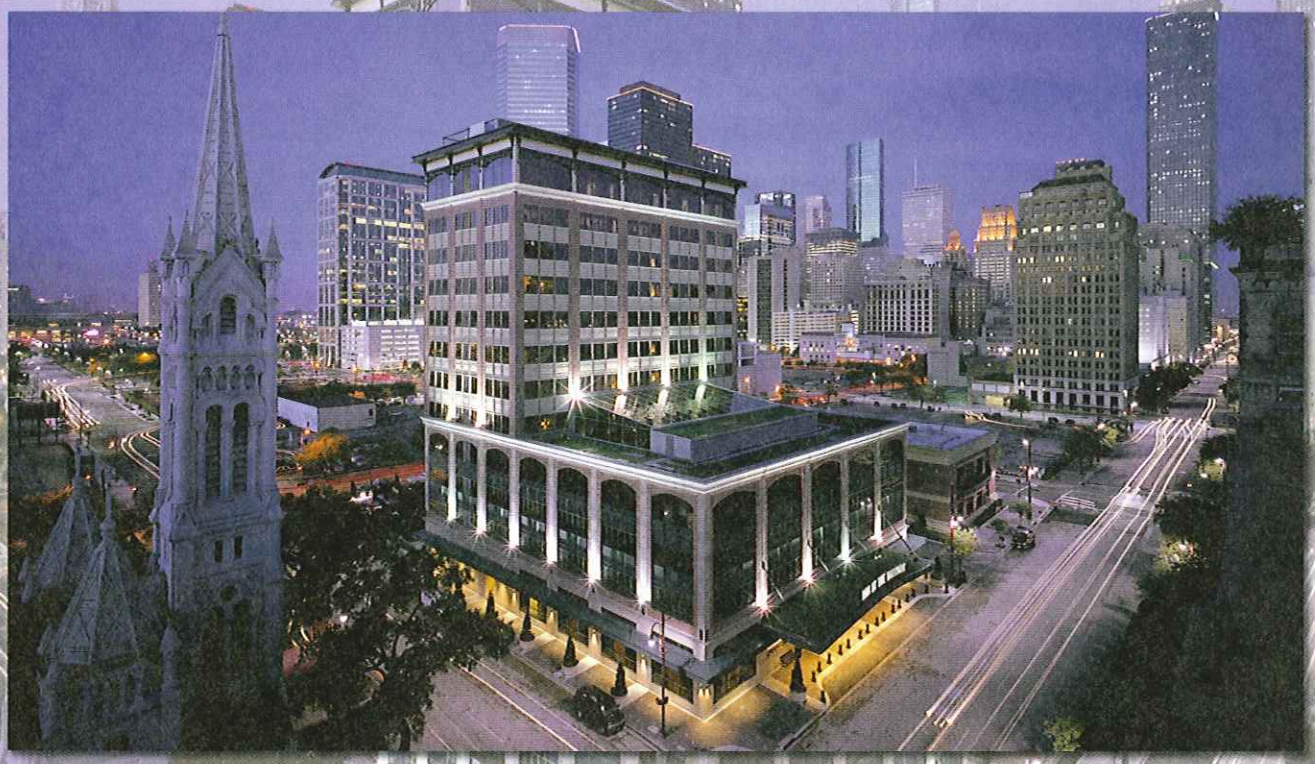
Conductor Installations

26206-05

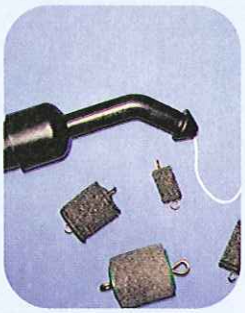


Inn at the Ballpark
Houston, Texas
Renovation $10–99 Million Award Winner
HOAR Construction, LLC

26206-05
Conductor Installations

Topics to be presented in this module include:

Overview



The first step in any conductor installation is planning. Most small conductors can be pulled into a conduit using manual techniques such as the two-person method in which one person pulls the conductors and another feeds the conductors at the supply end. A common manual pulling tool is the fish tape, which may be made of spring steel or fiberglass. The stripped ends of the conductors are fastened to the end of the fish tape and secured in place with electrical tape. As the person on the pulling end pulls, the person on the feeding end feeds the conductors into the conduit in unison with the pull, protecting the conductors from damage.

Wire-pulling ropes are often used in place of fish tapes because of their flexibility and non-conductive properties. To initially install a pulling rope in a conduit system, either a vacuum or blower system is used to install a lightweight string into the system. The pulling rope is then attached to the string and pulled through the conduit system. The conductors to be installed are attached to the pulling rope and either manually pulled through the raceway system or installed using a power pulling device.

There are several types of power pulling devices available. Most of them operate on the same principle as a power winch. Only properly trained personnel may install conductors using a power winch system, as high torques can be developed that can cause personal injury, damage to conductors, or both.

Objectives

When you have completed this module, you will be able to do the following:

1. Describe the various methods of installing conductors in conduit.
2. Plan and set up for a cable pull.
3. Understand the importance of selecting the proper location for cable pulls.
4. Describe how cable reels are transported to the pulling site.
5. Set up reel stands and spindles for a wire-pulling installation.
6. Explain how mandrels, swabs, and brushes are used to prepare conduit for conductors.
7. Properly install a pull line for a cable-pulling operation.
8. Explain the operation of power fish tape systems.
9. Prepare the ends of conductors for pulling.
10. Describe the types of cable pullers.
11. Describe the process of high-force cable pulling.
12. Explain how to support conductors in vertical conduit runs.
13. Describe the installation of cables in cable trays.
14. Explain the importance of communication during a cable-pulling operation.
15. Calculate the probable stress or tension in cable pulls.

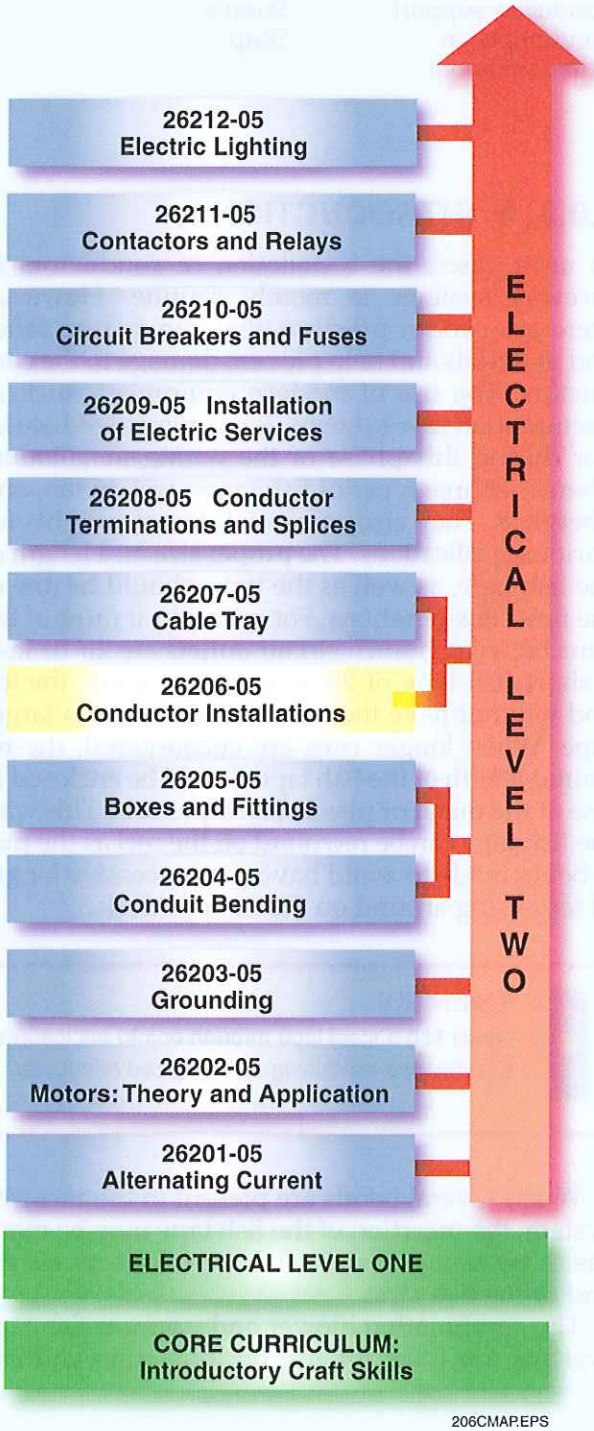
Required Trainee Materials

1. Paper and pencil
2. Appropriate personal protective equipment
3. Copy of the latest edition of the *National Electrical Code®*

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum; Electrical Level One;* and *Electrical Level Two,* Modules 26201-05 through 26205-05.

This course map shows all of the modules in *Electrical Level Two.* The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map. The local Training Program Sponsor may adjust the training order.



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Trade Terms

Basket grip
Cable grip
Capstan
Clevis
Conductor support
Conduit piston
Extension boom
Extension bushing
Fish line
Fish tape
Setscrew grip
Sheave
Soap

1.0.0 ◆ INTRODUCTION

In most cases, the installation of conductors in raceway systems is merely routine. However, there are certain practices that can reduce labor and materials and help prevent damage to the conductors. The use of modern equipment, such as vacuum **fish tape** systems, is one way to reduce labor during this phase of the wiring installation. There are three types of fish tape: steel, nylon, and fiberglass. They also come in different weights for various applications. The proper size and length of the fish tape, as well as the type, should be one of the first considerations. For example, if most of the runs between branch circuit outlets are 20' or less, a short fish tape of 25' will easily handle the job and will not have the weight and bulk of a larger tape. When longer runs are encountered, the required length of the fish tape should be enclosed in one of the metal or plastic fish tape reels. This way, the fish tape can be rewound on the reel as the pull is being made to avoid having an excessive length of tape lying around on the floor or deck.

WARNING!
Never fish a steel tape through or into enclosures or raceways containing an energized conductor.

When several bends are present in the raceway system, the insertion of the fish tape may be made easier by using flexible fish tape leaders on the end of the fish tape.

The combination blower and vacuum fish tape systems are ideal for use on long runs and can save much time. Basically, the system consists of a tank and air pump with accessories. An electrician can vacuum or blow a line or tape in any size conduit from ½" through 4", or even up to 6" conduit with optional accessories.

After the fish tape is inserted in the raceway system, the conductors must be firmly attached by some approved means. On short runs, where only a few conductors are involved, all that is necessary is to strip the insulation from the ends of the wires, bend these ends around the hook in the fish tape, and securely tape them in place. Where several wires are to be pulled together, the wires should be staggered and the fish tape securely taped at the point of attachment so that the overall diameter is not increased any more than is absolutely necessary.

Basket grips (*Figure 1*) are available in many sizes for almost any size and combination of conductors. They are designed to hold the conductors firmly to the fish tape and can save much time and trouble that would be required when taping wires.

In all but very short runs, the wires should be lubricated with wire lubricant prior to attempting the pull, as well as during the pull. Some of this lubricant should also be applied to the inside of the conduit.

Wire dispensers are great aids in keeping the conductors straight and facilitating the pull. Many different types of wire dispensers are now marketed that handle virtually any size spool of wire or cable. Some of the smaller dispensers can handle up to ten spools of wire from No. 22 to No. 10 AWG; the larger ones can handle a lot more. These dispensers are sometimes called wire caddies (see *Figure 2*).

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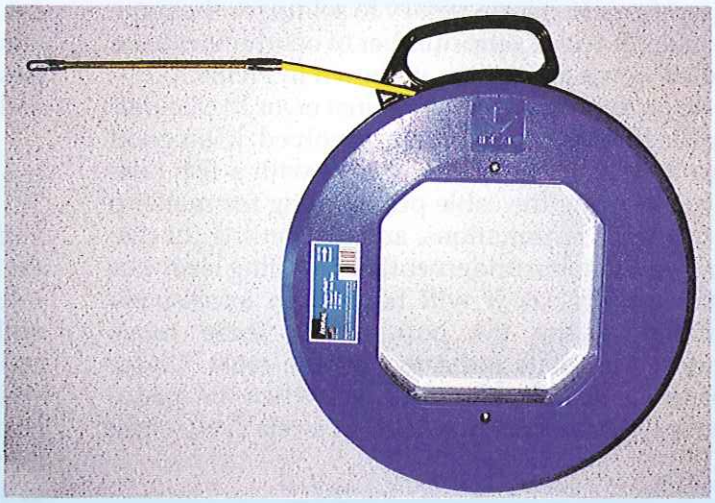
Figure 1 ◆ Basket grip.

INSIDE TRACK

Nonconductive Fish Tape

When fishing conductors in a conduit or raceway that already contains existing energized (live) conductors, the safest method is to turn off and lock out/tag the power sources for all the live conductors. However, in some rare instances, fishing a conductor through a conduit or raceway containing other live conductors may be unavoidable. In this case, always request your supervisor's approval before proceeding and always use a nonconductive fish tape made of nylon or fiberglass.



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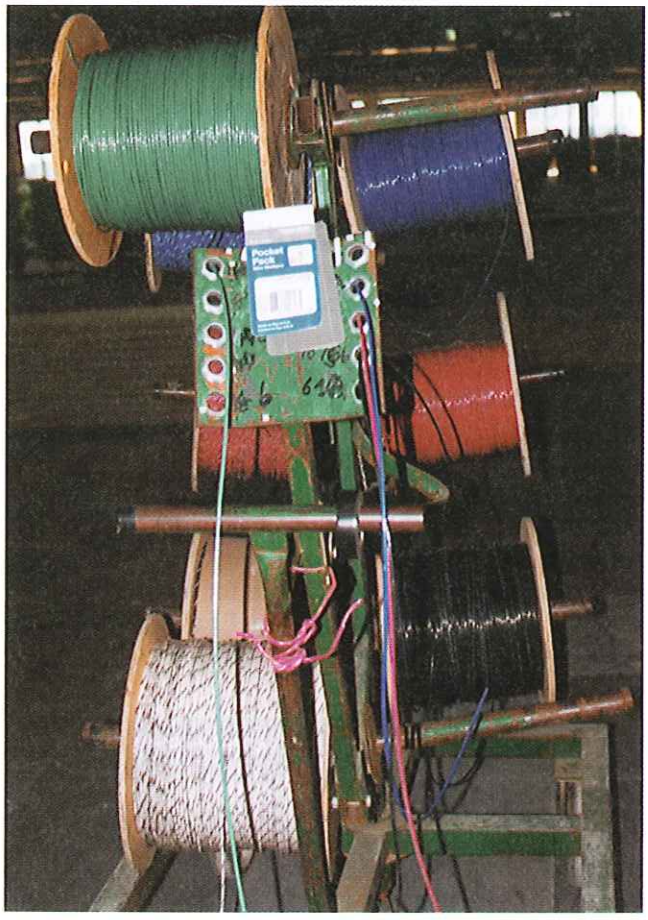

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Figure 2 ◆ Typical wire caddy.

2.0.0 ◆ PLANNING THE INSTALLATION

The importance of planning any wire-pulling installation cannot be over-stressed. Proper planning will make the work go easier and much labor will be saved.

Large sizes of conductors are usually shipped on reels, involving considerable weight and bulk. Consequently, setting up these reels for the pull, measuring cable run lengths, and similar preliminary steps will often involve a relatively large amount of the total cable installation time. Therefore, consideration must be given to reel setup space, proper equipment, and moving the cable reels into place.

Whenever possible, the conductors should be pulled directly from the shipping reels without pre-handling them. This can usually be done through proper coordination of the ordering of the conductors with the job requirements. While doing so requires extremely close checking of the drawings and on-the-job measurements (allowing for adequate lengths of conductors in pull boxes, elbows, troughs, connections, and splices), the extra effort is well worth the time to all involved.

When the lengths of cable have been established, the length of cable per reel can be ordered so that the total length per reel will be equal to the total of a given number of raceway lengths, and the reel so identified.

In most cases, the individual cables of the proper length for a given number of runs are reeled separately onto two or more reels at the factory, depending on the number of conductors in the runs.

When individual conductors are shipped on separate reels, it is necessary to set up for the same number of reels as the number of conductors to be pulled into a given run, as shown in *Figure 3*.

As an extra precaution against error in calculating the lengths of conductors involved, it is a good idea to actually measure all runs with a fish tape before starting the cable pull, adding for makeup to reach the terminations, and accounting for discarding the cable underneath the pulling sleeve or pulling wrap, as it will have been excessively stressed during the pull. Check these totals against the totals indicated on the reels. Under normal cable delivery schedules, when the feeder raceways have been installed at a relatively early stage of the overall building construction, it may not delay the final completion of the electrical installation to delay ordering the cables until the raceways can actually be measured.

When pulling conductors directly from the reels, care must be taken that each given run be cut off from the reel so that there is a minimum amount of waste. In other words, preclude the possibility of the final run of cable taken from the reel being too short for that run.

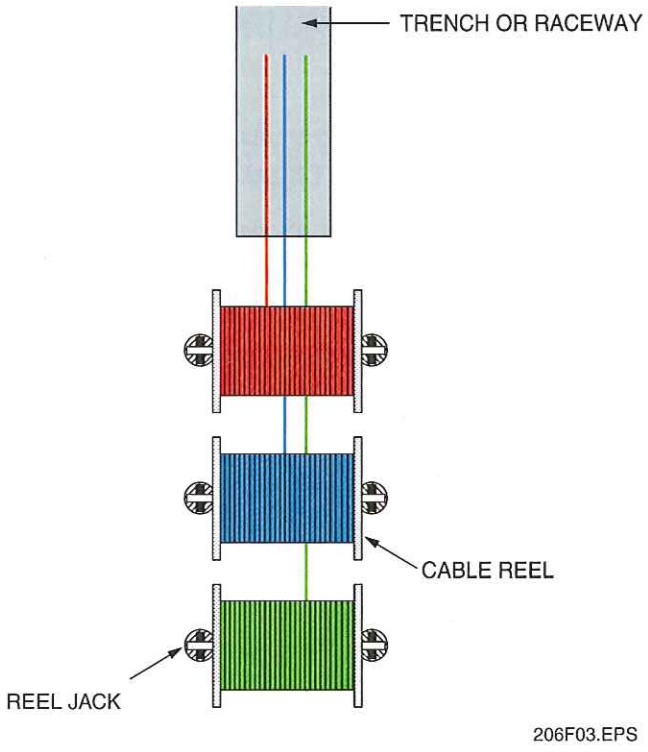


Figure 3 ◆ Multi-cable pull.

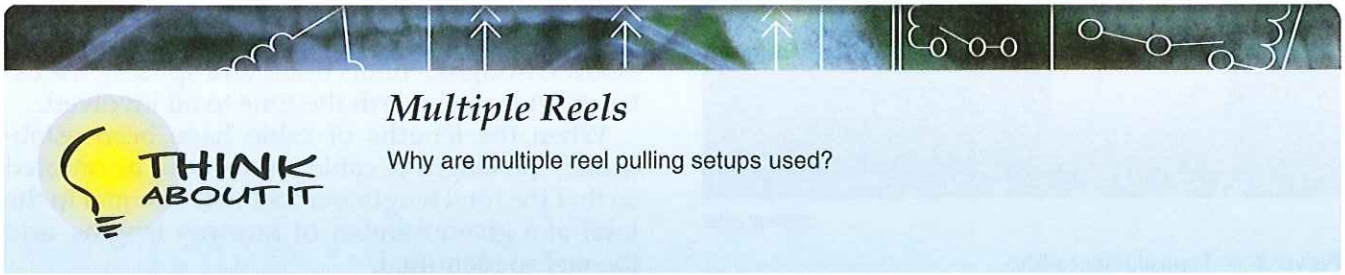
2.1.0 Pulling Location

Each job will have to be judged separately as to the best location of pulling setups; the number of setups should be reduced to a minimum in line with the best direction of the pull. The pulling location for a particular job is determined by the weight of the cable, height of the pull, practicality of moving the equipment to the pulling location, number of setups required, as well as the location of any bends. Also, a separate setup might have to be made at the top of each rise, whereas a single setup might be made at a ground floor pull box location from which several feeders are served with the same size and number of conductors.

The location of the pulling equipment determines the number of workers required for the job. A piece of equipment that can be moved in and set up on the first floor by four workers in an hour's time may require six workers working two hours when set up in basements or parking levels of buildings.

Every employer expects a day's work for a day's pay, but no employer should expect workers to do the work of two or three. Therefore, when planning a cable pull, make certain enough workers are on hand to adequately handle the installation.

It is a simple operation for a few workers to roll cable reels from a loading platform to a first floor setup, whereas moving them to upper floors involves much handling and usually requires a crane or other hoists. In addition, the reel jacks have to be moved to the setup point when a downward pull is made, and after the pulling operation is completed, they must be taken back to the first floor.



Multiple Reels

Why are multiple reel pulling setups used?

INSIDE TRACK

Measuring Tape

A waterproof polyester tape with permanent markings every foot from 0' to 3,000' is available on reels for use in measuring conduit/raceway runs. It can be fished through the run manually or using a power fishing system.

2.2.0 Cable Pull Operations

These operations are performed to a lesser or greater degree in almost all cable pulls with larger sizes of conductors:

Step 1 Measure or re-check runs and establish communications between both ends of the pull.

Step 2 Provide pulling equipment.

Step 3 Receive and unload pulling equipment.

Step 4 Move pulling equipment to the pulling location.

Step 5 Set up and anchor pulling equipment.

Step 6 Remove to another location or move to a loading platform and load on a truck or forklift.

Step 7 Receive and store cable; may be moved directly to setup location if job conditions permit.

Step 8 Move to setup point.

Step 9 Move reel jacks and mandrel to setup point.

Step 10 Jack up reels.

Step 11 Prepare cable ends.

Step 12 Install fish tape.

Step 13 Install pulling line or cable.

Step 14 Connect pulling line.

Step 15 Lubricate with proper lubricants.

Step 16 Pull cable.

Step 17 Disconnect pulling line.

Step 18 Remove reels.

Step 19 Identify conductor legs.

Step 20 Rack cables in pull boxes and troughs.

Step 21 Splice or connect cables.

Step 22 Check and test.

In some instances, the following additional operations are involved, depending upon the exact details of the project. Other items of importance will be discussed later in this module.

Step 23 Remove lagging or other protective covering from reels.

Step 24 Unreel cable and cut it to length.

Step 25 Re-reel cable for pulling.

Step 26 Replace lagging on reels.

Step 27 Operate such auxiliary equipment as guide-through cabinets or pull boxes and signal systems between reel and pulling setups.

Each of these pulling operations is discussed in detail in this module (also see *Figure 4*).

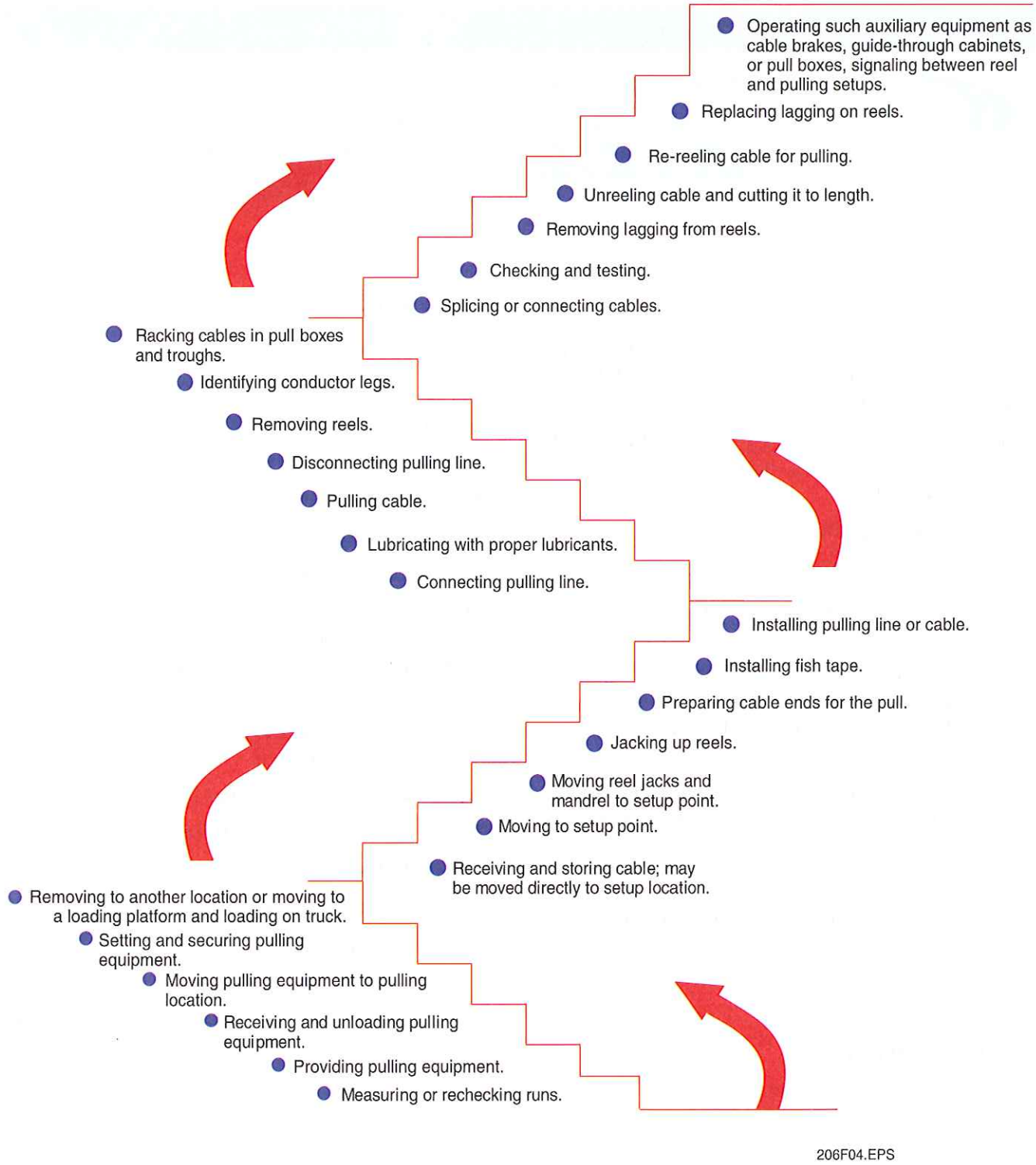


Figure 4 ◆ Basic steps of a wire-pulling operation.

3.0.0 ◆ SETTING UP FOR WIRE PULLING

As mentioned previously, much planning is required for pulling the larger sizes of conductors in raceways. There are several preliminary steps required before the actual pull begins.

The proper use of appropriate equipment is crucial to a successful cable installation. The equipment needed for most installations is shown in the checklist in *Figure 5*. Some projects may require all of these items, while others may require only some of them. Each cable-pulling project must be taken on an individual basis and analyzed accordingly. Seldom will two pulls require identical procedures.

NOTE

Think of everything that can go wrong and take every precaution.

3.1.0 Setting Up the Cable Reels

When reels of cable arrive at the job site, it is best to move them directly to the setup location if at all possible. This prevents having to handle the reels more than necessary. However, if this is not practical, arrangements must be made for storage until the cable is needed.

The exact method of handling reels of cable depends on their size and the available tools and equipment. In many cases, the reels may be rolled to the pulling location by one or more workers. For reels up to 24" wide × 40" in diameter, a cable reel transporter can be used to transport the cable reel; it also acts as a dispenser during the pulling operation. When available, a forklift is ideal for lifting and transporting cable reels. See *Figure 6*.

However, for very large reels (48" or more in diameter), a crane or similar hoisting apparatus is usually necessary for lifting the reels onto reel jacks supported by jack stands to acquire the necessary height. *Figure 7* shows a summary of proper and improper ways to transport reels of wire or cable on the job site.

Figure 8 shows several types of reel jacks, including the spindle. For a complete setup, two stands and a spindle are required for each reel. The reel jacks or stands are available in various sizes from 13" to 54" high to accommodate reel diameters up to 96". Extension stands used in conjunction with reel stands can accommodate 8", 10", 12", and 14" reels.

Reel-stand spindles are commonly available in diameters from 2⅜" to 3½" and from 59" to 100" in length for carrying reel loads up to 7,500 pounds. However, some heavy-duty spindles are rated for loads up to 15,000 pounds.

EQUIPMENT CHECKLIST

- ❑ PORTABLE ELECTRIC GENERATOR
- ❑ EXTENSION CORDS AND GFCI
- ❑ PUMP, DIAPHRAGM
- ❑ MAKEUP BLOWER AND HOSE
- ❑ MANHOLE COVER HOOKS
- ❑ WARNING FLAGS, SIGNS
- ❑ ELECTROSTATIC kV TESTER
- ❑ ELECTRIC SAFETY BLANKETS AND CLAMPS
- ❑ RADIOS OR TELEPHONES
- ❑ GLOVES
- ❑ FLOOD LAMPS
- ❑ FISH TAPE OR STRING BLOWER/VACUUM
- ❑ HAND LINE
- ❑ DUCT-CLEANING MANDRELS
- ❑ DUCT-TESTING MANDRELS
- ❑ CAPSTAN-TYPE PULLER
- ❑ SNATCH BLOCKS
- ❑ SHORT ROPES FOR TEMPORARY TIE-OFFS
- ❑ GUIDE-IN FLEXIBLE TUBING (ELEPHANT TRUNKS)
- ❑ SEVERAL WIRE ROPE SLINGS OF VARIOUS LENGTHS
- ❑ SHACKLES/ROPE CLEVIS
- ❑ GANG ROLLERS WITH AT LEAST 4' EFFECTIVE RADIUS
- ❑ HAND WINCHES
- ❑ MANHOLE EDGE SHEAVE
- ❑ PULLING ROPE
- ❑ SWIVELS
- ❑ BASKET GRIP PULLERS
- ❑ 0-1/5/10 KIP DYNAMOMETER
- ❑ REEL ANCHOR
- ❑ REEL JACKS
- ❑ CABLE CUTTERS
- ❑ LINT-FREE RAGS
- ❑ CABLE-PULLING LUBRICANTS
- ❑ PRELUBING DEVICES
- ❑ PLYWOOD SHEETS
- ❑ DIAMETER TAPE
- ❑ 50' MEASURING TAPE
- ❑ SILICONE CAULKING (TO SEAL CABLE ENDS)

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Figure 5 ◆ Wire-pulling equipment checklist.

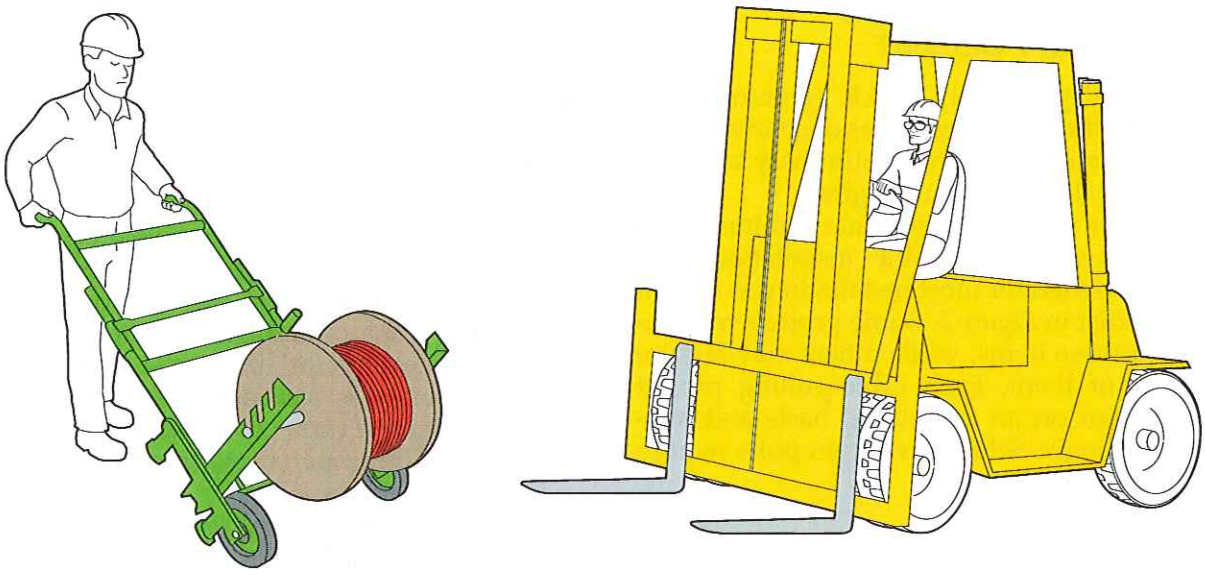

Figure 6 ◆ Two methods of transporting cable reels.

3.2.0 Preparing Raceways for Conductors

Another preliminary step prior to pulling conductors in raceway systems is to inspect the raceway itself. Few things are more frustrating than to pull four 1,000 kcmil conductors through a conduit and find out when the pull is almost done that the conduit is blocked or damaged. Such a situation usually requires pulling the conductors back out, repairing the fault, and starting all over again.

These problems are not too serious with exposed banks of conduit, as the conduit can usually be separated at the fault, the fault corrected, and another piece of conduit installed, using unions if necessary. However, in underground conduit runs—especially those encased in concrete—the situation can be both time-consuming and costly.

Figure 9 shows several devices used to inspect raceway systems, as well as to prepare raceways for easier and safer conductor pulls. Go and no-go steel and aluminum mandrels are available for pulling through runs of conduit before the cable installation. Mandrels should be approximately 80% of the conduit size (twice the 40% fill factor).

A test pull will detect any hidden obstructions in the conduit prior to the pull (*Figure 10*). If any are found, they can be corrected before wasting time on an installation that might result in conductor damage and the possibility of having to repull the conductors.

The conduit swab in *Figure 9* may be used ahead of the conductors during a pull. Its main purpose is to swab out water and debris from the raceway and spread a uniform film of pulling compound inside the conduit for easier pulling.

The conduit brush in *Figure 9* will help clean and polish the interior of conduit before pulling the cable. Such brushes remove sand and other light obstructions. Note that this brush has a pulling eye on one end and a threaded rod on the opposite end, enabling it to be pushed or pulled through the conduit.

One final step before starting the pull is to measure the length of the raceway, including all turns in junction boxes and the like. A fish tape may be pushed through the raceway system and a piece of tape used to mark the end. When it is pulled back out, a tape measure may be used to measure the exact length. An easier way, however, is to use a power fishing system to push or pull a measuring tape through the conduit run. Details of this operation are explained in the next section.

When measuring the conductor length, be sure to allow sufficient room where measurements are made through a pull box. Conductors should enter and leave pull boxes in such a manner as to allow the greatest possible sweep for the conductors. Large conductors are especially difficult to bend but with proper planning, you can simplify the feeding of these conductors from one conduit to another.

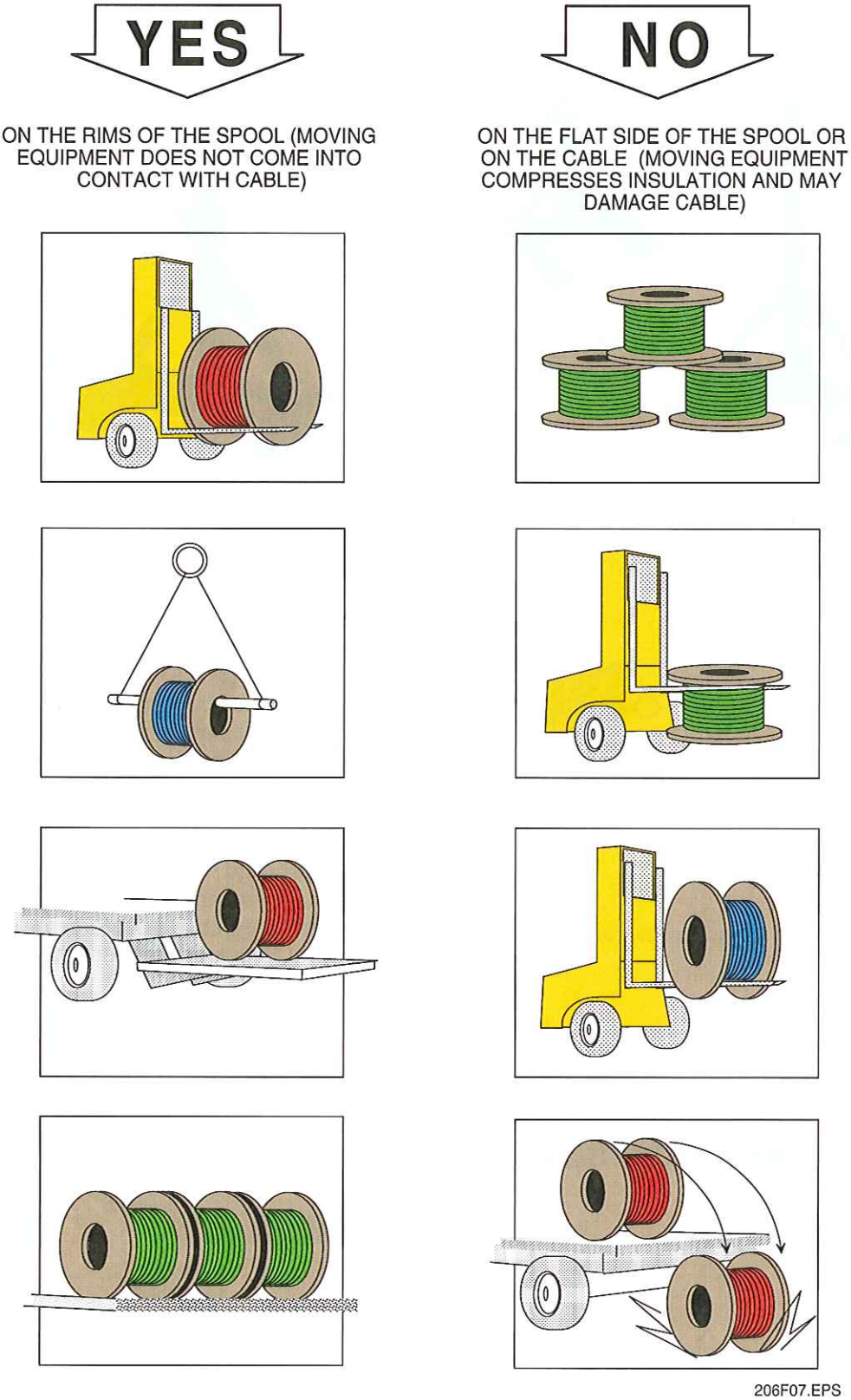

Figure 7 ◆ Proper and improper ways of transporting cable reels.

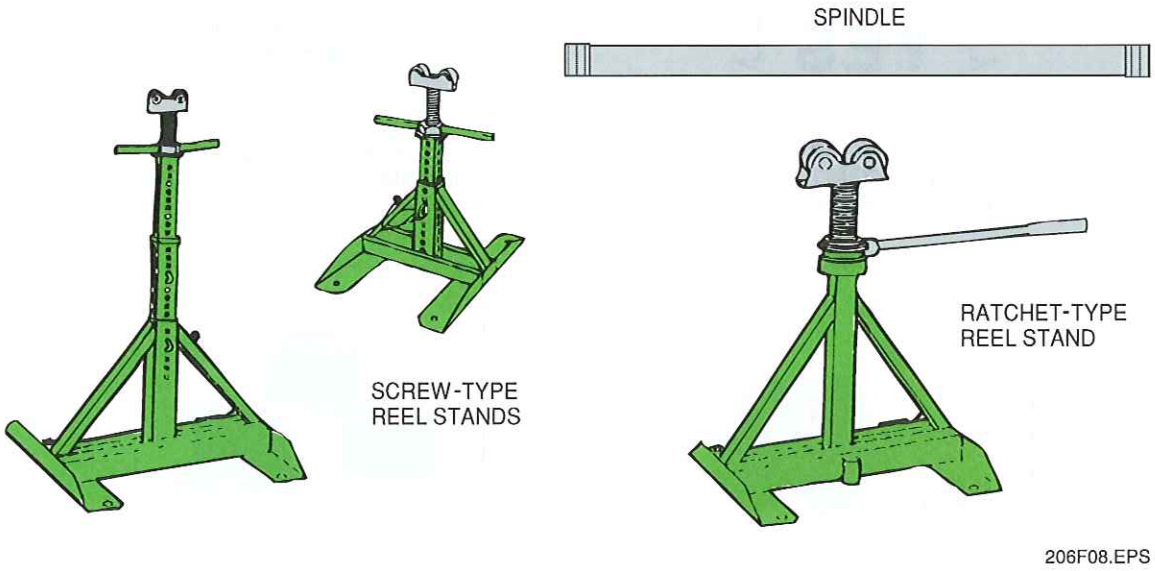

Figure 8 ◆ Typical reel stands.

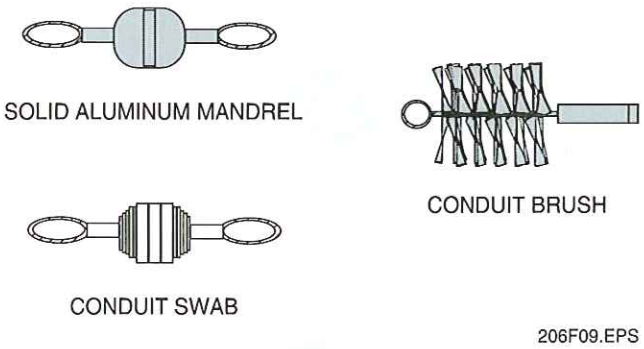

Figure 9 ◆ Devices used to inspect, clean, and lubricate raceway systems.

For example, if a conduit run makes a right-angle bend through a pull box, the conduit for a given feeder should come into the box at the lower left-hand corner and leave diagonally opposite at the upper right-hand corner, as shown in *Figure 11*. This gives the conductors the greatest possible sweep with the box, eliminating sharp bends and consequent damage to the conductor insulation.

Runs should also be calculated to allow for splices and terminations in junction boxes, panelboards, motor-control centers, the cable discarded under the sleeve or pulling wrap, etc.

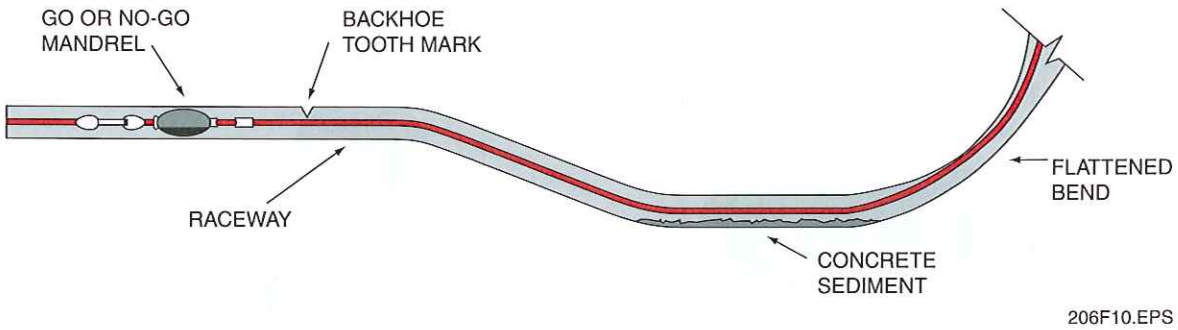

Figure 10 ◆ Faults that may be detected with a conduit mandrel.

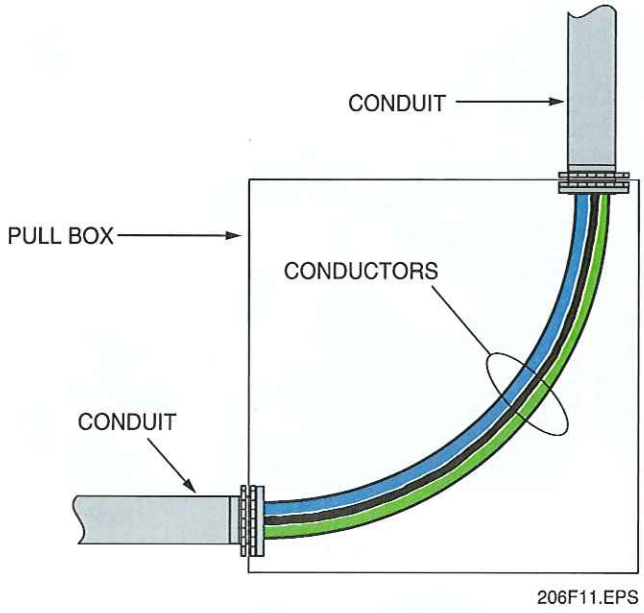

Figure 11 ◆ Obtaining the greatest possible conductor sweep in a pull box.

3.3.0 Installing the Pull Line

At one time, pull-in wires were frequently placed in conduit runs as the raceways were installed. However, in recent times, with modern cable-fishing equipment, this practice is seldom used.

Pull lines are sometimes manually fished in with a steel fish tape, but much time can be saved by using a blower/vacuum fish tape system. In general, a **conduit piston**—sometimes referred to as a mouse or missile—is blown with air pressure or vacuumed through the run. The foam piston is sized to the conduit and has a loop on both ends. In most cases, **fish line** or measuring tape is attached to the piston as it is blown or vacuumed through the conduit run. The measuring tape serves two purposes: it provides an accurate measurement of the conduit run, and the tape is used to pull the cable-pulling rope into the conduit run. In some cases, if the run is suitable, the pulling rope is attached directly to the piston and vacuumed into the run. *Figure 12* shows a blower/vacuum fish tape system being used to vacuum a pull line in a conduit while *Figure 13* shows the same apparatus blowing the piston through. Most of these units provide enough pressure to clean dirt or water from conduit during the fishing operation. *Figure 14* shows two types of pistons used with this system. The one on the right utilizes air-guide vanes to prevent the piston from tumbling inside the larger sizes of conduit.

3.4.0 Preparing Cable Ends for Pulling

The pulling-in line or cable must be attached to the cable or conductors in such a manner that it cannot part from the cable during the pull. Two common methods include direct connection with the cable conductors themselves and connection by means of pulling grips or baskets placed over the cable or group of conductors. The use of the proper type of grip or basket will facilitate the pull, but in many cases—especially on long pulls—workers prefer to use three- or four-hole **cable grips** with setscrews that secure each conductor to the pulling block. *Figure 15* shows several types of pulling grips.

Most pulling blocks have a rope **clevis** as an integral part of the block. However, when using pulling grips or baskets in 2" or larger conduit, a rope clevis is normally used to facilitate connecting the pulling rope to the wire grip. Two types are currently used: the straight clevis and the swivel clevis.

3.4.1 Stripping the Cable Ends

When the type of grip being used requires that the ends of the cable insulation be stripped from the conductors, conventional methods are used—the same as for terminating conductors for splices or connections to terminal lugs in panelboards, switchgear, etc.

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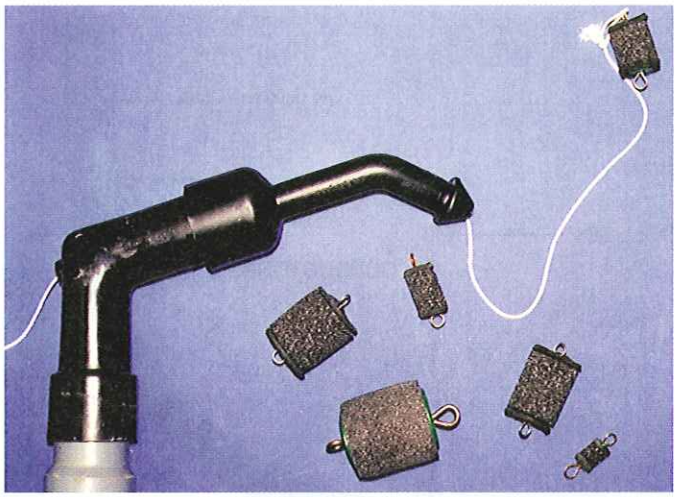

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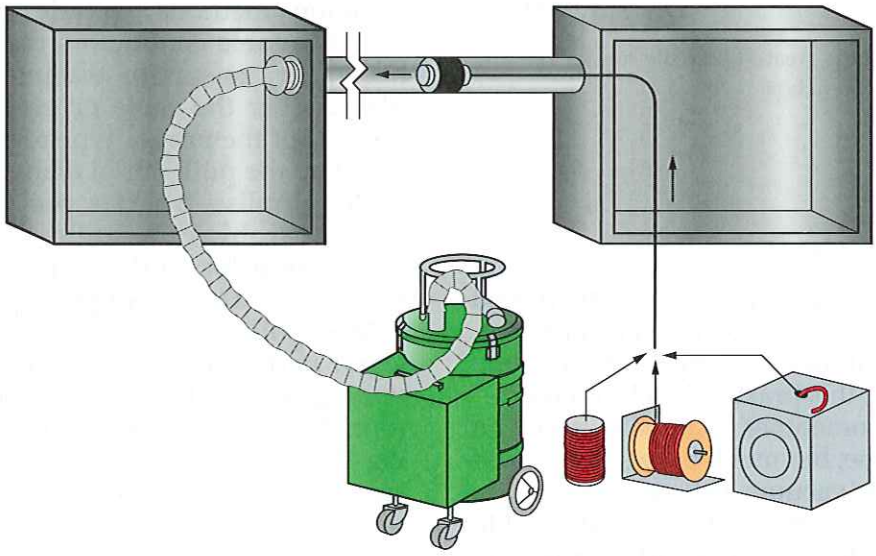

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Figure 12 ◆ Power fishing system.

Cable Blowing

INSIDE TRACK

Lightweight cables, especially fiber optic cable, can be floated through conduit using a special high-pressure blower unit.

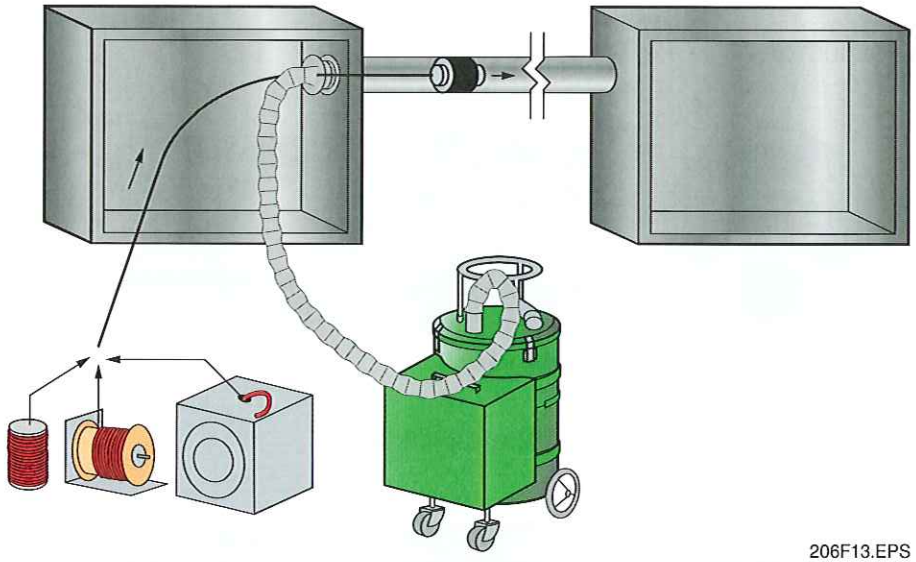

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Figure 13 ◆ Blower/vacuum fish tape system used to blow a pull line in conduit.

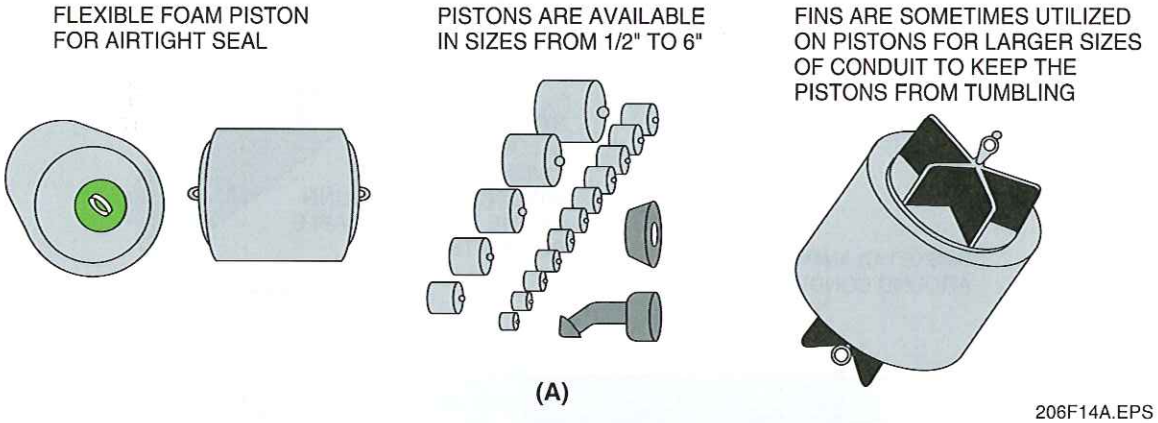

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Figure 14 ◆ Types of pistons in common use.

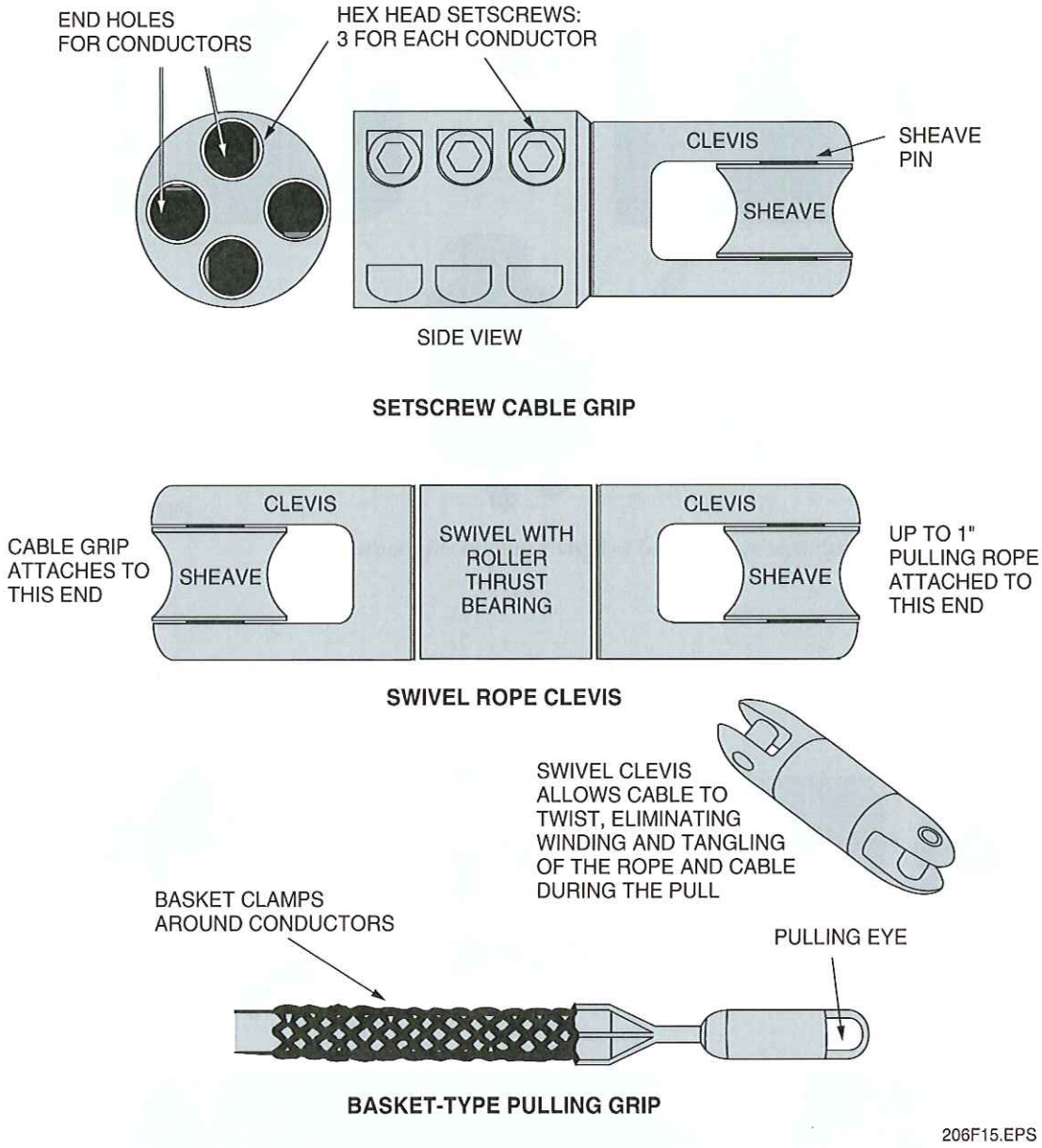


Figure 15 ◆ Various types of pulling grips used during conductor installation.

In general, the ends of conductors should first be trimmed. Cable cutters capable of cutting conductors through 1,000 kcmil save workers much time over using a hacksaw. There are also cable strippers, adjustable from 1/0 AWG through 1,000 kcmil, that handle midspan and termination stripping of THHN, THWN, XHHW, and similar insulation. These tools are excellent for stripping conductors for use in setscrew clamp-type pulling grips.

To use a stripping tool, first mark the required distance from the ends of the conductors, using the pulling grip as a gauge. Close the jaws of the stripping tool on the cable and twist. These self-feeding devices ensure positive progression down the cable to any position desired. To stop stripping, apply back pressure to the stripper until a full circle has been completed.

Once the conductor ends have been stripped, insert one conductor at a time into the **setscrew grip.** Make sure the end of the bare conductor is firmly in place, and then tighten the setscrews with a hex wrench. Continue on to the next conductor, and so on, until all conductors are secured in the pulling grip.

INSIDE TRACK

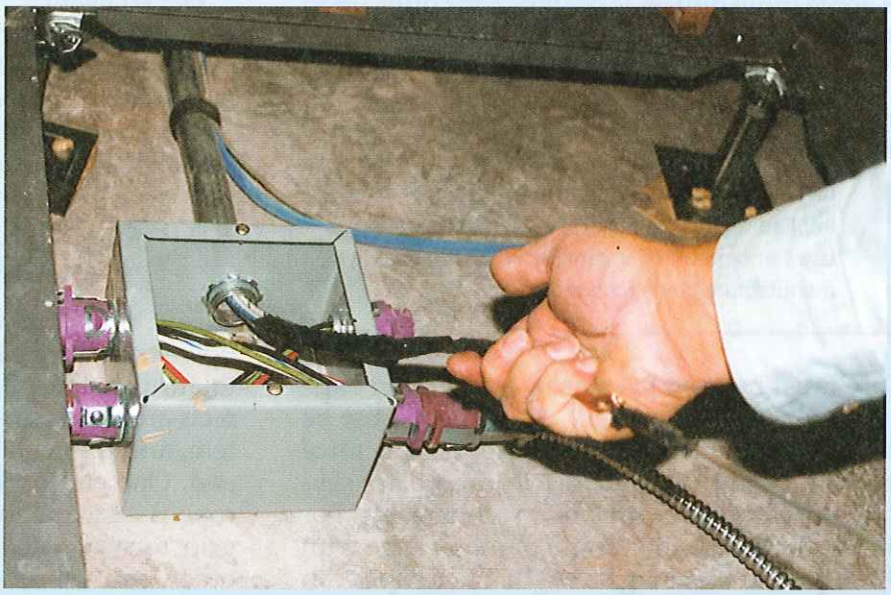
Pulling Eyes, Basket Grips, and Swivels

Conductors can be attached to a pulling line using various methods, including pulling eyes or basket grips.

Smaller conductors may require only a pulling eye attached to the fish tape or pulling line. To attach the pulling eye, the conductors are first stripped, exposing a length of bare wire. These bare wires are inserted through the eye and twisted back onto themselves. The exposed twisted wires of the conductors can then be wrapped with smaller copper wire to prevent them from untwisting. They are then completely taped with three layers of electrical tape, starting from the conductor insulation, to prevent snagging as they are drawn through the conduit run.

If a basket grip is used to pull the conductors, make sure to securely tape several inches of the grip to several inches of the conductor insulation beyond the grip using multiple layers of tape. This will prevent the grip from coming off the conductors in the middle of the run if the tension on the pulling line is released for one reason or another.

No matter what method is used, always insert a swivel of some sort between the pulling line or fish tape and the conductors to alleviate twisting of the conductors.



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3.4.2 Safety with Cutters

When using a stripping tool for the first time, make sure that you read and understand all instructions and warnings before using the tool. The following should also be observed when working with cable terminators:

- Wear eye protection.
- Inspect tools before using, and replace damaged, missing, or worn parts.
- Be prepared for the unexpected. Make sure your footing and body position are such that you will not lose your balance.
- Use only the type and size material in the stated capacity.
- Do not use the tool on or near live circuits.

3.5.0 Types of Pulling Lines

Wire-pulling ropes have come a long way from the hemp ropes used by electricians a couple of decades ago. The most common wire-pulling ropes on the market include the following:

- Nylon
- Polypropylene
- Multiplex polyester
- Double-braided polyester composite

The type of rope selected will depend mainly on the pulling load; that is, the weight of the cable, the length of the pull, and the total resistance to the pull. For example, Greenlee's Multiplex cable-pulling rope is designed for low-force cable pullers. It has a low stretch characteristic that makes it suitable for pulls up to 2,000 pounds. Lengths are available from 100 to 1,200 feet. Greenlee's double-braided composite rope for high-force cable pullers is designed for pulls up to 6,500 pounds.

CAUTION

Any equipment associated with the pull must have a working load rating in excess of the force applied during the pull. All equipment must be used and mounted in strict accordance with the manufacturer's instructions.

Care must be used in selecting the proper rope for the pull, and then every precaution must be taken to make sure that the cable-pulling force does not exceed the rope capacity. There are several reasons for this, but the main one is safety. For example, think of a 100' length of nylon rope with a 10,000-pound breaking strength. Such ropes can stretch 40' before breaking, releasing 200,000 foot-pounds of energy in the process. Think of the damage this amount of energy could do to a raceway system and to nearby workers if the rope broke under this amount of force.

In some cases, a power blower/vacuum fish tape system is used to vacuum the piston through the raceway with the pulling rope attached. In other cases, a line is first blown or vacuumed through the conduit and then the pulling rope is attached to the line for pulling it through the raceway system. In either case, there are certain precautions that should be taken when using a power fish tape system:

- Read and understand all instructions and warnings before using the tool.
- Never fish in runs that might contain live power.
- Be prepared for the unexpected. Make sure your footing and body position are such that you will not lose your balance in any unexpected event.
- Use blower/vacuum systems only for specified light fishing and exploring the raceway system.
- Never use pliers or other devices that are not designed to pull a fish tape. They can kink or nick the tape, creating a weak spot.

4.0.0 ◆ CABLE-PULLING EQUIPMENT

Except for short cable pulls, hand-operated or power-operated cable pullers or winches are used to furnish the pulling power. In general, cable reels are set in place at one end of the raceway system, and the cable puller is set up at the opposite end. One end of the previously-installed pulling rope is attached to a clevis, basket, or other cable grip to which the conductors are attached. The other end of the rope (at the cable puller) is wrapped around the rotating drum on the cable puller (*Figure 16*).

INSIDE TRACK

Be Sure to Check the Pulling Rope Rating

Many pulling ropes available today are made of synthetic materials designed for pulling by hand or with a winch-type puller. However, if you are using certain synthetic pulling ropes on friction-type capstan power pullers, make sure the rope is rated by the manufacturer for this use so that it will be able to withstand the heat generated by any extended slippage of the rope on the capstan. During high-force pulling operations, melting damage and possible failure of unrated synthetic rope can occur quickly during periods of capstan slippage.

WARNING!

Always use a wire-pulling lubricant that is compatible with the type of cable being pulled. Check with the cable manufacturer for their recommendations, and always contact the lubricant manufacturer about the compatibility of their products with specific cables. Also check the product's MSDS for any applicable safety requirements.

Wire-pulling lubricant—sometimes referred to as **soap**—is inserted into the empty conduit as well as wiped thoroughly onto the front of the cable. One or more operators are on hand to feed the cable, while one worker is usually all that is required on the pulling end.

The number of wraps on the puller drum decides the amount of force applied to the pull. For example, the operator needs to apply only 10 pounds of force to the pulling rope in all cases. With this amount of force applied by the operator, and with one wrap around the rotating drum, 21 pounds of pulling force will be applied to the pulling rope; 2 wraps, 48 pounds; 3 wraps, 106 pounds, etc. This principle is known as the **capstan** theory and is the same principle applied to block-and-tackle hoists or the lone cowboy who is able to rope and hold a 2,000-pound bronco by wrapping his lariat around the center post in a corral. *Table 1* gives the amount of pulling force with various numbers of wraps when the operator applies only 10 pounds of tailing force.

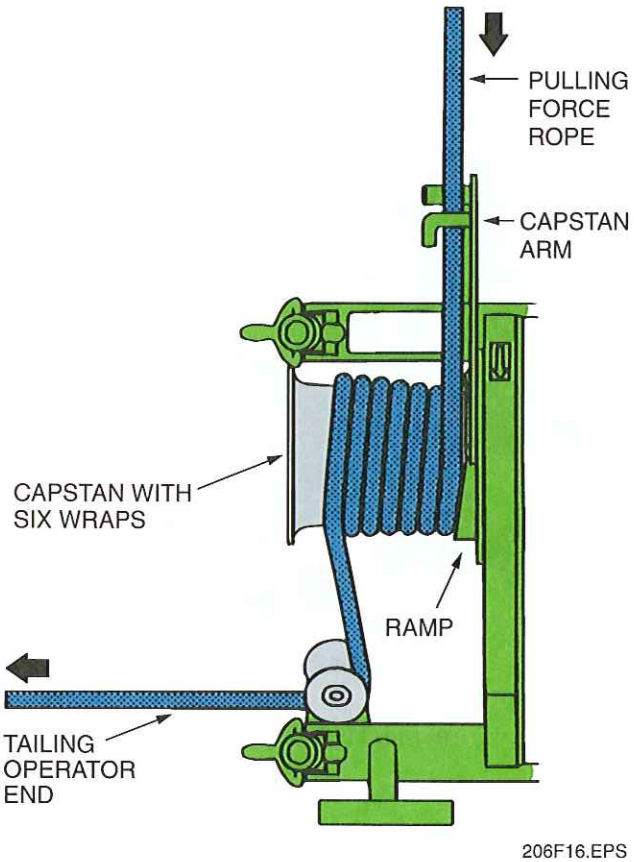

Figure 16 ◆ Basic parts of a power cable puller.

4.1.0 Pulling Safety

Adhere to the following precautions when using power cable-pulling equipment:

- Read and understand all instructions and warnings before using the tool.
- Use compatible equipment; that is, use the properly-rated cable puller for the job, along with the proper rope and accessories.
- Always be prepared for the unexpected. Make sure your footing and body position are such that you will not lose your balance. Keep out of the direct line of force.
- Make sure all cable-pulling systems, accessories, and rope have the proper rating for the pull.
- Inspect tools, rope, and accessories before using; replace damaged, missing, or worn parts.
- Personally inspect the cable-pulling setup, rope, and accessories before beginning the cable pull. Make sure that all equipment is properly and securely rigged.
- Make sure all electrical connections are properly grounded and adequate for the load.
- Use cable-pulling equipment only in uncluttered areas.

NOTE

The strain placed on the wrapped cable during the pull may weaken this part of the cable. Be sure to discard the wrapped cable after making the pull.

Table 1 Pulling Forces for Various Wraps

Number of Wraps	Operator Force (Lbs)	Pulling Force (Lbs)
1	10	21
2	10	48
3	10	106
4	10	233
5	10	512
6	10	1,127
7	10	2,478

CAUTION

Make absolutely certain that all communications equipment is in working order prior to the pull. Place personnel at strategic points with operable communications equipment to stop and start the pull as conditions warrant. Anyone involved with the pull has the authority to stop the pull at the first sign of danger to personnel or equipment.

4.2.0 Types of Cable Pullers

There are several types of cable pullers on the market. Most, however, operate on the same principle. The self-contained hand-crank wire puller in *Figure 17(A)* is designed to pull up to 1,500 pounds with only 30 pounds of handle force. It is used mostly on projects where only a few cable runs need to be pulled (i.e., those projects that do not warrant the setup time required for a power cable puller).

An electric cable puller is lightweight and easy to set up. It is also designed to pull up to 1,500 pounds. An electric cable puller is shown in *Figure 17(B)*.

WARNING!

Make absolutely certain that all cable-pulling equipment is anchored properly. Follow the manufacturer's recommendations for the type of puller being used.

4.2.1 Setting Up Cable Pullers

Figure 18 shows the basic setup for an up cable pull where the conduit is concealed. The first step is to remove the locknut from the end of the conduit and attach the pipe adapter with the proper **extension bushing** to the end of the conduit. Then, attach the pipe adapter **sheave** to the flexible pipe adapter. Add the mobile T-boom and cable puller for a flush-mounted pull, resting the **extension boom** on the floor.

Figure 19 shows a setup for a down pull through concealed conduit. The setup is similar to the one described for the up pull except the flexible pipe adapter and pipe adapter sheave are attached to the top conduit rather than the bottom conduit.

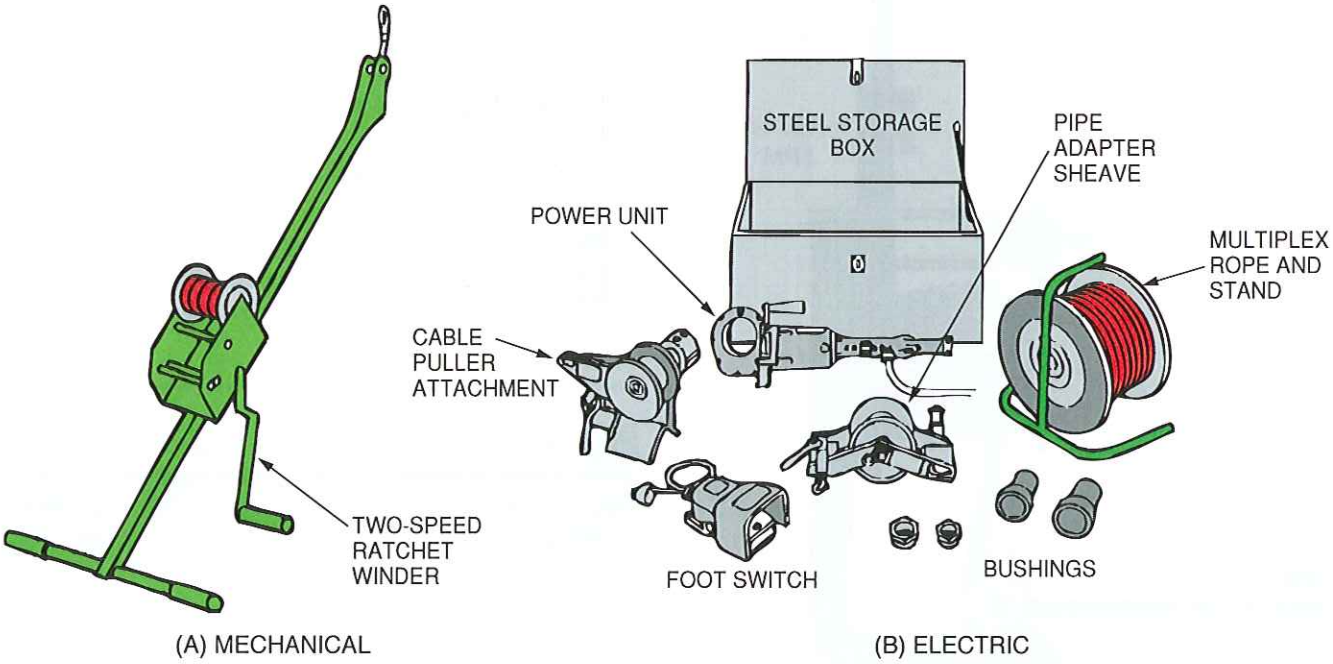

Figure 17 ◆ Cable pullers.

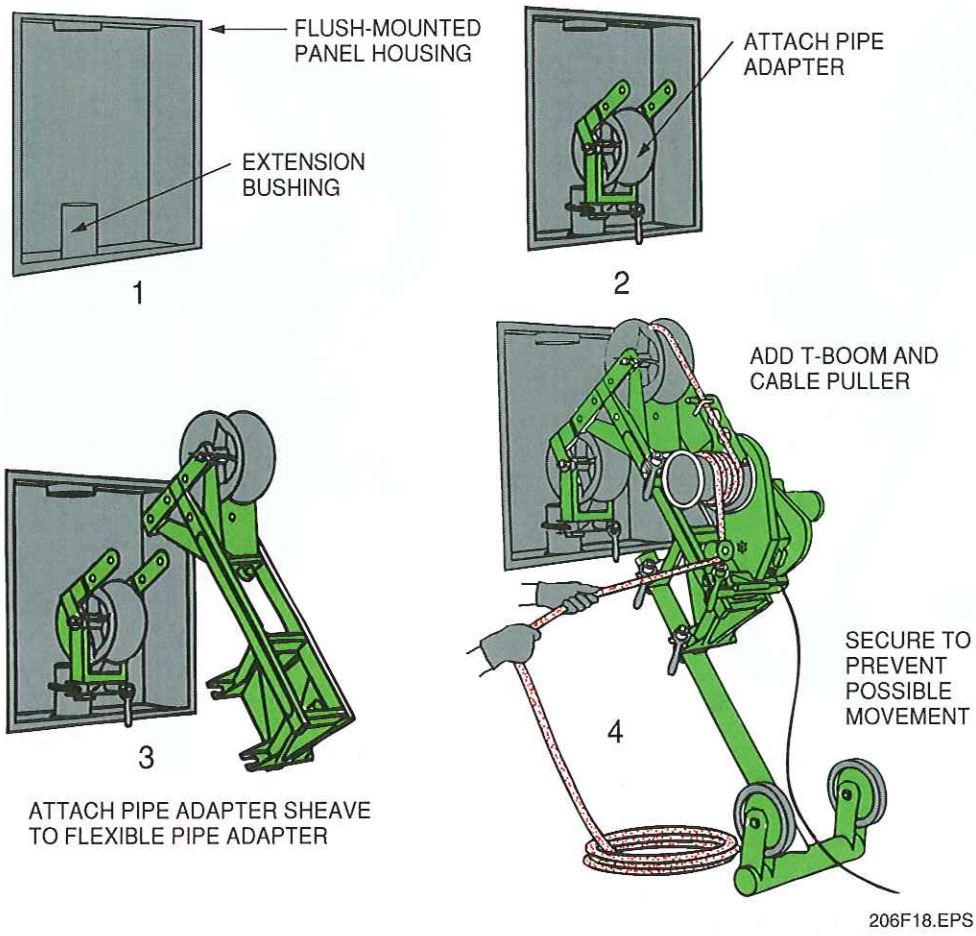

Figure 18 ◆ Steps in setting up cable puller for concealed conduit pull.

INSIDE TRACK

Guiding and Lubricating Conductors

When guiding conductors into a conduit/raceway during a pull, the conductors may tend to twist, overlap, or become crossed during the pulling operation, especially if fed from boxes instead of reels. Excessive twisting, overlaps, crossovers, etc. can cause binding of the conductors in conduit/raceway turns, create bunching obstructions in the conduit/raceway, and can contribute to insulation burns. Operators at the feeding end of the pull must attempt to keep the conductors as straight as possible during the pulling operation and lubricants should be applied liberally during the pull to allow the conductors to slide against each other and the sides of the run.

Monitored Cable Pullers

Besides basic power cable pullers, relatively expensive pullers with a dynamometer and an automatic over-tension shutoff device are also available. These units prevent you from accidentally exceeding the maximum recommended pulling tension for the conductor(s) being pulled.

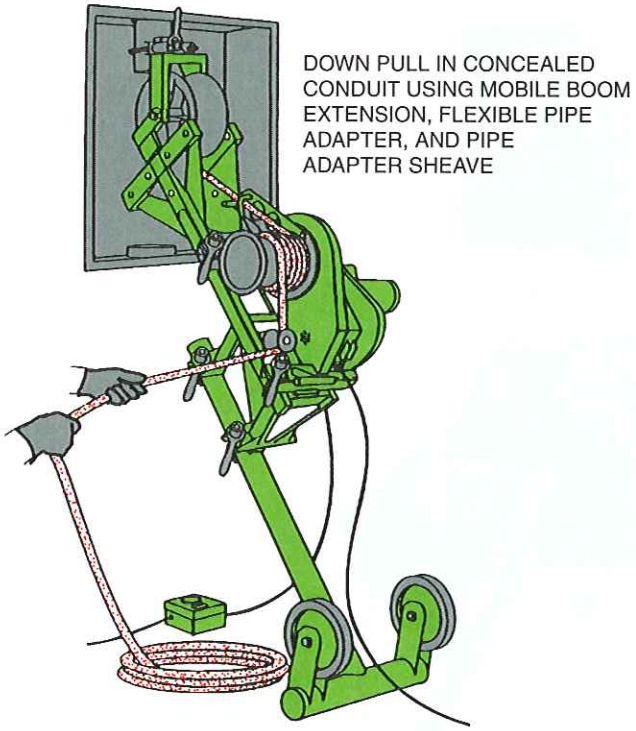

Figure 19 ◆ Puller setup for down pull in concealed conduit system.

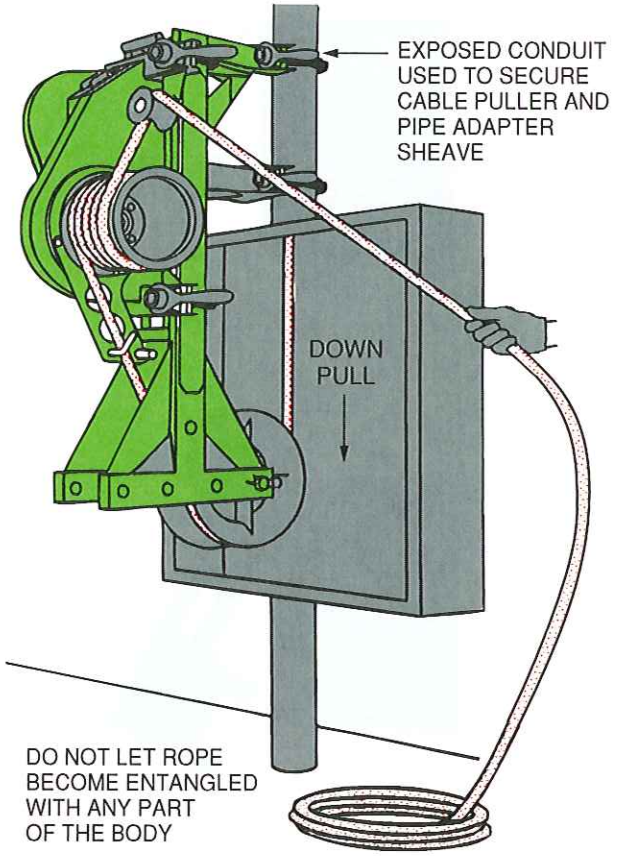

Figure 20 ◆ Puller setup for down pull in exposed conduit system.

Attaching the cable puller to exposed conduit is done in a somewhat different way. The exposed conduit itself is used for support of the pulling apparatus (*Figure 20*), and no floor support is necessary.

5.0.0 ◆ HIGH-FORCE CABLE PULLING

High-force cable pulling is not done every day. It is actually a small part of any electrical raceway installation. Workers may take days, weeks, or even months to install the complete raceway system; the cable pulling operation may only take an hour or two for each run.

There are several items to consider during high-force cable pulling:

- The design of the raceway system must be studied by consulting the working drawings and by examining the installed system to ensure that it is properly installed for the type of conductors that will be pulled through the system. Items to consider include conduit sizes, number and size of conductors, number of bends, sufficient pull boxes, and adequate supports.
- The conductors need to be matched to the proper pulling equipment.
- The proper pulling rope must be selected. Choose a rope that has at least four times the strength of the required pulling force; that is, if the estimated pulling force is 1,200 pounds, the rope should be rated for no less than 4,800 pounds. Also check the rope carefully for wear or damage prior to the pull. Remember that a rope is only as strong as its weakest point.
- A decision must be made as to the best end of the raceway for pulling. The reel setup must also be carefully placed. In general, conductors that are to be installed downward should be fed off the top of the reel and where conductors are to be fed upward, the best method is to feed from the bottom of the reel. This eliminates sharp kinks or bends in the conductors.
- The appropriate pulling equipment must be used. The equipment must be of the proper capacity for the job. Space consideration for the equipment is also important, as is the particular type of mounting.

- Having enough workers is critical. Never be caught short. This is where experienced workers earn their pay. In high-force wire pulling, experience is the best teacher.
- Safety must be foremost in everyone's mind.

When planning the cable pull, make sure that enough cable is on hand for the run. Cable may be verified while still on the reel by using a cable-length meter. Of course, the conduit run length should have already been checked, as discussed previously. Do not proceed further until everyone is assured that enough cable is on hand for all bends, sweeps in junction boxes, etc. If the cable falls short, take steps to correct the situation before continuing.

Equipment with feeding sheaves will help provide a smooth guide for the cable. Also, have sufficient lubricant on hand and use it both before and during the pull.

Select and install proper cable grips on the cable ends. Gripping must be adequate to handle the imposed force.

When pulling cables in a horizontal run, the worker simply has to reduce the amount of operator pull in order to slow down the cable pull. Releasing all operator pull stops the pulling force entirely. However, when pulling vertical runs, the rope must be tied off after stopping the pull to keep the cable from reversing in the raceway.

The entire operation should be supervised from start to finish. Therefore, communications equipment must be utilized on both ends of the pull at all times.

During the pull, make sure that the pulling rope remains free and is not wrapped around any part of the body.

A typical cable-pulling setup is shown in *Figure 21*, including cable reels, reel stands, a power cable puller, conduit system, and other accessories necessary for the pull.

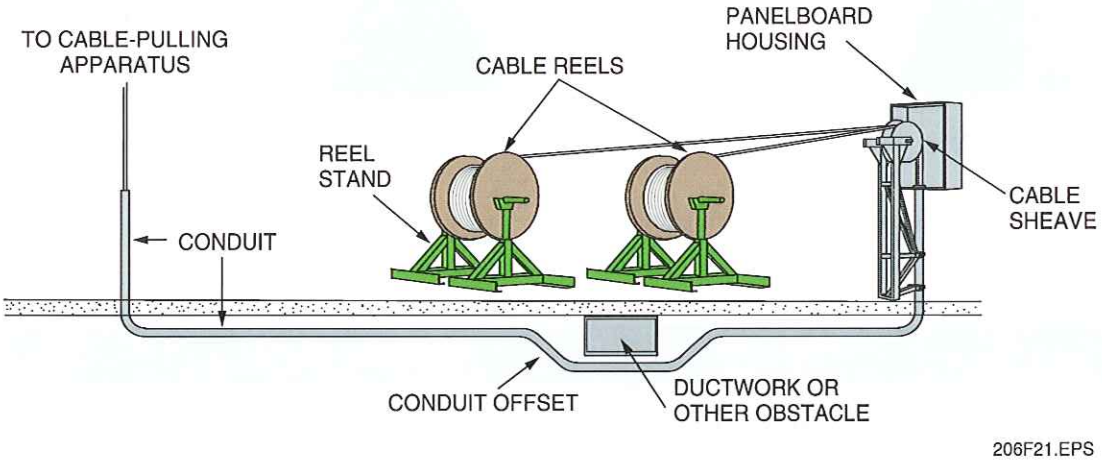

Figure 21 ◆ Typical cable-pulling setup.

Communications

What type of communications equipment would most likely be used during cable-pulling operations?

5.1.0 The Feeding End—Sheaves and Rollers

The feed-in setup should unreel the cable along its natural curvature, as shown in *Figure 22(A)*, as opposed to a reverse S curvature, as shown in *Figure 22(B)*. Feed-in setups are shown in *Figure 23* for manhole, underfloor duct, and overhead cable tray. Note the use of auxiliary equipment in some of these drawings, that is, cable reels, guide-in tubes, sheaves, and rollers.

Single sheaves may be used only for guiding cables. Multiple blocks should be arranged to hold the cable-bending radius wherever the cable is deflected, as shown in *Figure 24(A)*. For pulling around bends, use conveyor sheave assemblies of the appropriate radius series, as shown in *Figure 24(B)*.

Sheaves and pulleys must be positioned to ensure the effective curvature is smooth and deflected evenly at each pulley. Never allow a polygon curvature to occur, as shown in *Figure 25*.

CAUTION

Use the radius of the surface over which the cable is bent, not the outside flange diameter of the pulley. For example, a 10" cable sheave typically has an inside (bending) radius of 3".

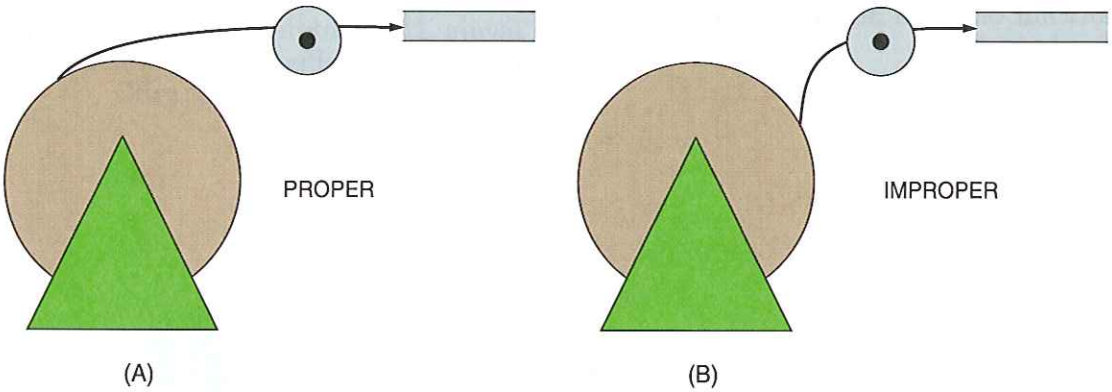

Figure 22 ◆ Unreel the cable along its natural curvature.

Feed-In Setups

Why is an S-curve setup not desirable?

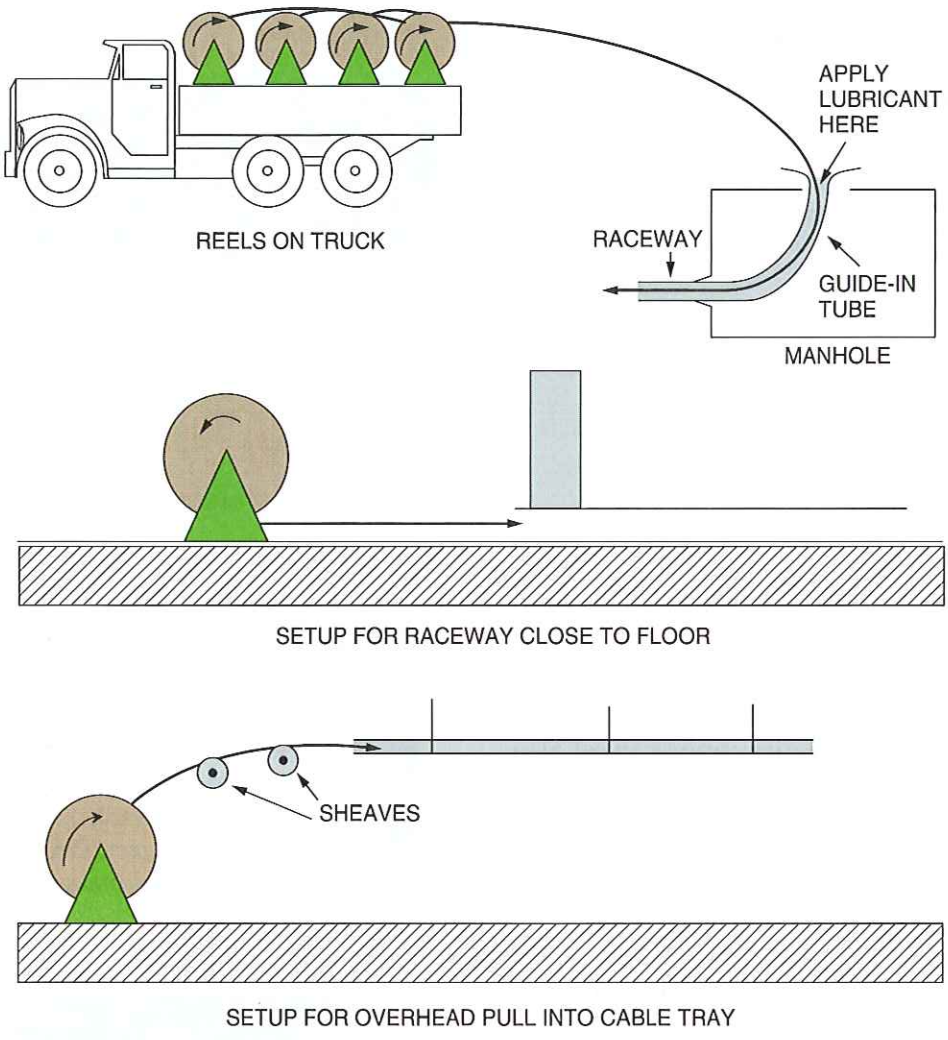

Figure 23 ◆ Cable feed-in setups.

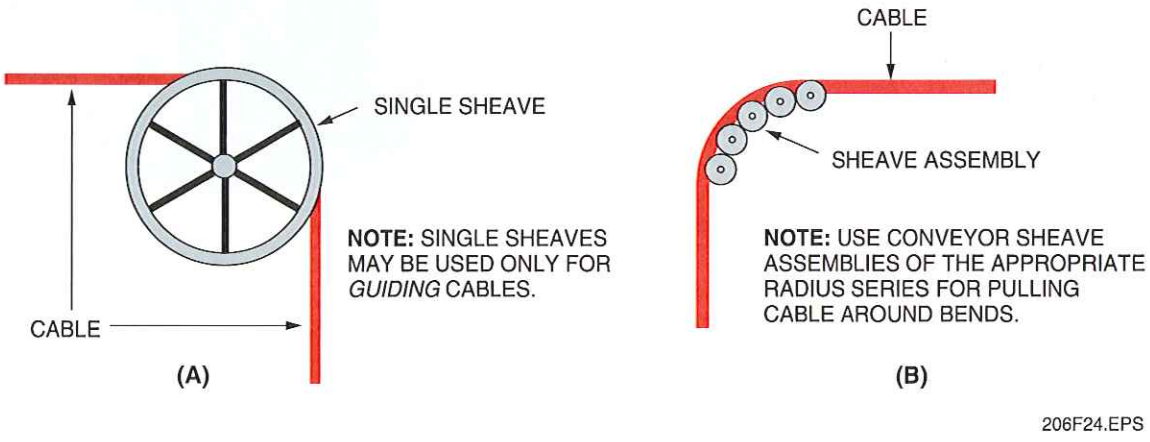

Figure 24 ◆ Arrangement of cable pulleys and sheaves.

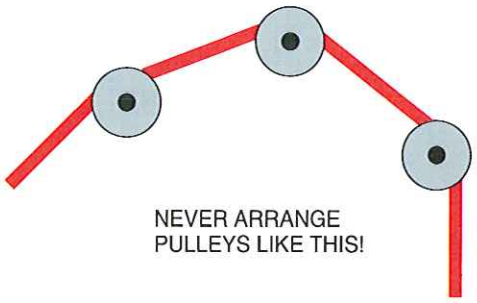

Figure 25 ◆ Never allow a polygon curvature to occur in a cable-pulling operation.

6.0.0 ◆ SUPPORTING CONDUCTORS

Conductors in vertical raceways must be supported in accordance with *NEC Section 300.19* if the vertical rise exceeds the values in *Table 2*. In general, one **conductor support** must be provided at the top of the vertical raceway or as close to the top as practical. Intermediate supports must also be provided as necessary to limit supported conductor lengths to not greater than those values specified in *NEC Table 300.19(A)*.

The *NEC*® allows several different methods of supporting conductors in vertical raceways; the following are typical:

- Conductors may be supported by clamping devices constructed of or employing insulating wedges inserted in the ends of the conduit, as shown in *Figure 26*. Where clamping of insulation does not adequately support the cable, the conductor itself must also be clamped.
- Conductors may be supported by inserting boxes at the required intervals in which insulating supports are installed and secured in a satisfactory manner to withstand the weight of the conductors attached to them. The boxes must be provided with covers.
- Cables may be supported in junction boxes by deflecting the cables not less than 90° and carrying them horizontally to a distance not less than twice the diameter of the cable. The cables are carried on two or more insulating supports and additionally secured to these supports by tie wires, if desired. Where this method is used, cables must be supported at intervals not greater than 20% of those mentioned in *NEC Table 300.19(A)*.
- Cables may be supported by a method of equal effectiveness.

Table 2 Spacings for Conductor Supports in Vertical Raceways

Size of Wire	Support (Aluminum or Copper-Clad Aluminum Conductor)	Support (Copper Conductor)
18 AWG through 8 AWG	≤ 100'	≤ 100'
6 AWG through 1/0 AWG	≤ 200'	≤ 100'
2/0 AWG through 4/0 AWG	≤ 180'	≤ 80'
Over 4/0 through 350 kcmil	≤ 135'	≤ 60'
Over 350 kcmil through 500 kcmil	≤ 120'	≤ 50'
Over 500 kcmil through 750 kcmil	≤ 95'	≤ 40'
Over 750 kcmil	≤ 85'	≤ 35'

CAUTION

When installing conductors in vertical raceways, install proper supporting devices to hold the conductors before removing the pulling equipment or cutting the conductors.

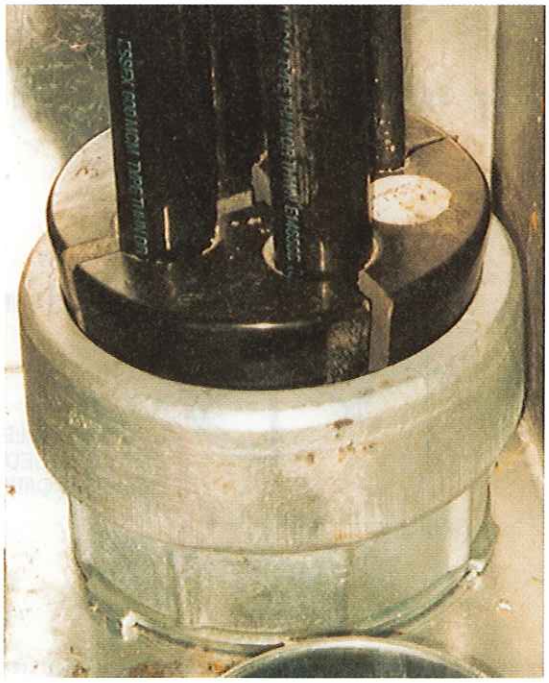

Figure 26 ◆ Conductors supported with wedges.

A variety of supports are manufactured specifically for supporting cable in vertical conduit runs, and many ideas can be obtained from the manufacturers' catalogs. Therefore, make an effort to obtain such catalogs from electrical suppliers or manufacturer's representatives. In fact, manufacturers' catalogs of electrical tools and equipment are excellent study guides for any phase of the electrical industry. Manufacturers of electrical equipment want their equipment used, and they have found that one of the best ways to accomplish this is to provide easy-to-understand instructions and examples of practical applications. Most manufacturers go to great expense to provide this information, but it is usually free of charge for those working in the industry.

There are several precautionary measures that must be taken when pulling cables in vertical runs. The worst danger is runaways; that is, the weight of the cable combined with gravity exceeds the speed of the pull and falls at a rapid rate down the raceway run. Such a situation can cause injury to workers on both ends of the pull. Consequently, braking systems should be used on all long vertical cable pulls. To do otherwise is asking for trouble. Get specific instructions from your supervisor before beginning a vertical pull—either up or down.

WARNING!

Guard against runaways on all vertical pulls. Make certain that proper braking equipment is used to stop a conductor fall should a runaway occur.

7.0.0 ◆ PULLING CABLE IN CABLE TRAYS

When long lengths of cable are to be installed in raceways or cable trays, problems are frequently encountered, particularly when the cable has to be pulled directly into the tray and changes in direction of the tray sections are involved. An entire cable-pulling system has to be planned and set up so that the cable may be pulled into the trays without scuffing or cutting the sheathing and insulation, and also to avoid damaging the cable trays or the tray hangers. To accomplish a successful cable tray pull, a complete line of installation tools is available for pulling lengths of cable up to 1,000 feet or longer. These tools consist mainly of conveyor sheaves and cable rollers. *Figure 27* shows a partial cable tray system with sheaves and rollers in place.

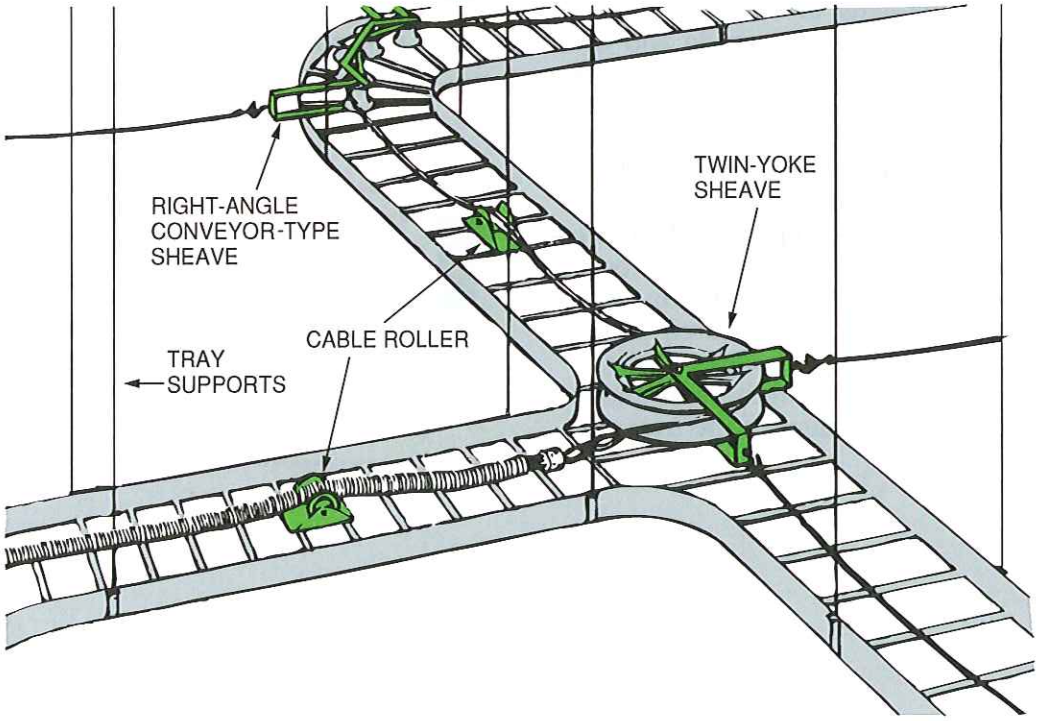

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Figure 27 ◆ Typical cable tray cable-pulling arrangement.

Short lengths of cable can be laid in place without tools or pulled with a basket grip. Long lengths of small cable (2" or less in diameter) can also be pulled with a basket grip. Larger cables, however, should be pulled by the conductor and the braid, sheath, or armor. This is done with a pulling eye applied at the cable factory or by tying the conductor to the eye of a basket grip and taping the tail end of the grip to the outside of the cable.

In general, the pull exerted on the cables pulled with a basket grip that is not attached to the conductor should not exceed 1,000 pounds. For heavier pulls, care should be taken not to stretch the insulation, jacket, or armor beyond the end of the conductor nor bend the ladder, trough, or channel out of shape.

The bending radius of the cable should not be less than the values recommended by the cable manufacturer, which range from four times the diameter for a rubber-insulated cable with a 1" maximum outside diameter without lead, shield, or armor, to eight times the diameter for interlocked armor cable. Cables or special construction such as wire armor and high-voltage cables require a larger radius bend.

Best results are obtained in installing long lengths of cable up to 1,000 feet with as many as a dozen bends by pulling the cable in one continuous operation at a speed of 20 to 25 feet per minute. It may be necessary to brake the reel to reduce sagging of the cables between rollers and sheaves.

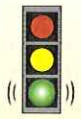
The pulling line diameter and length will, of course, depend on the pull to be made and the tools and equipment available. Winch and power units must be of adequate size for the job and capable of developing the high pulling speeds required for the best and most economical results.

In general, single or multi-cable rollers are placed in the bottom of trays to protect the cable as it is pulled along. Sheaves are placed at each change of direction—either horizontally or vertically. The bottom rollers may be secured to the tray bottoms except at vertical changes in direction. Extra support is necessary at these locations to prevent damage or movement of the tray system (see *Figure 28*).

NOTE

If single cables are to be installed, always place them on the outside of a bend to allow room on the inside of the bend for pulling other cables.

Sheaves must be supported in the opposite direction of the pull. For example, all right-angle conveyor sheaves should be supported at two locations, as shown in *Figure 29,* to compensate for the pull of the cable.



NOTE

Power cable pulls should not be stopped unless absolutely necessary. However, anyone associated with the pull—upon evidence of danger to either the cable or the workers—may stop a cable-pulling operation. Communication is the most important factor in these cases.

CAUTION

Workers feeding a cable pull must carefully inspect the cable as it is paid off the cable reel. Any visible defects in the cable at the feeding end warrants stopping the pull.

WARNING!

At the first sign of any type of malfunctioning equipment, broken sheaves, or other events that could present a danger to either the workers or the cable, the pull should be stopped. Make certain that all communications equipment is in proper order before starting a pull.

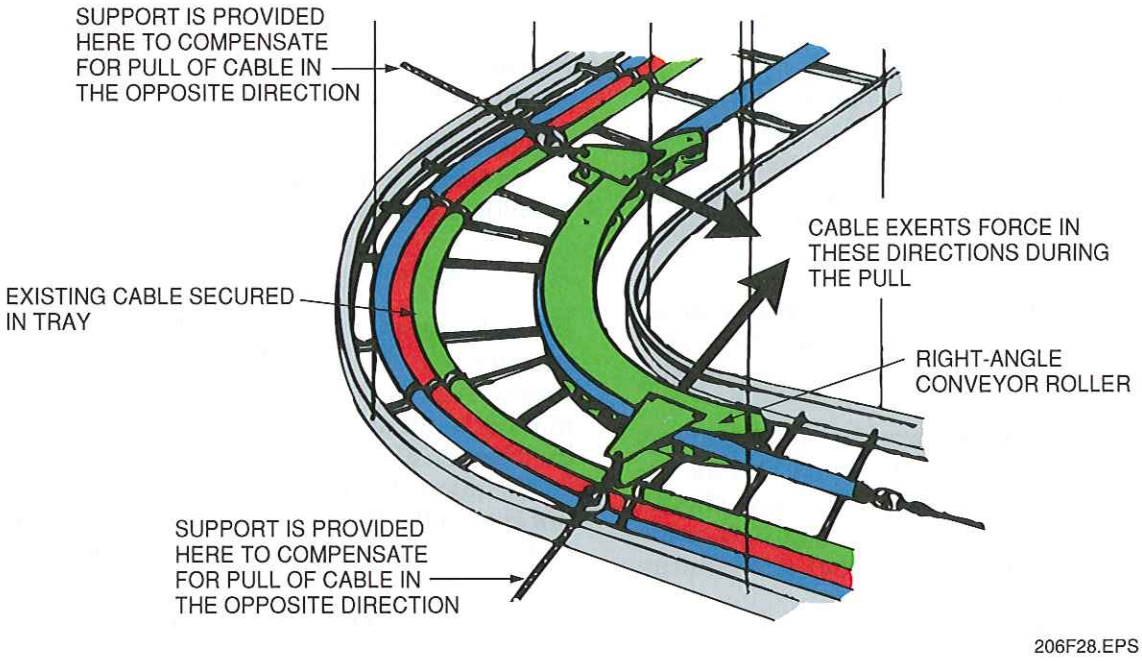


Figure 28 ◆ Support points for right-angle turns.

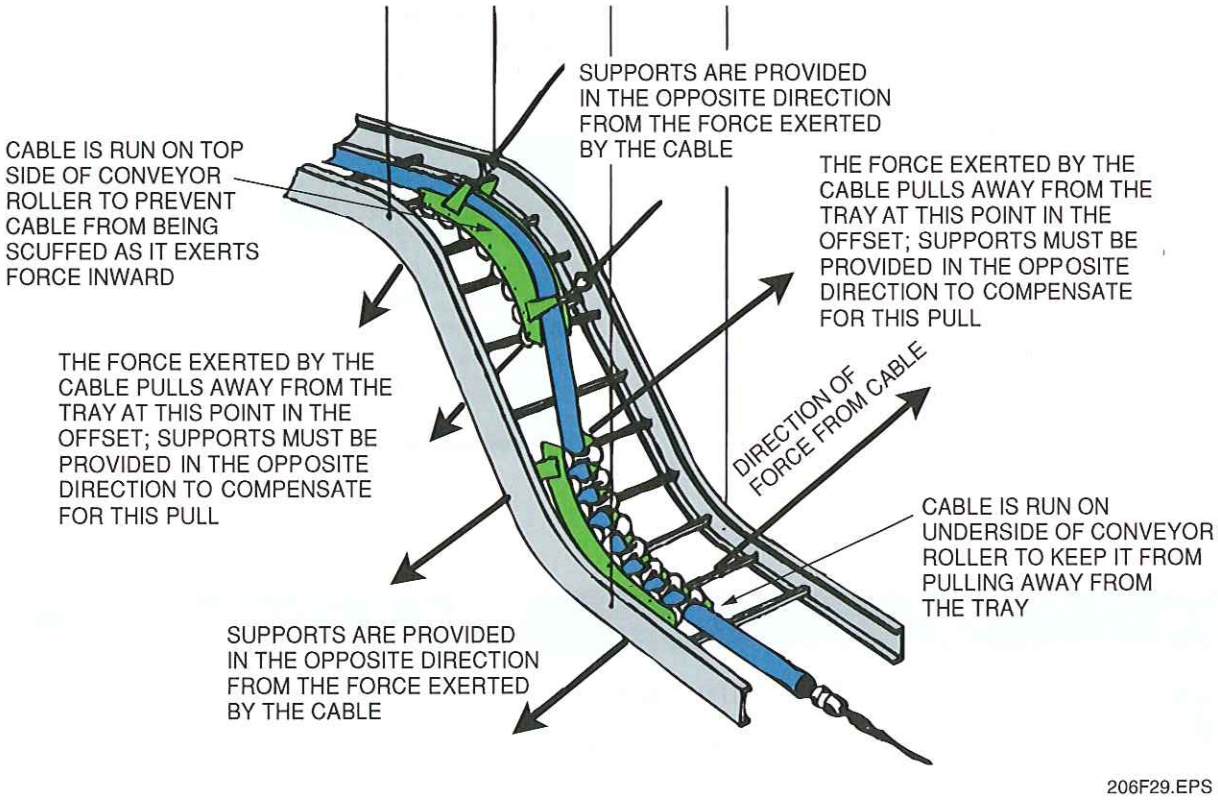


Figure 29 ◆ Typical support points for a cable tray offset.

8.0.0 ◆ PHYSICAL LIMITATIONS OF CABLE

Consideration must be given to the physical limitations of a cable as it is being pulled into position. Pulling subjects cable to extreme stress and, if done improperly, can displace a cable's components. Thus, it is important that the following guidelines be observed:

- While reels are in storage—either before or after a pull—the conductor ends must be sealed to prevent moisture from entering or creeping into the cable ends.
- The minimum ambient working temperatures for cable-pulling operations depend on the cable jackets. In cold weather, cable reels should be stored in a warm area overnight so that the cable jackets will be at the proper temperature for pulling the next day.
- Calculate and stay within the cable's maximum pulling tension, maximum sidewall load, and minimum bending radii.
- Ensure that the raceway joints are aligned and that the wiring space is sufficient.
- Train the cable to avoid dragging on the edge of the raceway; also avoid laying or dragging cable on the ground.
- If using a basket grip, secure it to the cable with steel strapping and cut well behind the areas it covers once the cable is in place. The portion of the cable under the grip should be discarded.
- Ensure that the elongation of the pull rope minimizes jerking.
- Pull with a capstan and no faster than 40 feet per minute.
- Do not stop a pull unless absolutely necessary.
- Never pull the middle of the cable.
- Seal the ends with appropriate putty or silicone caulking and overwrap with tape until the conductors are terminated.

8.1.0 Maximum Pulling Tension

Maximum pulling tension should not exceed the smaller of the following values:

- Allowable tension on pulling device
- Allowable tension on conductor
- Allowable sidewall load

8.1.1 Allowable Tension on Pulling Device

Do not exceed the working load stated by the manufacturer of the pulling devices (pulling eyes, ropes, anchors, basket grips, etc.). If catalog information is not available, work at 10% of the rated braking tensile strength.

The allowable tension with a basket grip must not exceed the lbs/cmil value (as shown in *Table 3*) or 1,000 pounds, whichever is smaller. Exceptions to this rule, however, do occur, but seldom will this figure rise to over 1,250 pounds.

8.1.2 Allowable Tension on Conductors

The metallic phase conductors are the tensile members of the cables and should bear all of the pulling force. Never use shielding drain wires or braids for pulling. Table 3 provides the allowable pulling tensions of various types of conductors. The listed values should never be exceeded.

Table 3 Physical Limitations of Cable

Material	Cable Type	Temper	Lbs/Cmil
Copper	All	Soft	0.008
Aluminum	Power	Hard	0.008
Aluminum	Power	¾ Hard	0.006
Aluminum	Power	AWM	0.005
Aluminum	URD (solid)	Soft (½ hard)	0.003
All	Thermocouple	—	0.008

INSIDE TRACK

Installation Aids

Other tools available to simplify the pulling of cables into cable tray systems include triple pulleys, bull wheels, and both wide and narrow rollers. Be sure to position these pulleys and rollers at the proper locations to prevent damage to the cables during the installation and also to help the installation proceed as quickly as possible.

CAUTION

When smaller conductors are pulled with large conductors, the smaller conductors may be damaged.

Reduce the maximum pulling tension by 20% to 40% if several conductors are being pulled simultaneously since the tension is not always evenly distributed among the conductors.

8.2.0 Calculating Pulling Tension

Normally, the maximum tension for a specific type of cable can be found using data from the cable manufacturer.

In general, the maximum tension for a single-conductor cable should not exceed 6,000 pounds. The maximum tension for two or more conductors should not exceed 10,000 pounds.

The maximum stress for leaded cables must not exceed 1,500 pounds per square inch of lead sheath area when pulled with a basket grip.

The maximum tension must not exceed 1,000 pounds per square inch of insulation area for non-leaded cables when pulled with a basket grip.

The maximum tension at a bend must not exceed 500 times the radius of curvature of the conduit or duct expressed in feet.

8.2.1 Tension in Horizontal Pulls

The pulling tension in a given horizontal raceway section may be calculated as follows:

For a straight section, the pulling tension is equal to the length of the duct run multiplied by the weight per foot of the cable and the coefficient of friction, which will vary depending on the type and amount of lubrication used. Therefore, the equation is as follows:

$$T = L \times w \times f$$

Where:

T = total pulling tension
L = length of raceway run in feet
w = weight of cable in pounds per foot
f = coefficient of friction

For ducts having curved sections, the following equation applies:

$$T_{OUT} = T_{in}\, e^{fa}$$

Where:

T_{OUT} = tension of bend
T_{in} = tension into bend
f = coefficient of friction
e = Napierian logarithm base 2.718
a = angle of bends in radians

To aid in solving the above equation, values of e^{fa} for specific angles of bend and coefficients of friction are listed in *Table 4*. For more precise values, tables are available from cable manufacturers.

8.3.0 Sidewall Loading

Before actually getting into a practical application of calculating cable-pulling tension, we will discuss one more factor involved during the process of wire pulling—sidewall loading or sidewall bearing pressure.

The sidewall load is the radial force exerted on a cable being pulled around a conduit bend or sheave. Excessive sidewall loading can crush a cable and is, therefore, one of the most restrictive factors in installations having bends or high tensions. *Figure 30* shows a section taken across a conduit run in a 90° bend. Note that pulling tension is exerted parallel with the walls of the

Table 4 Angle of Bend vs. Coefficients of Friction

Angle of Bend (degrees/ radians)	Values of e^{fa} for Coefficients of Friction		
	f = 0.75	f = 0.50	f = 0.35
15/0.2618	1.22	1.14	1.10
30/0.5236	1.48	1.30	1.20
45/0.7854	1.80	1.48	1.32
60/1.0472	2.19	1.68	1.44
90/1.5708	3.25	2.20	1.73

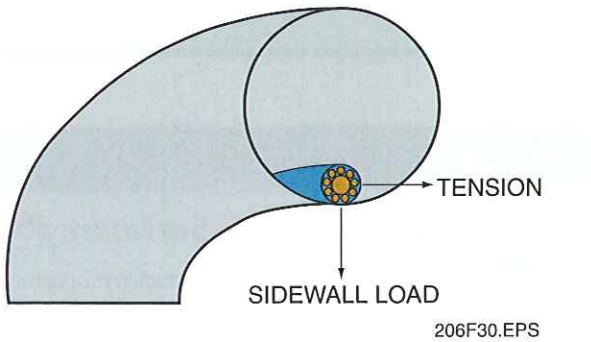


Figure 30 ◆ Sidewall loading.

conduit. However, due to the 90° bend, pressure is also exerted downward against the wall of the conduit. Once again, this is known as the sidewall load. Sidewall loading is reduced by increasing the radius of bends.

In general, the sidewall load on any raceway run should not exceed 500 pounds/foot of bend radius. This pressure, however, must be reduced on some types of cables. For example, *Table 5* shows one manufacturer's recommendations for the maximum sidewall pressures permitted for various types of cables. Always refer to the cable manufacturer's instructions for the type of cable being used.

8.4.0 Practical Applications

Figure 31 shows a typical raceway system containing three 500 kcmil lead sheath copper conductors. Note the straight 300' run from A to B, a 45° kick, and then another 100' straight run from C to D. We will find the calculated pulling tension from D to A.

Referring to cable data in the manufacturer's catalogs, we find that this cable weighs 8 pounds per foot and has a 0.141" lead sheath. The outside diameter of the three-conductor cable assembly is 3". We will use 0.5 as the coefficient of friction and proceed with our calculation of the pulling tension from A to B *(Figure 31)* as follows:

Table 5 Maximum Sidewall Pressures for Various Types of Cable

Cable Type	Sidewall Pressure in Pounds/Foot of Bend Radius
600V nonshielded control	300
600V and a kV nonshielded EP power	500
5kV and 15kV EP power	500
25kV and 35kV power	300
Interlocked armored cable (all voltages)	300

Step 1 Find the tension between points A and B.

$$\text{Tension at B} = T_1 = L_1 \times w \times f$$

L_1 is the length between points A and B while w is the weight of the cable per foot, and f is the coefficient of friction, which we have determined to be 0.5. Substituting the known values in the equation, we have:

$$T_1 = 300 \times 8 \times 0.5 = 1{,}200 \text{ pounds}$$

Step 2 Find the tension between points B and C.

$$\text{Tension at C} = T_1 e^{fa}$$

Since the distance between B and C involves an angle, refer to *Table 4* of this module. Looking in the left column of the table, we see that 45° equals 0.7854 radians; this figure multiplied by the coefficient of friction (0.5) equals 0.3927. Radians of angles may also be found with electronic pocket calculators if they have scientific functions. Follow the instructions in the manual accompanying the calculator. The exact key strokes will vary with the brand of calculator, but most require pressing the degree key, entering the numeral for degrees, then pressing the convert key, and finally pressing the radian or RAD key. The radians of the entered angle will be displayed.

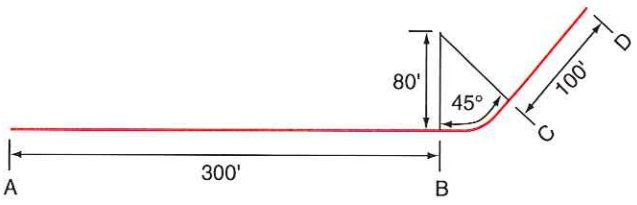


Figure 31 ◆ Sample conduit run.

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Software Programs

Software programs are now available to take the math out of calculating pulling tensions. These programs typically calculate pulling tension and sidewall pressures based on conductor size using their own data on friction coefficients. These programs also determine conduit fill, conductor configuration, jam ratios, and the amount of lubricant required for the pull.

Once again, refer to *Table 4*. Find the 45° angle of bend in the left column; read across the row to the column under 0.50—our coefficient of friction figure. The number is 1.48, the value of e^{fa}. Substituting these values in the equation, we have the following:

$$A = 45° = 0.7854 \text{ radians}$$

$$fa = 0.7854 \times 0.5 = 0.3927$$

$$e^{fa} = 1.48$$

$$1{,}200 \times 1.48 = 1{,}776 \text{ pounds}$$

Therefore, the tension at C is 1,776 pounds.

Step 3 Find the tension from points C to D.

$$\text{Tension from C to D} = T_2 = L_2 \times w \times f$$
$$T_2 = 100 \times 8 \times 0.5 = 400 \text{ pounds}$$

Step 4 Find the total pulling tension by adding the figures obtained previously.

$$T = T_2 + T_1 e^{fa} = 400 + 1{,}776$$
$$= 2{,}176 \text{ pounds}$$

The maximum pulling force using a basket grip for this size cable should not exceed 1,900 pounds. Therefore, if the pull is made from point A to point D, a pulling eye will have to be used since the total pulling tension exceeds 1,900 pounds. However, if the pull is reversed—pulling from point D to point A—the total pulling tension will be reduced since the distance from point D to the 45° angle (point C) is ⅓ the distance from point A to the 45° angle (point B).

$$\text{Tension at C} = 400 \text{ pounds}$$

$$\text{Tension at B} = 400 \times 1.48 = 592 \text{ pounds}$$

$$\text{Total tension at A} = 1{,}200 + 592$$
$$= 1{,}792 \text{ pounds}$$

Therefore, if the cable is pulled from point D to point A, either a pulling eye or basket grip may be used.

NOTE

A lower tension is obtained by feeding the pull from the end nearest the bend.

9.0.0 ◆ CABLE PULLING INSTRUMENTS

There are several instruments used in conjunction with cable pulling operations. Since details of operation vary with the manufacturer, these instruments will only be briefly discussed in this module. However, your instructor will cover exact operating details of one or more of these instruments during your training sessions. Operating manuals are also packaged with each instrument before shipping. Try to obtain manuals for the instruments used by your employer and study these to obtain a better understanding of the instruments you will be using on the job.

- *Cable length meters* – Cable length meters are available for direct reading in lengths from 2,000' to 20,000'. Most are calibrated for different wire sizes whereas the sizes are selected with a selector switch on the instrument. Controls may also be set for either copper or aluminum conductors. These instruments are ideal for determining the exact length of conductors on reels prior to making a pull.
- *Wire sorter* – This instrument is for use on unenergized circuits for tracing conductors. In use, one lead is attached to ground while the numbered leads are attached to the wires being traced. The wires are then marked to correspond with the instrument leads. The instrument is then taken to the opposite end of the circuit. Attach the identifier to ground and then touch each wire end with the probe to read the wire number. This end of the run is then marked accordingly.
- *Dynamometer* – This type of meter is designed to read dynamic friction during a cable pull. Many are designed for a specific cable-pulling tool and are shipped as an integral or optional part of the cable puller. For example, one common cable puller electronically displays both actual speed and actual force while running. Furthermore, this puller automatically shuts down when maximum preset force is reached to prevent damage to the cable being pulled. Others are portable units for use with any type of cable-pulling equipment. Such instruments are invaluable for use during high-force cable pulls to avoid damage to conductors during the pull. When the instrument indicates that the maximum pulling force has been reached, the pull can be stopped before damage occurs to the cable or conductors.

CASE HISTORY

Cable Pulling

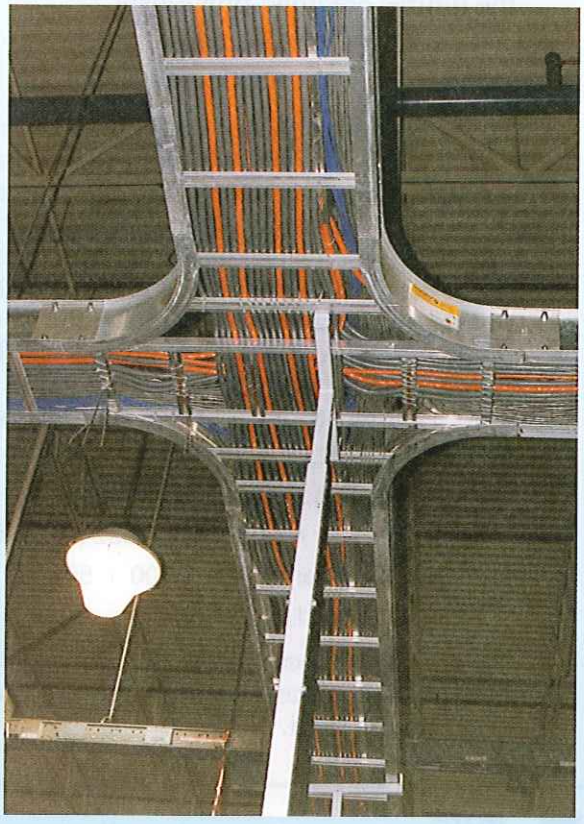
At a large commercial job site this past summer, workers began a complex pull shortly before the end of the day. At 5 P.M., they left for the day, having completed only a portion of the pulling operation. The next day, they resumed work promptly at 8 A.M., but the pulling lubricant had already dried in the conduit. As a result of the excess friction on the pull, the rope broke, destroying thousands of feet of expensive cable.

The Bottom Line: Don't stop a pull in the middle of a job.

INSIDE TRACK

Complex Installations

Complex cable-pulling installations are best handled by highly experienced contractors. This is one small portion of an award-winning installation that took over 70,000 hours to complete.



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Review Questions

1. Who is allowed to stop the pull at the first sign of danger to the cable, raceway system, or personnel?
   a. Only the project supervisor
   b. Only workers on the feeding end of the run
   c. Only workers on the pulling end of the run
   d. Anyone involved with the pull

2. After some length of conductor has been used from a cable reel, what should be done before placing the reel in storage?
   a. A stress test should be made to see if the cable has been damaged.
   b. An insulation test should be made using a megger.
   c. The ends of the conductors should be sealed.
   d. The conductor jacket should be warmed before storing.

3. Which of the following precautions should be taken when making a cable pull in extremely cold weather?
   a. The cable should be stored in a warm area overnight.
   b. The cable should be stored outside overnight.
   c. Antifreeze should be mixed with the pulling lubricant.
   d. Electric warming blankets should be used during the pull.

4. Which of the following pulling methods should be used when the pulling tension exceeds 1,000 pounds?
   a. A basket grip by itself
   b. A pulling eye
   c. Conductors bent around a hook and taped
   d. Conductors bent around a snake hook and left untaped

5. Which of the following methods is *not* true with regard to transporting or storing cable reels?
   a. Reels should be stored in an upright position.
   b. Reels should be laid flat on their sides.
   c. Reels should be lifted by a rigged crane with a spindle through the reel.
   d. Reels should be carried with a forklift so that the forks do not touch the cable.

6. Where is the best place to seek information about a wire-pulling lubricant that is compatible with a particular type of cable insulation?
   a. The lubricant manufacturer
   b. The cable manufacturer
   c. Both the cable and lubricant manufacturers
   d. The *NEC*®

7. How should the feed-in setup be handled during a cable installation?
   a. The cable should unreel with a reverse S curvature.
   b. It makes no difference.
   c. Only the pulling end is important when unreeling the cable.
   d. The cable should unreel along its natural curvature.

8. Which of the following is *not* used to guide cable during a pull?
   a. A conveyor sheave
   b. A polygon setup
   c. A guide-in tube
   d. A cable reel

9. Which of the following is the most important consideration when pulling cables in vertical pulls?
   a. Calculate the cable weight before installation.
   b. Install the cable from the bottom up.
   c. Guard against runaways.
   d. Use less wire lubricant than in horizontal applications.

10. Which of the following best describes the location of sheave supports for pulling cable in cable trays?
    a. They should be supported in the opposite direction of the pull.
    b. They should be supported in the same direction as the pull.
    c. They should be supported only by the tray assembly itself.
    d. No support is necessary when sheaves are used in cable trays.

Summary

A cable-pulling operation involves careful planning. Furthermore, the proper use of appropriate equipment is crucial to a successful cable installation. Think of everything that can go wrong, and then plan accordingly.

Communications equipment is another crucial part of a cable installation. Workers on both ends must be in constant contact with each other in case something goes wrong. The workers feeding the cable must carefully inspect the cable as it is paid off the reels and stop the pull immediately if the cable appears damaged. In fact, anyone involved with the pull should be able to stop the pull whenever the safety of the cable or personnel is threatened. Again, good communication is crucial.

Safety precautions must be followed exactly during any cable installation. Use the correct size and type of equipment for the job. Never exceed the maximum force of the weakest component. Do not position yourself in a direct line with a cable pull.

Notes

Trade Terms Introduced in This Module

Basket grip: A flexible steel mesh grip that is used on the ends of cable and conductors for attaching the pulling rope. The more force exerted on the pull, the tighter the grip wraps around the cable.

Cable grip: A device used to secure ends of cables to a pulling rope during cable pulls.

Capstan: The turning drum of a cable puller on which the rope is wrapped and pulled. An increase in the number of wraps increases the pulling force of the cable puller.

Clevis: A device used in cable pulls to facilitate connecting the pulling rope to the cable grip.

Conductor support: The act of providing support in vertical conduit runs to support the cables or conductors. The *NEC*® gives several methods in which cables may be supported, including wedges in the tops of conduits, supports to change the direction of cable in pull boxes, etc.

Conduit piston: A cylinder of foam rubber that fits inside the conduit and is then propelled by compressed air or vacuumed through the conduit run to pull a line, rope, or measuring tape. Also called a *mouse*.

Extension boom: Part of a cable-pulling apparatus that is usually used when pulling conductors through concealed conduit runs.

Extension bushing: Used to extend the end of the conduit in panels and other enclosures to provide a grip for the flexible adapter sheave.

Fish line: Light cord used in conjunction with vacuum/blower power fishing systems that attaches to the conduit piston to be pushed or pulled through the conduit. Once through, a pulling rope is attached to one end and pulled back through the conduit for use in pulling conductors.

Fish tape: A flat iron wire or fiber cord used to pull conductors or a pulling rope through conduit.

Setscrew grip: A cable grip, usually with built-in clevis, in which the cable ends are inserted in holes and secured with one or more setscrews.

Sheave: A pulley-like device used in cable pulls in both conduit and cable tray systems.

Soap: Slang for wire-pulling lubricant.

Additional Resources

This module is intended to present thorough resources for task training. The following reference works are suggested for further study. These are optional materials for continued education rather than for task training.

American Electrician's Handbook, Latest Edition. New York: Croft and Summers, McGraw-Hill.

Cable Installation Manual, Latest Edition. New York: Cablec Corp.

National Electrical Code® Handbook, Latest Edition. Quincy, MA: National Fire Protection Association.