequency
RFI	radio frequency interference
RG	radio guide
RG/U	radio guide utility
RJ	registered jack
SC	subscriber connector
SCCP	skinny call control protocol
SIP	session initiation protocol
SLS	stabilized laser source
SMA	sub-miniature version A
SMF	single mode fiber optic
***SQI**	skill qualification identifier
ST	straight tip
STP	shielded twisted pair
TDM	time division multiplexing
TFOCA	tactical fiber optic cable assembly
TIA	Telecommunications Industry Association
***TM**	technical manual
TNC	terminal node controller
TT	telephone terminal
UL	Underwriters Laboratory
UPS	uninterrupted power supply
USB	universal serial bus
UTP	unshielded twisted pair
VAC	volts alternating current
VDC	volts direct current
VFL	visual fault locator
VLAN	virtual local area network
VoIP	Voice over Internet Protocol
WAN	wide area network
WD	wire data
WF	field wire

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