US ARMY ENGINEER CENTER AND SCHOOLS

INSTALL CONDUIT SYSTEMS

"LET US TRY"

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM
INSTALL CONDUIT SYSTEMS

Subcourse Number EN5143

EDITION A

United Status Army Engineer School
Fort Leonard Wood, Missouri 65473

8 Credit Hours

Edition Date: July 1993

SUBCOURSE OVERVIEW

This subcourse is designed to teach the knowledge necessary to classify and size, cut and thread, bend, and install conduit, and to install conductors.

There are no prerequisites for this subcourse.

This subcourse reflects the doctrine which was current at the time it was prepared. In your own work situation, always refer to the latest official publications.

Unless otherwise stated, the masculine gender of singular pronouns is used to refer to both men and women.

TERMINAL LEARNING OBJECTIVE

ACTION: You will describe the different types and sizes of conduit, the methods of cutting and threading conduit, the use of calculations and methods of making bends in conduit, and the installation of conduit and conductors.

CONDITION: You will be given subcourse booklet EN 5143 and an ACCP examination response sheet.

STANDARD: To demonstrate competency of this task you must achieve a minimum of 70% on the subcourse examination.
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LESSON 1
CLASSIFYING AND SIZING CONDUIT

Critical Task: 051-246-1114

OVERVIEW

LESSON DESCRIPTION:
In this lesson, you will learn to identify and describe the different types and sizes of conduit.

TERMINAL LEARNING OBJECTIVE:
ACTION: Describe the different types and sizes of conduit.

CONDITION: You will be given subcourse booklet EN5143 and an ACCP examination response sheet You will work at your own pace and in your own selected environment with no supervision.

STANDARDS: Complete the lesson and the practice exercise.

REFERENCES: No supplementary references are needed for this lesson.

INTRODUCTION

This lesson, part of the MOS 51R Skill Levels 1 and 2 course, is designed to teach the knowledge necessary to identify and describe the different types and sizes of conduit.

Although several types of conduit are used in electrical work, only four types will be discussed in this subcourse: rigid steel, electrical metallic tubing (EMT), flexible, and polyvinyl chloride (PVC) conduit.

Conduit is a rugged, protective tube through which wires are pulled. Careful planning and a certain amount of practice will result in a professional-looking electrical system. A conduit wiring system is probably the most challenging of the electrical systems to install.
PART A: IDENTIFYING RIGID STEEL CONDUIT

Rigid steel conduit is a heavy-duty pipe which is threaded at each end. Rigid steel conduit provides the best protection from physical abuse. (See Figure 1-1.)

![Figure 1-1. Rigid steel conduit](image)

Conduit comes in a variety of sizes. The size is the inside-diameter measurement. Rigid steel conduit is available in sizes from 1/2 to 6 inches. These sizes will accommodate any job. A breakdown of the sizes of rigid steel conduit is shown below.

<table>
<thead>
<tr>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4</td>
</tr>
<tr>
<td>1/2</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1 1/2</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>2 1/2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>3 1/2</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

A full-length piece or slick of rigid steel conduit is 10 feet long. Galvanized steel conduit is available for application in wet areas or underground. Galvanizing prevents rusting of the wet conduit.
PART B: IDENTIFYING ELECTRICAL METALLIC TUBING (EMT)

EMT is a light-gauge pipe often referred to a thin-wall conduit (Figure 1-2). The wall thickness of EMT is about 40 percent of that of rigid steel conduit.

![Figure 1-2. EMT conduit](image)

EMT is available in inside-diameter size ranging from 1/2 to 4 inches and in one length of 10 feet. A breakdown of the size is shown below. Like rigid steel, EMT is also measured by the inside diameter.

<table>
<thead>
<tr>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
</tr>
<tr>
<td>3/4</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>1 1/2</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>2 1/2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>3 1/2</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>
PART C: IDENTIFYING POLYVINYL CHLORIDE (PVC) CONDUIT

PVC (plastic) is produced and used for below-ground (direct burial or concrete encasement) installation. PVC conduit provides high strength, low absorption rate, watertight joints, and low installation costs. Plastic conduit comes in sizes (inside diameter) of 1 1/2 to 6 inches and in one length of 20 feet (See Figure 1-3.)

![Figure 1-3. Plastic conduit](image)

PVC conduit is available in the inside-diameter sizes listed below.

<table>
<thead>
<tr>
<th>Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>3 1/2</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

PART D: IDENTIFYING FLEXIBLE METAL CONDUIT

Flexible metal conduit is similar in appearance to metallic armor cable. Wires, however, are not installed until the conduit is installed. Flexible conduit is generally used where some type of movement or vibration may be present, such as wiring motors. The size range of flexible metal conduit for steel and aluminum is shown in Figure 1-4.

Flexible metallic and nonmetallic liquid-tight conduit is available for use in wet areas. (See Figure 1-5.)
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LESSON 1

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this part of the lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which of the following types of conduit provide the best protection from physical abuse?

   A. Flexible
   
   B. EMT
   
   C. Rigid steel
   
   D. PVC

2. How can rusting of steel conduit be prevented when underground installation is called for?

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

1-7
## LESSON 1

### PRACTICE EXERCISE

### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>C. Rigid steel conduit is the heaviest and has the thickest wall of the metallic conduit. Rigid steel conduit provides the best protection for conductors. (See page 1-2.)</td>
</tr>
<tr>
<td>2.</td>
<td>When installation of conduit in wet soil is necessary, galvanized steel conduit can be used to prevent rusting of the conduit (See page 1-2.)</td>
</tr>
</tbody>
</table>
LESSON 2

CUTTING AND THREADING CONDUIT

Critical Task: 051-246-1114

OVERVIEW

LESSON DESCRIPTION:

In this lesson you will learn to describe the methods of cutting and threading conduit so that connections can be made electrically secure and mechanically tight.

TERMINAL LEARNING OBJECTIVE:

ACTION: Describe the methods of cutting and threading conduit

CONDITION: You will be given subcourse booklet EN 5143 and an ACCP examination response sheet. You will work at your own pace and in your own selected environment with no supervision.

STANDARDS: Complete the lesson and the practice exercise.

REFERENCES: No supplementary references are needed for this lesson.

INTRODUCTION

This lesson, part of the MOS 51R Skill Levels 1 and 2 course, is designed to teach the knowledge necessary to identify the methods used for cutting and threading conduit so that connections can be made electrically secure and mechanically tight. Although it may seem at first glance to be a simple task, cutting and threading conduit efficiently requires considerable skill. With the instructions that follow, and with on-the-job experience, you should soon be able to do this well.
PART A: CUTTING CONDUIT

Regardless of the type of conduit you are installing, you will often have to cut it to make it fit. Rigid conduit can be cut with either a hacksaw or a pipe cutter. Although a vise is not absolutely necessary, it makes cutting with either tool much easier. (See Figure 2-1.)

![Figure 2-1. Conduit-cutting tools](image)

When you cut any conduit with a hacksaw, you should use a blade with 18 to 32 teeth per inch. A blade with fewer teeth will hang up, bind, or even break (See Figure 2-2.).

Place the blade in the hacksaw frame so that the teeth will cut when you push the saw forward. Place the pipe in the vise so there will be ample room between the vise and where the cut will be. This will let you saw without hitting your hands on the vise, and will also allow enough room for threading purposes after the cut is made. Remember, let the saw work for you, do not force it. Use a steady, forward cutting stoke with light to medium pressure.
To use a pipe cutter, place the conduit in the vise as was described for cutting with a hacksaw. Put the cutter over the conduit and adjust it until the cutting wheel makes contact at the point of the cut (See Figure 2-3, page 2-4.)

Tighten the cutter just enough to score the pipe on the first turn. Then screw the handle in approximately one-fourth of a turn for each turn around the conduit until the cut is complete. Cutting oil can be used to ease the cutting action. Intermediate conduit and rigid conduit are cut the same way.
Thin-wall conduit (EMT) and PVC should be cut with a hacksaw because pipe cutters may flatten the end of the pipe. Pipe cutters also leave a ridge on the inside of the pipe that is very hard to remove. There are tubing cutters made specifically for cutting EMT or PVC (Figure 2-4), but you must be sure you have the correct cutter for the job. As stated before, when you are cutting conduit with a hacksaw or tubing cutter, using the vise will make the job much easier. The tubing cutter is used the same way as the pipe cutter.
Flexible conduit (flex) and tubing should also be cut with a hacksaw. Because of its spiral construction, flex should be cut at an angle so that only one ribbon is cut all the way through. A slight reverse twist will separate the two ends. (See Figure 2-5.)

Figure 2-5. Cutting flexible conduit

Cutting any type of conduit leaves a sharp edge or burrs on the inside of the pipe that must be removed by reaming. As shown in Figure 2-6, page 2-6, reaming can be done with several tools.

To ream rigid and intermediate conduit the reamer shown in Figure 2-6 can be used. A rat-tail file does a good job on any type of conduit. The jaws of a pair of pliers, such as needle-nose or side-cutting pliers, should be used to ream EMT that has been cut with a hacksaw. The important thing is to remove any edge or burrs in the pipe that might cut the insulation when the conductors are pulled into the conduit.
PART B: THREADING CONDUIT

Once rigid metal conduit or intermediate metal conduit is cut, it must be threaded for use with threaded couplings, locknuts, and bushings. To thread conduit, use a standard conduit-cutting die with a 3/4-inch taper per root. This die cuts a deeper thread on the end of the conduit and then tapers the cut at the rear or shoulder of the thread. This is just the opposite of a running thread on a bolt (See Figure 2-7)
You can see both conduits are wrench-tight in the coupling but thread is showing on the outsides. The dies used for threading smaller sizes of conduit are usually hand-driven. The handle may be solidly attached to the die, or the die assembly may be of the ratchet type. For larger sizes or when large installations are made that require considerable conduit threading, a motor-driven, pipe-threading machine is recommended.

The most common rigid conduit threader uses nonadjustable ratchet dies (Figure 2-8), which come in sizes to fit conduit from 1/2 to 2 inches.
Before threading the pipe, inspect the dies to see that they are sharp and free from nicks and wear. Next, insert the pipe into a vise, place the guide end of the pipe threader on the pipe, and push the threading dies against the pipe with the heel of your hand. (See Figure 2-9.)

![Image]

**Figure 2-9. Placing the die**

With pressure against the threader, take three or four short, clockwise strokes downward to start the threads. Continue the threading with clockwise strokes, mixed with a reverse stroke every now and then, unless two or three threads extend beyond the die. To reverse the threader, you must pull the ratchet lock out and turn it a half turn. The reverse turns keep the threads and dies clean and free of bits of metal. Cutting oil applied during the threading helps the cutting process by reducing friction. To remove the threader, release the ratchet lock and turn the die by hand counterclockwise. Removal of the die also cleans the threads.

It is important that the right amount of threads be cut for the job. In other words, a full thread must be cut so that the ends of the conduit will come together in a coupling.

Full threads are also necessary for the conduit to make a firm seat in the shoulder of a threaded hub of a conduit fitting. Cutting threads until two or three threads extend beyond the die will usually give you a full thread. However, if too many threads are cut, the conduit will fit too loosely in the coupling or hub.

Power threaders come in basically two types: stationary threaders built for use in the shop and portable threaders built for use in the field. Both types are driven by electric motors that have adjustable chucks and dies for use on different size conduits. Portable threaders will normally handle up to 2-inch conduit. Shop threaders may be built to handle up to 6-inch conduit. The manufacturer's operating instructions should be consulted before using these power tools.
LESSON 2

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this part of the lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. How many teeth per inch should a hacksaw blade have for cutting intermediate or thin-wall conduit?
   
   A. 10-15
   B. 14-20
   C. 16-24
   D. 18-32

2. What is the taper in inches per foot of a standard conduit-cutting die?
   
   A. 3/4
   B. 1
   C. 1 1/4
   D. 1 1/2
### LESSON 2

#### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>D. When you cut any conduit with a hacksaw, you should use a blade with 18 to 32 teeth per inch. (See page 2-2.)</td>
</tr>
<tr>
<td>2.</td>
<td>A. To thread conduit, you should use a standard conduit-cutting die with a 3/4-inch taper per foot. (See page 2-6.)</td>
</tr>
</tbody>
</table>
LESSON 3
BENDING CONDUIT

Critical Task: 051-246-1114

OVERVIEW

LESSON DESCRIPTION:
In this lesson, you will learn to describe the use of calculations and methods of making bends in conduit.

TERMINAL LEARNING OBJECTIVE:

ACTION: Describe the use of calculations and methods of making bends in conduit.

CONDITION: You will be given subcourse booklet EN 5143 and an ACCP examination response sheet. You will work at your own pace and in your own selected environment with no supervision.

STANDARDS: Complete the lesson and the practice exercise.

REFERENCES: No supplementary references are needed for this lesson.

INTRODUCTION

This lesson, part of the MOS 51R Skill Levels 1 and 2 course, is designed to teach the knowledge necessary to describe the use of calculations and methods of making bends in conduit.

One of the tasks you will have as an electrician is to make field bends in conduit. Although conduit bending is thought by many electricians to be difficult, it is fairly simple. It does require some thought, simple math calculations, and a lot of practice. However, it is like swimming—once you have learned how, you never forget.
PART A: METHODS OF BENDING CONDUIT

When you are installing conduit, you will need to make bends to go over or around obstacles. These bends must be made without reducing the inside diameter of the conduit at the bend. You will make most bends on the job as a part of the installation procedure. These are called field bends. Factory-made bends may be used instead of field bends; however, they increase the cost of the job because they may require more cutting, threading, and bending.

Since most of the bending you do will be done with manual bending the bending procedures taught will be made with those types of tools. There are basically two types of manual benders used for bending rigid metal conduit and EMT. They are rigid benders, called hickeys, and the one-shot benders. The one-shot bender is normally made for EMT, but some are made to be used for both EMT and rigid conduit. The one-shot bender is so called because a full 90-degree bend can be made with a single motion. Conduit sizes up to 1-inch rigid or 1 1/4-inch EMT can be bent using manual benders. Larger sizes are usually bent with power benders. (See Figure 3-1.)

Figure 3-1. Conduit benders
Conduit installations are normally referred to as runs of conduit. A run of conduit is the conduit, fittings, straps, conductors, and bends needed from one opening to the next; for example, from the panelboard to the first outlet or from the first outlet to the second outlet. In a run of conduit, or from the first outlet to the second outlet, there cannot be more than the equivalent of four 90-degree bends, for a total of 360 degrees. This includes the bends located at the box or opening. The purpose of allowing only so many bends in a run of conduit is to help in pulling conductors into the conduit. Experience has taught that if more than 360 degrees of bends are used, it is very difficult to pull conductors through the bends. By using a conduit body in a run, you provide an opening for pulling the conductors without having to mount a box. At the same time, you can make a turnaround or go over an obstacle and maintain a neat conduit installation. (See Figure 3-2.)

One of the most common bends you will make in the field is the right-angle bend, more commonly called a 90-degree bend, or just a 90. It can be used for going around an inside corner, into the top or bottom of a box from a horizontal run, or going over an object.

Anyone can make a 90-degree bend in a stick of conduit and then cut it off to make it fit the situation, but this practice wastes time and material. The secret is to find out where the bend is needed, mark the conduit accordingly, and make the bend in the right place.

This practice will save time and material. Before you can determine where to place your bender on the pipe, there are some things you must know. First, the distance from the end of the conduit to the back of the 90-degree bend is called the stub length or simply the stub (Figure 3-3A). Second, the radius of the bend takes up a part of the stub. This
part of the stub is called take-up, and is shown in Figure 3-3B. The amount of take-up depends on the type and size of the conduit you are bending (Table 3-1.)

![Figure 3-3. Conduit take-up and stub](image)

**Table 3-1. Conduit take-up**

<table>
<thead>
<tr>
<th>Size and Type of Conduit</th>
<th>Take-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2&quot; EMT</td>
<td>5&quot;</td>
</tr>
<tr>
<td>3/4&quot; EMT or 1/2&quot; rigid*</td>
<td>6&quot;</td>
</tr>
<tr>
<td>1&quot; EMT or 3/4&quot; rigid*</td>
<td>8&quot;</td>
</tr>
<tr>
<td>1 1/4&quot; EMT or 1&quot; rigid*</td>
<td>11&quot;</td>
</tr>
</tbody>
</table>

*IMC and rigid will be the same.

Now, let us see how a 90-degree bend is made to fit a specific situation. Suppose the conduit is to be run from the top of a panel to the ceiling and then run horizontally along the ceiling. The conduit is to be 1/2-inch EMT and a one-shot bender is to be used. The first step will be to measure from the top of the panel to the ceiling. This will give you the stub length. Assume this length is 18 inches. Measure 18 inches from the end of the conduit and make a mark at this point as shown in Figure 3-4.

Next look at Table 3-1 to find the take-up inches back toward the end of the conduit from your first mark. Make a second mark as you see in Figure 3-4.
Hold the bender in one hand with the lip on the floor pointed toward the stub end. Use the other hand to place the conduit in the bender. Align the bender arrow with the takeup mark (Figure 3-4). Put one foot on the footrest and hold the handle with both hands. To make the bend, apply pressure on the footrest as you pull on the handle until the handle is at about a 30-degree angle with the floor (Figure 3-5, page 3-6).

You should now have a 90-degree bend with an 18-inch stub. To see whether the bend will fit properly, you can place it next to anything that you know is a right angle and measure from the floor to the end of the stub. If the bend is not a full 90, you can place the bender back on the conduit as described previously and pull more bend. If it is more than a 90, you can place the handle of the bender over the end of the stub and, with one foot on the conduit on the floor, spring the stub back. (Right-angle bends should always be made with the conduit and the bender on the floor.)

The back-to-back bend is actually two adjacent 90-degree bends made in the same piece of conduit. You make the first 90 degree bend with a certain amount of stub as described previously. To determine where to place the bender for the second bend, you must first have an outside-to-outside measurement. This measurement is the distance from the back of the first bend to where you want the back of the second bend. You must then transfer this measurement to the conduit and make a mark.
There are two methods to make the second bend. The first is to subtract the take-up, use the arrow on the bender, and pull the bend in the same direction as you did the first bend. The second method, and probably the easiest is to turn the bender around, line up the star on the bender with your outside-to-outside measurement, and pull the bend in the opposite direction (Figure 3-6).
An offset bend is two equal bends in opposite directions. It is used to avoid contacting a part of the structure or to bring the conduit out from the structure to match a knockout in a box or panel.

Figure 3-7 shows an offset into a utility box. The angle of the bends in an offset depends on several things—how much offset is needed, how much room there is where the offset is going to be placed, and the type of obstacle you are avoiding. The offset shown is usually about 1 inch deep, and the bends are about 10-degree angles. There is no way to mark the conduit for a box offset this deep. The amount of bend and the distance between bends are estimated. The key to making a good box offset is practice. Notice that after the bends are made, the conduit sections on each end of the offset are parallel to each other.

To make accurate offsets of 2 inches or more in depth, a predetermined distance can be marked on the conduit. The distance between the bends depends on the depth of the offset and the amount of bend that you are going to use. Table 3-2, page 3-8, shows the formula you should use to find the distance to be marked on the conduit. It also shows the constant multiplier that must be used in the formula for the angle of bends you intend to use.
Let us use an example to see how the formula works. Suppose you need to avoid a part of a structure that requires a 3-inch offset and you are going to use 30-degree bends. Table 3-2 shows that the constant multiplier for 30-degree bends is 2.0. Using the formula, multiply the depth of the offset (3 inches) times the constant multiplier (2.0 inches). The result is the distance needed between the bends (6 inches).

Place the marks for the bends 6 inches part. Using the arrow of the bender, make a 30-degree bend on the same side of each mark (Figure 3-8). In this example, a 30-degree bend gives us the offset we need. If you make both bends inside the marks, you will end up with much less than the desired offset. If you make both bends outside the marks, you will have too much offset. The amount of bend, in this case 30 degrees at each mark, is obtained by using the degree markings on the bender (Figure 3-9).

Notice that the side of the conduit closest to the bender is in line with the 30-degree marking on the bender. If you have a bender without markings, you can make a layout of a 30-degree angle on a large piece of paper or on the floor with chalk. Then, check the bend against the 30-degree angle of the layout. Normally, offsets are made by making the first bend on the floor and the second bend in the air.
Figure 3-8. Bending an offset

Figure 3-9. Bender degree markings
PART C: TYPES OF BENDERS

The procedures for making the different types of bends discussed thus far have all been with a one-shot bender. The same bends can be made with a hickey bender, although the procedures are slightly different. For instance, to make a 90-degree bend in 1/2-inch rigid metal conduit, several steps must be used. (See Figure 3-10.)

Let us say you need a 20-inch stub at the end of the 1/2-inch stick of rigid conduit. The steps for bending with a hickey are as follows:

- Mark off 20 inches from the end of the conduit
- Determine the take-up for 1/2-inch rigid conduit (Table 3-1, page 3-4).
- Make a second mark 6 inches back toward the end of the conduit
- Place the hickey at the second mark and pull approximately a 30-degree bend.
- Move the bender toward the 20-inch mark about 2 inches. Pull another 30-degree bend.
- Move the bender to where the heel of the bender is on the 20-inch mark and complete the 90-degree bend.
Since the hickey bender does not usually have degree markings on it, you must estimate the amount of bend you are making with each bite. Small bites reduce the possibility of crimping or kinking the conduit.

Bending conduit is an art. Like all forms of art, the more often it is done correctly, the better the artist becomes.

Power benders are used for bending larger sizes of EMT, intermediate metal conduit (IMC), and rigid conduit. They are also used where many bends must be made, regardless of the size of conduit being used. They come in many types and sizes. Some of the more common ones are the hydraulic one-shot thin-wall and mechanical thin-wall and sweep benders. The hydraulic benders use either a hand pump or an electric pump to move a sheet that does the actual bending.

Figure 3-11, page 3-12, shows a hydraulic sweep bender that uses a hand pump. By using different size bending dies at different locations on the tie bar, this bender can be used to bend several types and sizes of conduit. The procedures for making the different types of bends with power benders are very similar to those used with manual benders. The main difference is that with the power benders, take-up for 90-degree bends and the distance between bends for offsets will not be the same as those shown in Tables 3-1 and 3-2, pages 3-4 and 3-8. This is due mainly to the fact that you are dealing with larger sizes of conduit or the shoes of the bender give a different radius of bend. Because there are so many different types and manufacturers of bends, be sure to check the manufacturer's instructions before doing any bending.

Nonmetallic conduit is used primarily in underground or permanently wet locations. Nonmetallic conduit must have a separate equipment grounding conduct installed. Allowance must be made for this conductor when the maximum number of conductors permitted by the National Electrical Code (NEC) is calculated.

Most nonmetallic conduit is made of PVC plastic.

Elbow and offset fittings are available for standard bends. For other bends, a special device called a hotbox must be used. The hotbox heats the PVC electrically and softens it so that it can be bent to the desired shape (Figure 3-12, page 3-12). Before heating the PVC (especially sizes 2 inches and larger), both ends of the section should be plugged. This traps air in the conduit. The air, heated in the hotbed, expands to prevent kinks or dislocation of the conduit when it is bent.

Nonmetallic conduit is durable, easy to work with, and moderate in cost. It is particularly well suited to areas where resistance-to moisture and corrosion is essential. The main disadvantage of nonmetallic conduit is that joints cannot be taken apart after they are cemented.
Figure 3-11. Hydraulic bender

Figure 3-12. Bending PVC
LESSON 3

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this part of the lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. Which manual bender is used to make a full 90-degree bend with one motion?
   A. Hickey
   B. EMT bender
   C. Hotbox
   D. Hydraulic

2. How many degrees of bends can be made in a run of conduit between openings?
   A. 90
   B. 180
   C. 360
   D. 420
### LESSON 3

#### PRACTICE EXERCISE

#### ANSWER KEY AND FEEDBACK

<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B. The EMT bender or one-shot bender should be used when making 90-degree bends. (See page 3-2.)</td>
</tr>
<tr>
<td>2.</td>
<td>C. When adding together the total number of degrees in a bend you must not exceed a total of 360 degrees between boxes or openings. (See page 3-3.)</td>
</tr>
</tbody>
</table>
LESSON 4
INSTALLING CONDUIT AND CONDUCTORS

Critical Task: 051-246-1114

OVERVIEW

LESSON DESCRIPTION:

In this lesson, you will learn to describe the installation of conduit and conductor as per construction prints and the NEC.

TERMINAL LEARNING OBJECTIVE:

ACTION: Describe the installation of conduit and conductors as per construction prints and the NEC.

CONDITION: You will be given subcourse booklet EN5143 and an ACCP examination response sheet. You will work at your own pace and in your own selected environment with no supervision.

STANDARDS: Complete the lesson and the practice exercise.

REFERENCES: No supplementary references are needed for this lesson.

INTRODUCTION

This lesson, part of the MOS 51R Skill Levels 1 and 2 course, is designed to teach the knowledge necessary to describe the installation of conduit and conductors. In previous lessons, we have discussed types of conduit and the fittings used with these types. We have also discussed cutting, threading, and bending conduit. In this lesson, we will cover the specific requirements for installing conduit and discuss how conductors are pulled into them.
PART A: INSTALLING CONDUIT

Several general requirements apply to all types of conduit installation. All runs must be installed as a complete system before any conductors are pulled into them. In other words, the run of conduit as described previously including conduit, fittings, and supports, must be complete before the conductors are installed. A run of conduit should be as straight and direct as possible. When a number of conduit runs are to be installed parallel and next to each other, you should install them all at the same time. The minimum size raceway that can be installed is generally 1/2-inch electrical trade size. Specific exceptions to this rule include EMT, rigid, and flexible conduit installed in specific locations. The exceptions for each type are outlined in the NEC.

All types of conduit must be reamed after they have been cut. Conduit threaded in the field must be threaded with a die that has a 3/4-inch taper per foot. Also, never use threaded couplings with running threads. Running threads weaken the conduit and may come loose. Threaded couplings and connectors used with any type of conduit must be made with tight connections. When the couplings or connectors are to be buried in concrete or masonry, they must be the concrete-tight type. When installed in wet locations, they must be the watertight type.

Fittings for EMT are of two general types: (1) watertight fittings that may be used outdoors or in any location and (2) fittings that provide strong mechanical and electrical connections, but may be used only in dry locations.

The watertight fittings join sections of tubing by means of a five-piece compression fitting (See Figure 4-1.)

![Figure 4-1. EMT watertight compression coupling](image-url)
• Place a gland nut and compression ring over the end of each piece of tubing.

• Slip a double-threaded ring (called the body) over the end of each section.

• Screw the gland nuts onto the body and tighten them to squeeze the compression ring. The ring forms a watertight seal.

A similar fitting having only three pieces is used to make a watertight joint to metal boxes (Figure 4-2).

![Figure 4-2. Compression-type box connector](image)

• Place the large nut and compression ring on the end of the EMT.

• Place the double-threaded body over the end.

• Screw the nut onto the body, squeezing the compression ring and making a watertight seal.

• Use the exposed threads on the body to secure the EMT to a weatherproof box using a locknut and bushing (Figure 4-3, page 4-4).
Fittings for use in dry locations are simpler to use and less expensive. One type consists of a sleeve and two or four setscrews (Figure 4.4).

Another form of couplings is made by using a plain sleeve and an indenting tool (Figure 4-5).

- Place the sleeve over the ends to be joined.
- Use the indenting tool to make indents in the coupling and the tubing to secure the joint. The tool makes two indents at once on either side of the coupling (Figure 4-6.)
- Use the tool twice, 1/4 turn apart, on each end of the coupling to make a total weight of eight indents at the joint (Figure 4-7.)
Fittings used for rigid conduit are similar to those used for EMT. Threaded and threadless couplings and connectors are available for use with rigid conduit. The threadless fittings are installed in the same way as those described for use with EMT. The advantage of using threadless couplings and connectors is that threading the conduit is not required (Figure 4-8, page 4-6).
Threaded couplings are screwed onto the threaded ends of the conduit and tightened with a pipe wrench (Figure 4-9).

Rigid conduit is connected to electrical boxes by locknuts (Figure 4-10). The locknuts are tightened against each side of the box wall. The bushing is placed over the end of the conduit to provide the conductor with protection from physical damage.

Fittings for flexible conduit are either internally or externally attached to the conduit. The internal type is designed to screw into the spiral of the conduit. This type of connector covers the end of the conduit completely, protecting the conductors from contact with the cut edge of the conduit. Externally attached connectors are secured to the conduit with clamping screws (Figure 4-11).

When using these connectors, make sure the cut end of the conduit is pushed as far as possible into the connector, covering the cut end and protecting the conductors from damage.
NOTE: The spiral construction of flexible conduit causes it to have a higher resistance per foot than solid metal conduit. For this reason, flexible conduit should not be used as a pounding conductor. An additional bare or green insulated grounding conductor should be included with the current-carrying conductors in flexible conduit installations.

A special type of flexible conduit is made for use in wet areas. This is known as liquid-tight flex. Liquid-tight fittings are available for use with this conduit (Figure 4-12, page 4-8).
Joints are made in PVC conduit by cementing together (Figure 4-13). The cement used is actually a solvent that softens the plastic at the joint and allows the softened areas to flow together to form a "weld". The resulting joint is watertight and strong. PVC conduit can be cut readily with any fine-tooth saw.

When you run conduit from one point to another, you often need to make more turns than the NEC allows in a single run (360 degrees of bend). When this is the case, you can use a fitting called a conduit body. Conduit bodies are often referred to by their brand name, such as Condulet or Unilet. A conduit body, as defined in the NEC, is "a separate portion of a conduit or tubing system that provides access through a removable cover to the interior of the system at a junction of two or more sections of the system or at a terminal.
point of the system." Figure 4-14 shows some of the more common conduit bodies and covers.

A conduit body is put in conduit between two outlets to keep the bends within NEC limits for a single run (Figure 4-15). As you can see, the run on the left has bends that total 360 degrees, which is all the NEC permits. Thus, a conduit body had to be installed so that the conduit could be continued to the box on the right.
Conduit must be supported by straps or hangers throughout the entire run (Figure 4-16).

On a wooden surface, nails or wood screws can be used to secure the straps. On brick or concrete surfaces, you must first make a hole with a star or carbide drill and then install an expansion anchor. Use an expansion tool to force the anchors apart forming a wedge to hold the anchor in the hole. Secure the strap to the surface with machine screws attached to the anchor. On tile or other hollow material, secure the straps with toggle bolts. If the installation is made on metal surfaces, you can drill holes to secure straps or hangers with machine or sheetmetal screws.

The number of supports needed depends on the type of conduit being used. Holes or notches in framing members may serve as supports. EMT and IMC require supports within 3 feet of each outlet box, junction box, cabinet, or fitting, and every 10 feet thereafter. Rigid metal conduit must also be supported within 3 feet of a box. The distance between supports may be increased to 20 feet on direct vertical runs of rigid conduit from machine tools and other equipment. If threaded couplings are used and the riser is supported at each end.

Rigid nonmetallic conduit must be supported as follows:

<table>
<thead>
<tr>
<th>Conduit Size (Inches)</th>
<th>Maximum Space Between Supports (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 to 1</td>
<td>3</td>
</tr>
<tr>
<td>1 1/4 to 2</td>
<td>5</td>
</tr>
<tr>
<td>2 1/2 to 3</td>
<td>6</td>
</tr>
<tr>
<td>3 1/2 to 5</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

In addition, rigid nonmetallic conduit must be supported within 3 feet of each opening.

Flexible metal conduit and liquid-tight flex must be supported at intervals not to exceed 4 1/2 feet and within 12 inches on each side of every outlet box or fitting. Exceptions to this are runs of 3 feet or less where flexibility is needed, or 6 feet when connecting light fixtures.

After all conduit has been installed, supported, and connected to the boxes, you are ready to install the wire.
Nearly all types of wire may be used in conduit installation; however, the most common type used is thermoplastic, moisture-resistant (TW). To determine the length of wire to be pulled, add (1) the length of conduit, (2) the size and number of boxes that a conductor will pass through, (3) the length of wire to be left in the boxes, and (4) the makeup at the breaker panel.

The general procedure for installing conductors in conduit is the same for all types of conduit. Conductors are installed by pulling them through the conduit. The pulling is done with a special tool called a fish tape (Figure 4-17).

The fish tape is fed through the conduit from its storage reel. Usually the tape is fed in at a box installed for a switch or receptacle. The tape is pulled out of the next opening in the line (Figure 4-18, page 4-12).

Conductors are fastened to the end of the tape. The tape is then pulled or reeled in to draw the conductors through the conduit. If the run is long, two people are needed for this job. One feeds the conductors in at one end as the other reel in the fish tape.

In most cases, there will be more than one conductor being fed into the conduit. It is important to keep the conductors smooth and free of kinks. Set up the conductor spools so that they unwind freely and can be kept free of bends and crossovers.

When more than one conductor is to be pulled, the connection to the fish tape should be staggered to avoid a bulky connection that would make pulling difficult (Figure 4-19, page 4-12).
Figure 4-18. Fish tape fed through boxes

Figure 4-19. Staggered conductors for easy pull

If the conductors become twisted, they are difficult to pull around bends. For particularly long runs or where there are many bends, wires can be coated with a lubricating compound. Noncorrosive lubricating components are available in dry powder form and in paste.

Sometimes nonmetallic cable, rather than individual conductors, is installed, in conduit. This is done in locations where special protection is needed, such as below grade in residences. The extra stiffness and larger diameter of cable require that special care be taken when feeding the cable into the conduit to avoid damage to the cable.
The procedure of pulling conductors between switch or receptacle boxes is continued until the complete system is wired. Sometimes, if no switch or receptacle box is called for on a long run, a conduit body of Condulet must be installed near the middle of the run to make conductor installation easier. Condulets can be used as pull boxes by opening the hatch. Be sure to leave at least 6 inches of wire at each box to make connections to the switch, receptacle, or fixture that will be installed later.

Whenever possible, run conductors from box to box without a break (Figure 4-20). In particular, the white or gray insulated (neutral) wire should be continued unbroken. When the fish tape has been reeled in, hold the red or black conductors and pull out enough white wire to reach the next box or the end of the run. At each box where a connection must be made, leave a loop of white wire. The wire can be connected by removing a section of insulation without cutting the conductor. In many cases, the red and black wires can also be continued in this manner. Continuing conductors in this way reduces the number of connections that must be made in electrical boxes. This speeds up work and keeps boxes uncrowded.

![Figure 4-20. Continuing conductors box to box](image-url)
LESSON 4

PRACTICE EXERCISE

The following items will test your grasp of the material covered in this part of the lesson. There is only one correct answer for each item. When you complete the exercise, check your answer with the answer key that follows. If you answer any item incorrectly, study again that part of the lesson which contains the portion involved.

1. All but one type of metal conduit can serve as a grounding conductor. Which one cannot?
   
   A. Rigid
   B. Flexible
   C. EMT
   D. Intermediate

2. Referring to the answer to question 1, tell why this type of conduit is not allowed to be used as a grounding conductor.

   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
   ____________________________________________________________
<table>
<thead>
<tr>
<th>Item</th>
<th>Correct Answer and Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>B. Flexible conduit should not be used as a grounding conductor. (See page 4-7.)</td>
</tr>
<tr>
<td>2.</td>
<td>The spiral construction of flexible conduit causes it to have a much higher resistance per foot than solid medal conduit. (See page 4-7.)</td>
</tr>
</tbody>
</table>
# APPENDIX A

## LIST OF COMMON ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCP</td>
<td>Army Correspondence Course Program</td>
</tr>
<tr>
<td>AIPD</td>
<td>Army Institute for Professional Development</td>
</tr>
<tr>
<td>AMEDD</td>
<td>Army Medical Department</td>
</tr>
<tr>
<td>AV</td>
<td>autovon</td>
</tr>
<tr>
<td>DINFOS</td>
<td>Defense Information School</td>
</tr>
<tr>
<td>EMT</td>
<td>electrical metallic tubing</td>
</tr>
<tr>
<td>EN</td>
<td>engineer</td>
</tr>
<tr>
<td>FC</td>
<td>flat cable assembly</td>
</tr>
<tr>
<td>IMC</td>
<td>intermediate metal conduit</td>
</tr>
<tr>
<td>IPD</td>
<td>Institute for Professional Development</td>
</tr>
<tr>
<td>JFK</td>
<td>John F. Kennedy</td>
</tr>
<tr>
<td>MA</td>
<td>Massachusetts</td>
</tr>
<tr>
<td>MI</td>
<td>middle initial</td>
</tr>
<tr>
<td>MO</td>
<td>Missouri</td>
</tr>
<tr>
<td>MOS</td>
<td>military occupational specialty</td>
</tr>
<tr>
<td>NEC</td>
<td>National Electrical Code</td>
</tr>
<tr>
<td>PVC</td>
<td>polyvinyl chloride (plastic)</td>
</tr>
<tr>
<td>RCOAC</td>
<td>Reserve Component Officer Advanced Course</td>
</tr>
<tr>
<td>Reg</td>
<td>regulation</td>
</tr>
<tr>
<td>RYE</td>
<td>retirement year ending</td>
</tr>
<tr>
<td>SM</td>
<td>soldier's manual</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>SSN</td>
<td>social security number</td>
</tr>
<tr>
<td>STP</td>
<td>soldier training publication</td>
</tr>
<tr>
<td>TG</td>
<td>trainers guide</td>
</tr>
<tr>
<td>TRADOC</td>
<td>United States Army Training and Doctrine Command</td>
</tr>
<tr>
<td>TW</td>
<td>moisture-resistant thermoplastic</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>VA</td>
<td>Virginia</td>
</tr>
</tbody>
</table>
APPENDIX B

RECOMMENDED READING LIST


NOTE: This publication provides additional information about the material in this subcourse. You do not need this material to complete this subcourse.