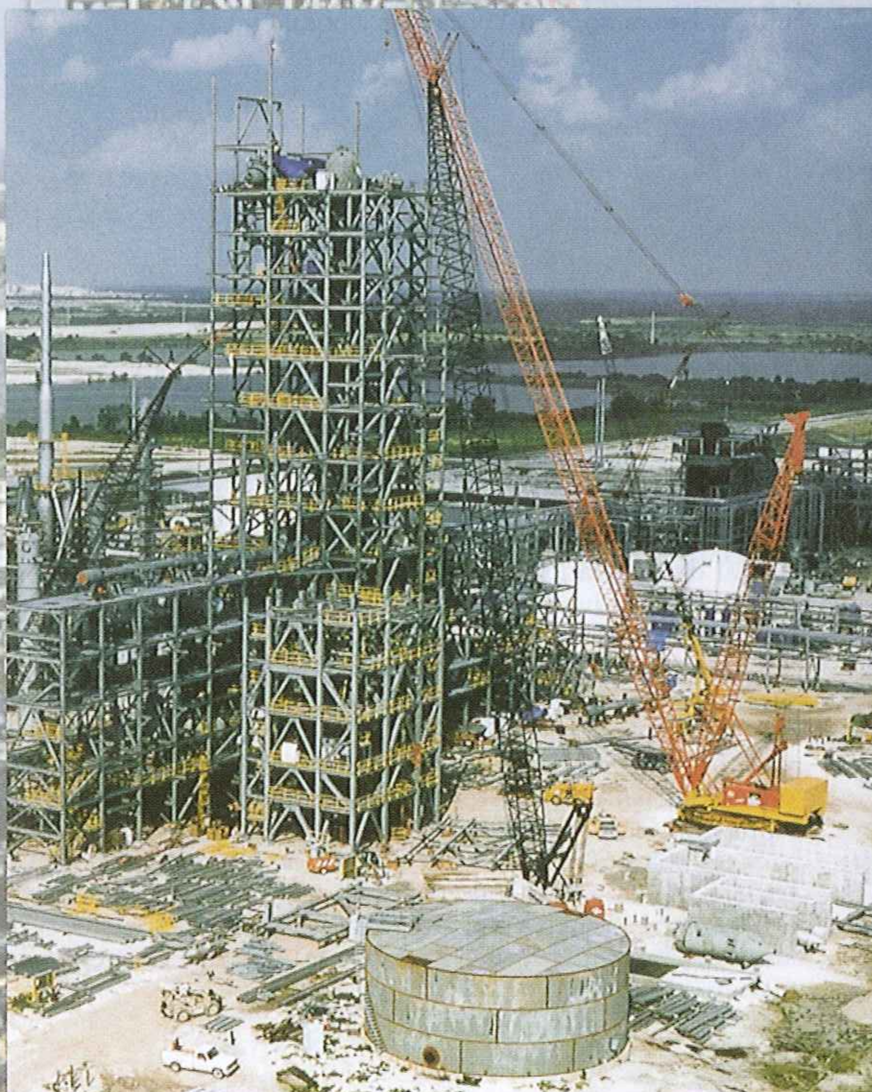
Hand Bending
26102-05



Polk Power Station

The Polk Power Station in Mulberry, Florida, set a new standard for producing electricity and introduced a new generation of advanced technology. It combines coal gasification and combined cycle. This integration efficiently creates electricity at a low cost and is environmentally friendly. The Polk Power Station is built on former phosphate mining land. Now over 1,511 acres of the land, which looked like a moonscape before construction began, is being transformed to a wildlife habitat that attracts bald eagles, wild hogs, turkeys, and other animals. This project was sponsored by the U.S. Department of Energy Clean Coal Technology Program.

26102-05
Hand Bending

Topics to be presented in this module include:

Overview

An electrical conduit is a pipe or tube that protects electrical wires from accidental damage and exposure to the elements. Electricians working on commercial and industrial jobs must know how to bend and install conduit to go over and around obstacles. The *National Electrical Code*® limits the number and degree of bends allowed in a single run of conduit. The primary purpose of these limits is to permit easy installation and provide physical protection of conductors once the conduit is installed. It is up to the electrician to comply with these regulations. To bend conduit correctly, the electrician must make precise measurements of lengths and angles, refer to tables of predetermined values, and apply knowledge of basic geometry.

Scrap piles of bent conduit are found on many job sites because some electricians rely on a trial-and-error approach instead of learning how to bend conduit properly. When a construction job involves extensive conduit installation, knowing how to cut, bend, and ream conduit correctly can save time and money.

Objectives

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

1. Identify the methods of hand bending conduit.
2. Identify the various methods used to install conduit.
3. Use math formulas to determine conduit bends.
4. Make 90° bends, back-to-back bends, offsets, kicks, and saddle bends using a hand bender.
5. Cut, ream, and thread conduit.

Trade Terms

90° bend
Back-to-back bend
Concentric bends
Developed length
Gain
Offsets
Rise
Segment bend
Stub-up

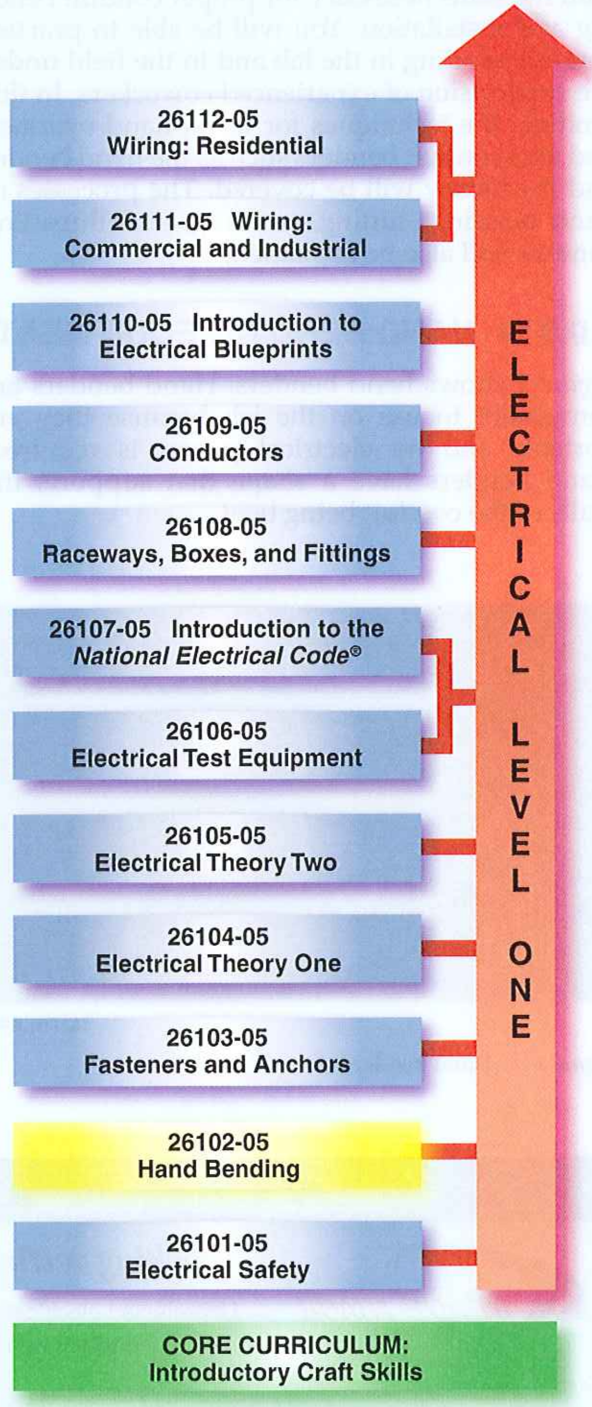
Required Trainee Materials

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

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum* and *Electrical Level One*, Module 26101-05.

This course map shows all of the modules in *Electrical Level One*. 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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1.0.0 ◆ INTRODUCTION

The art of conduit bending is dependent upon the skills of the electrician and requires a working knowledge of basic terms and proven procedures. Practice, knowledge, and training will help you gain the skills necessary for proper conduit bending and installation. You will be able to practice conduit bending in the lab and in the field under the supervision of experienced coworkers. In this module, the techniques for using hand-operated and step conduit benders such as the hand bender and the hickey will be covered. The processes of hand bending, cutting, reaming, and threading conduit will also be explained.

2.0.0 ◆ HAND BENDING EQUIPMENT

Figure 1 shows hand benders. Hand benders are convenient to use on the job because they are portable and no electrical power is required. Hand benders have a shape that supports the walls of the conduit being bent.

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Figure 1 ◆ Hand benders.

These benders are used to make various bends in smaller-size conduit (½" to 1¼"). Most hand benders are sized to bend rigid conduit and electrical metallic tubing (EMT) of corresponding sizes. For example, a single hand bender can bend either ¾" EMT or ½" rigid conduit. The next larger size of hand bender will bend either 1" EMT or ¾" rigid conduit. This is because the corresponding sizes of conduit have nearly equal outside diameters.

The first step in making a good bend is familiarizing yourself with the bender. The manufacturer of the bender will typically provide documentation indicating starting points, distance between **offsets**, **gains**, and other important values associated with that particular bender. There is no substitute for taking the time to review this information. It will make the job go faster and result in better bends.

CAUTION

When making bends, be sure you have a firm grip on the handle to avoid slippage and possible injury.

When performing a bend, it is important to keep the conduit on a stable, firm, flat surface for the entire duration of the bend. Hand benders are designed to have force applied using one foot and the hands. See *Figure 2*. It is important to use constant foot pressure as well as force on the handle to achieve uniform bends. Allowing the conduit to rise up or performing the bend on soft ground can result in distorting the conduit outside the bender.

INSIDE TRACK

Working with Conduit

Unprotected electrical cable is susceptible to moisture and physical damage; therefore, protect the wiring with conduit.

Bending Conduit

A good way to practice bending conduit is to use a piece of No. 10 or No. 12 solid wire and bend it to resemble the bends you need. This gives you some perspective on how to bend the conduit and it will also help you to anticipate any problems with the bends.

Figure 2 ◆ Pushing down on the bender to complete the bend.

NOTE

Bends should be made in accordance with the guidelines of *NEC Article 342* (intermediate metal conduit or IMC), *Article 344* (rigid metal conduit or RMC), *Article 352* (rigid nonmetallic conduit or RNC), or *Article 358* (electrical metallic tubing or EMT).

A hickey should not be confused with a hand bender. The hickey, which is used for RMC and IMC only, functions quite differently. See *Figure 3.*

When you use a hickey to bend conduit, you are forming the bend as well as the radius. When using a hickey, be careful not to flatten or kink the conduit. Hickeys should only be used with RMC and IMC because very little support is given to the walls of the conduit being bent. A hickey is a segment bending device. First, a small bend of about 10° is made. Then, the hickey is moved to a new position and another small bend is made. This process is continued until the bend is completed. A hickey can be used for conduit **stub-ups** in slabs and decks.

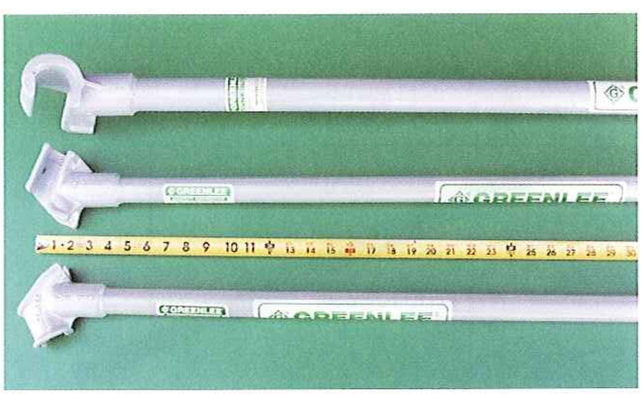
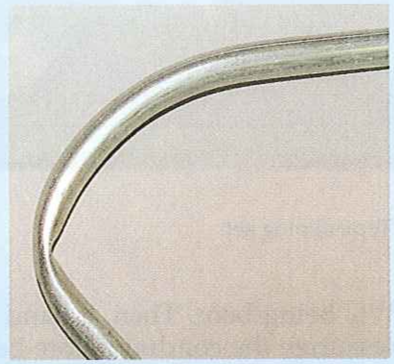


Figure 3 ◆ Hickeys.

INSIDE TRACK

Proper Bends

Kinks are created by bending too small a radius using a hickey.



Polyvinyl chloride (PVC) conduit is bent using a heating unit (*Figure 4*). The PVC must be rotated regularly while it is in the heater so that it heats evenly. Once heated, the PVC is removed, and the bending is performed by hand. Some units use an electric heating element, while others use liquid propane (LP). After bending, a damp sponge or cloth is often used so that the PVC sets up faster.

When bending PVC that is 2" or larger in diameter, there is a risk of wrinkling or flattening the bend. A plug set eliminates this problem (*Figure 5*). A plug is inserted into each end of the

Figure 4 ◆ Typical PVC heating units.

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Figure 5 ◆ Typical plug set.

piece of PVC being bent. Then, a hand pump is used to pressurize the conduit before bending it. The pressure is about 3 to 5 psi.

CAUTION

Avoid contact with the case of the heating unit; it can become very hot and cause burns. Also, to avoid a fire hazard, ensure that the unit is cool before storage. If using an LP unit, keep a fire extinguisher nearby.

NOTE

The plugs must remain in place until the pipe is cooled and set.

What's wrong with this picture?

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2.1.0 Geometry Required to Make a Bend

Bending conduit requires that you use some basic geometry. You may already be familiar with most of the concepts needed; however, here is a review of the concepts directly related to this task. A right triangle is defined as any triangle with a 90° angle. The side directly opposite the 90° angle is called the hypotenuse, and the side on which the triangle sits is the base. The vertical side is called the height. On the job, you will apply the relationships in a right triangle when making an offset bend. The offset forms the hypotenuse of a right triangle (*Figure 6*).

NOTE

There are reference tables for sizing offset bends based on these relationships (see *Appendix A*).

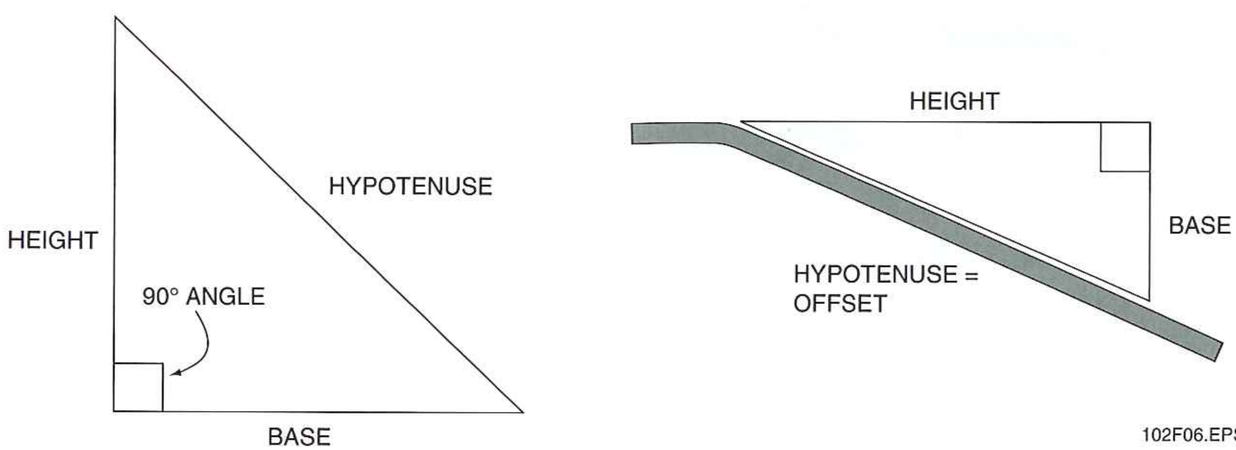

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Figure 6 ◆ Right triangle and offset bend.

A circle is defined as a closed curved line whose points are all the same distance from its center. The distance from the center point to the edge of the circle is called the radius. The length from one edge of the circle to the other edge through the center point is the diameter. The distance around the circle is called the circumference. A circle can be divided into four equal quadrants. Each quadrant accounts for 90°, making a total of 360°. When you make a **90° bend**, you will use ¼ of a circle, or one quadrant. Concentric circles are circles that have a common center but different radii. The concept of concentric circles can be applied to **concentric bends** in conduit. The angle of each bend is 90°. Such bends have the same center point, but the radius of each is different. See *Figure 7.*

To calculate the circumference of a circle, use the following formula:

$$C = \pi \times D \text{ or } C = \pi D$$

In this formula, C = circumference, D = diameter, and $\pi = 3.14$. Another way of stating the formula for circumference is $C = 2\pi R$, where R equals the radius or ½ the diameter. To figure the arc of a quadrant use:

$$\text{Length of arc} = (0.25)\ 2\pi R = 1.57R$$

INSIDE TRACK

Practical Bending

When making offset bends of 45° to step conduit up to another level, square floor tiles make a convenient grid to gauge the distance and angles.

For this formula, the arc of a quadrant equals ¼ the circumference of the circle or 1.57 times the radius.

A bending radius table is included in *Appendix B.*

2.2.0 Making a 90° Bend

The 90° stub bend is probably the most basic bend of all. The stub bend is used much of the time, regardless of the type of conduit being installed. Before beginning to make the bend, you need to know two measurements:

- Desired **rise** or stub-up
- Take-up distance of the bender

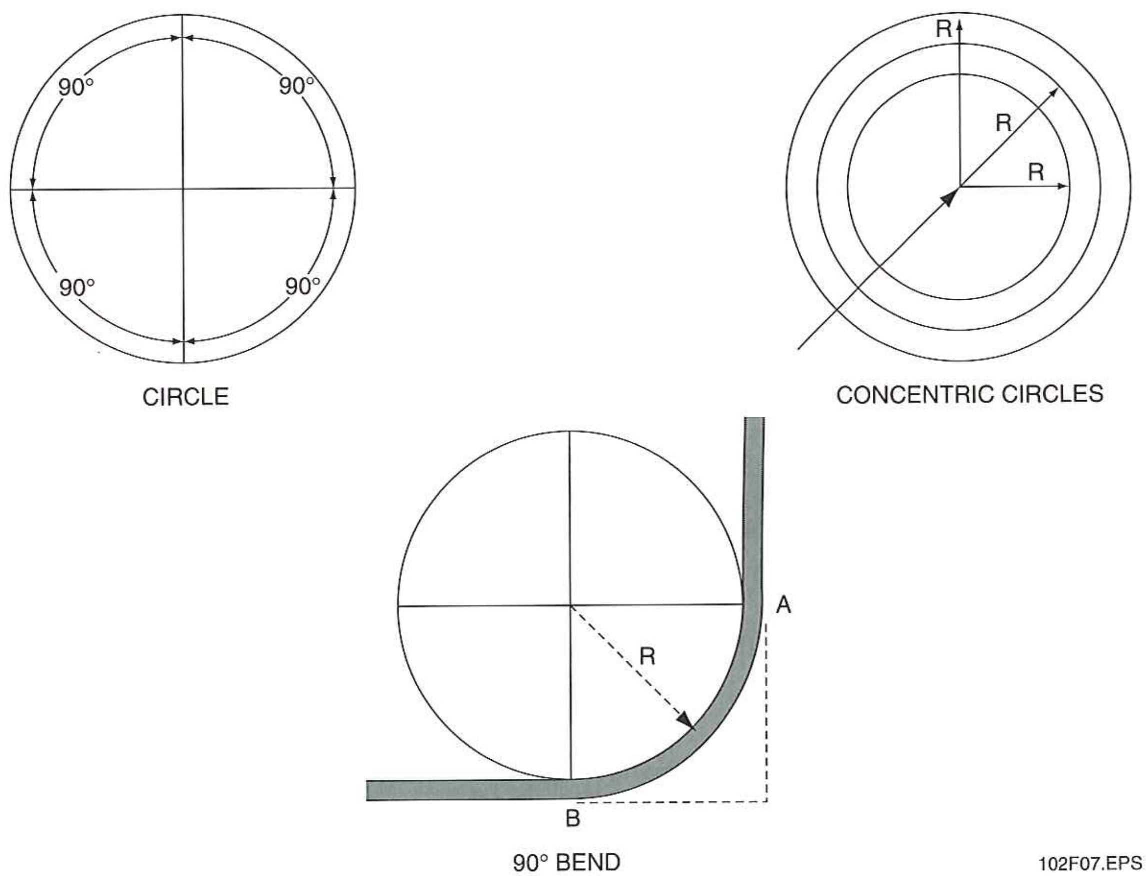


Figure 7 ◆ Circles and 90° bends.

The desired rise is the height of the stub-up. The take-up is the amount of conduit the bender will use to form the bend. Take-up distances are usually listed in the manufacturer's instruction manual. Typical bender take-up distances are shown in *Table 1*.

Once you have determined the take-up, subtract it from the stub-up height. Mark that distance on the conduit (all the way around) at that distance from the end. The mark will indicate the point at which you will begin to bend the conduit. Line up the starting point on the conduit with the starting point on the bender. Most benders have a mark, like an arrow, to indicate this point. *Figure 8* shows the take-up required to achieve an 18" stub-up on a piece of ½" EMT.

Once you have lined up the bender, use one foot to hold the conduit steady. Keep your heel on the floor for balance. Apply pressure on the bender foot pedal with your other foot. Make sure you hold the bender handle level, as far up as possible, to get maximum leverage. Then, bend the conduit in one smooth motion, pulling as steadily as possible. Avoid overstretching.

Table 1 Typical Bender Take-Up Distances

EMT	Rigid/IMC	Take-Up
½"	—	5"
¾"	½"	6"
1"	¾"	8"
1¼"	1"	11"

NOTE

When bending conduit using the take-up method, always place the bender on the conduit and make the bend facing the hook of the conduit from which the measurements were taken.

After finishing the bend, check to make sure you have the correct angle and measurement. Use the following steps to check a 90° bend:

Step 1 With the back of the bend on the floor, measure to the end of the conduit stub-up to make sure it is the right length.

Step 2 Check the 90° angle of the bend with a square or at the angle formed by the floor and a wall. A torpedo level may also be used.

NOTE

If you overbend a conduit slightly past the desired angle, you can use the bender to bend the conduit back to the correct angle.

The above procedure will produce a 90° one-shot bend. That means that it took a single bend to form the conduit bend. A **segment bend** is any bend that is formed by a series of bends of a few degrees each, rather than a single one-shot bend. A shot is actually one bend in a segment bend. Segment or sweep bends must conform to the provisions of the *NEC*®.

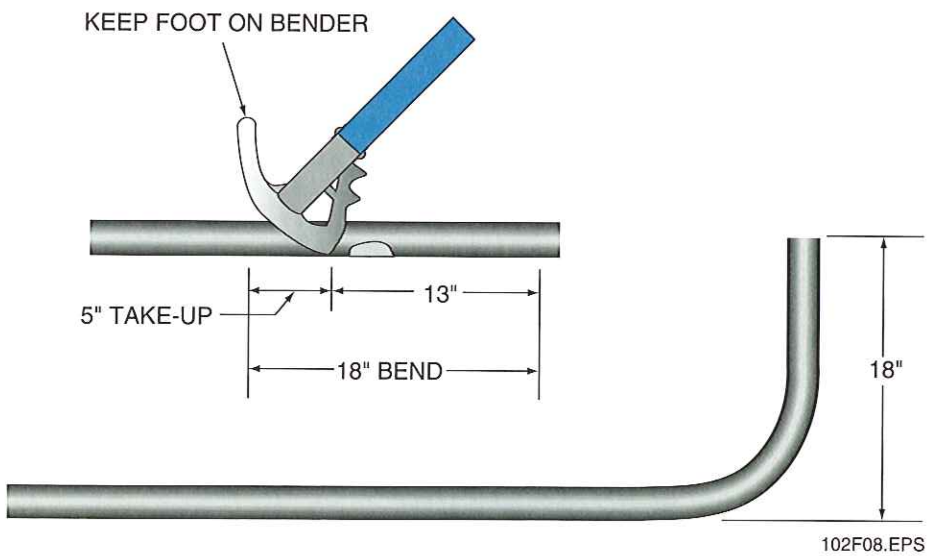


Figure 8 ◆ Bending an 18-inch stub-up.

Matching Bends in Parallel Runs

INSIDE TRACK

Suppose you are running 1" rigid conduit along with a 2" rigid conduit in a rack and you come to a 90° bend. If you used a 1" shoe, the radius would not match that of the 2" conduit bend. To match the 2" 90° bend, take your 1" conduit and put it in the 2" shoe of your bender, then bend as usual. This 1" 90° bend will now have the same radius as the 2" 90° bend. This trick will only work on rigid conduit. If done with EMT, it will flatten the pipe.

Take-Up Method

When bending conduit using the take-up method, always place the bender on the conduit and make the bend facing the end of the conduit from which the measurements were taken. It helps to make a narrow mark with a soft lead pencil or marker completely around the conduit to ensure straight bends.

2.3.0 Gain

The gain is the distance saved by the arc of a 90° bend. Knowing the gain can help you to precut, ream, and prethread both ends of the conduit before you bend it. This will make your work go more quickly because it is easier to work with conduit while it is straight. *Figure 9* shows that the overall **developed length** of a piece of conduit with a 90° bend is less than the sum of the horizontal and vertical distances when measured square to the corner. This is shown by the following equation:

Developed length = (A + B) − gain

An example of a manufacturer's gain table is also shown in *Figure 9*. These tables are used to determine the gain for a certain size conduit.

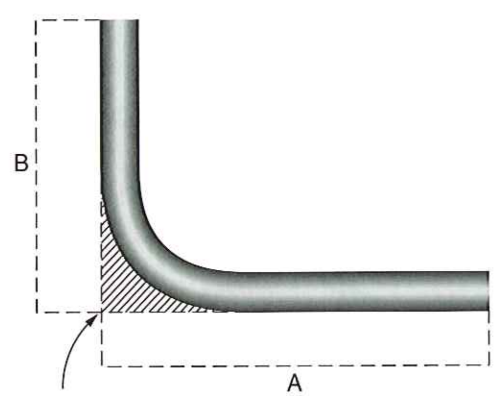
THINK ABOUT IT

Gain

What is the difference between the gain and the take-up of a bend?

Smooth Bends

Why are smooth bends so important?



Conduit Size	NEC® Radius	90° Gain
½"	4"	2⅝"
¾"	5"	3¼"
1"	6"	4"
1¼"	8"	5⅝"

TYPICAL GAIN TABLE

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Figure 9 ◆ Gain.

INSIDE TRACK

Checking Vertical Rise

Use a torpedo level to check for plumb on a vertical rise.

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2.4.0 Back-to-Back 90° Bends

A **back-to-back bend** consists of two 90° bends made on the same piece of conduit and placed back-to-back (*Figure 10*).

To make a back-to-back bend, make the first bend (labeled X in *Figure 10*) in the usual manner. To make the second bend, measure the required distance between the bends from the back of the first bend. This distance is labeled L in the figure. Reverse the bender on the conduit, as shown in *Figure 10*. Place the bender's back-to-back indicating mark at point Y on the conduit. Note that outside measurements from point X to point Y are used. Holding the bender in the reverse position and properly aligned, apply foot pressure and complete the second bend.

2.5.0 Making an Offset

Many situations require that the conduit be bent so that it can pass over objects such as beams and other conduits, or enter meter cabinets and junction boxes. Bends used for this purpose are called offsets (kicks). To produce an offset, two equal bends of less than 90° are required, a specified distance apart, as shown in *Figure 11*.

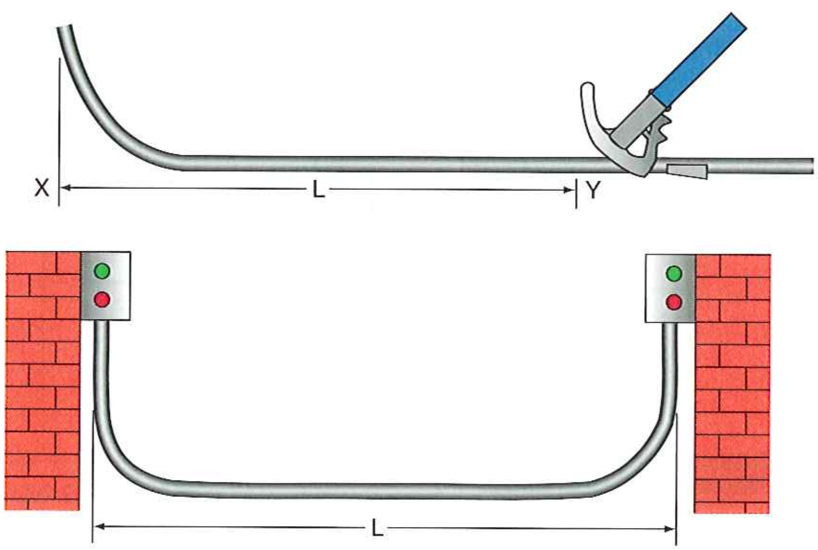


Figure 10 ◆ Back-to-back bends.

Offsets are a trade-off between space and the effort it will take to pull the wire. The larger the degree of bend, the harder it will be to pull the wire. The smaller the degree of bend, the easier it will be to pull the wire. Use the shallowest degree of bend that will still allow the conduit to bypass the obstruction and fit in the given space.

When conduit is offset, some of the conduit length is used. If the offset is made into the area, an allowance must be made for this shrinkage. If the offset angle is away from the obstruction, the shrinkage can be ignored.

Table 2 shows the amount of shrinkage per inch of rise for common offset angles.

The formula for figuring the distance between bends is as follows:

Distance between bends = depth of offset × multiplier

Table 2 Shrinkage Calculation

Offset Angle	Multiplier	Shrinkage (per inch of rise)
10° × 10°	6.0	1/16"
22½° × 22½°	2.6	3/16"
30° × 30°	2.0	¼"
45° × 45°	1.4	⅜"
60° × 60°	1.2	½"

The distance between the offset bends can generally be found in the manufacturer's documentation for the bender. *Table 3* shows the distance between bends for the most common offset angles.

Calculations related to offsets are derived from the branch of mathematics known as trigonometry, which deals with triangles. The multipliers shown in *Table 2* represent the cosecant (CSC) of the related offset angle. The multiplier is

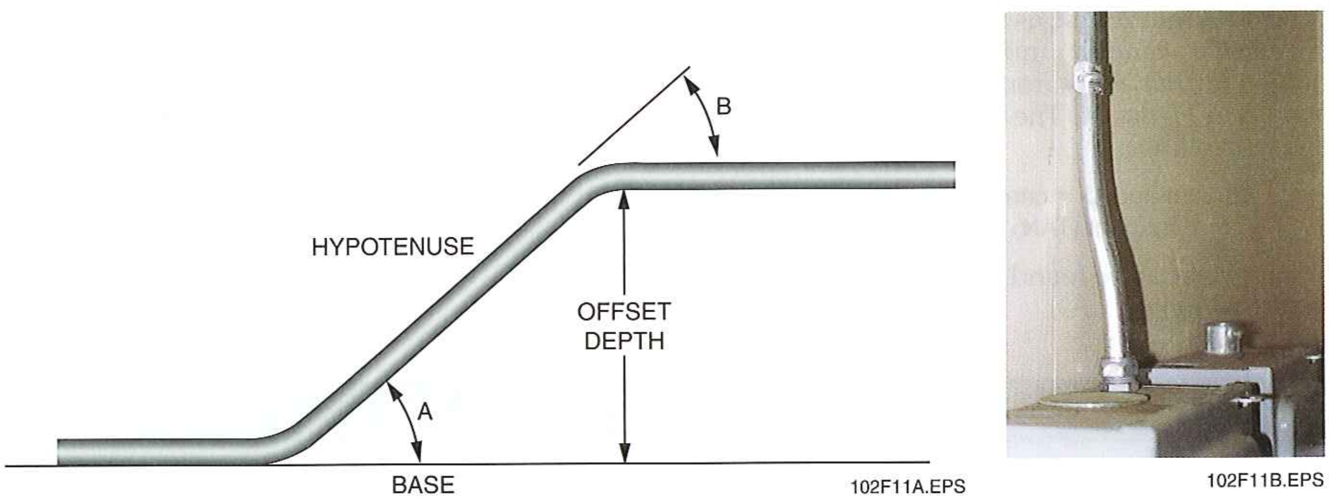


Figure 11 ◆ Offsets.

Table 3 Common Offset Factors (in Inches)

Offset Depth	22½° Between Bends	22½° Shrinkage	30° Between Bends	30° Shrinkage	45° Between Bends	45° Shrinkage	60° Between Bends	60° Shrinkage
2	5¼	⅜	—	—	—	—	—	—
3	7¾	9/16	6	¾	—	—	—	—
4	10½	¾	8	1	—	—	—	—
5	13	15/16	10	1¼	7	1⅞	—	—
6	15½	1⅛	12	1½	8½	2¼	7¼	3
7	18¼	1 5/16	14	1¾	9¾	2⅝	8⅜	3½
8	20¾	1½	16	2	11¼	3	9⅝	4
9	23½	1¾	18	2¼	12½	3⅜	10⅞	4½
10	26	1⅞	20	2½	14	3¾	12	5

determined by dividing the hypotenuse of the triangle created by the offset by the depth of the offset (*Figure 11*).

Basic trigonometry (trig) functions are briefly covered in *Appendix A*. As you will see in the next section, the tangent (TAN) of the offset angle is also used in calculating parallel offsets. Understanding trig functions will help you understand how offsets are determined. If you have a scientific calculator and understand these functions, you can calculate offset angles when you know the dimensions of the triangle created by the offset and the obstacle.

2.6.0 Parallel Offsets

Often, multiple pieces of conduit must be bent around a common obstruction. In this case, parallel offsets are made. Since the bends are laid out along a common radius, an adjustment must be made to ensure that the ends do not come out uneven, as shown in *Figure 12*.

The center of the first bend of the innermost conduit is found first, as shown in *Figure 13*. Each successive conduit must have its centerline moved farther away from the end of the pipe, as shown in *Figure 14*. The amount to add is calculated as follows:

Amount added = center-to-center spacing × tangent (TAN) of ½ offset angle

Tangents can be found using the trig tables provided in *Appendix A*.

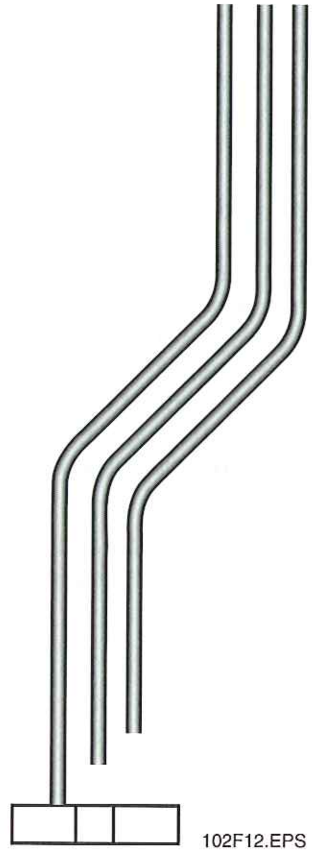


Figure 12 ◆ Incorrect parallel offsets.

Calculating Shrinkage

THINK ABOUT IT

You're making a 30° by 30° offset to clear a 6" obstruction. What will be the distance between bends? What will be the developed length shrink? Make the same calculations for a 10" offset with 45° bends.

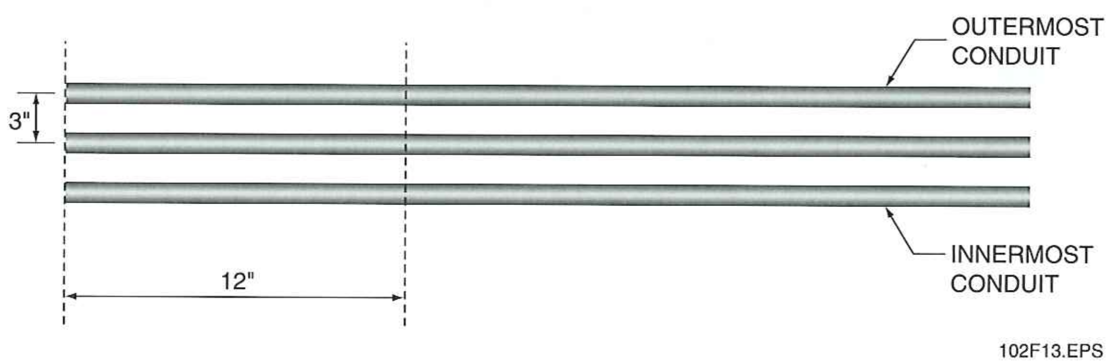


Figure 13 ◆ Center of first bend.

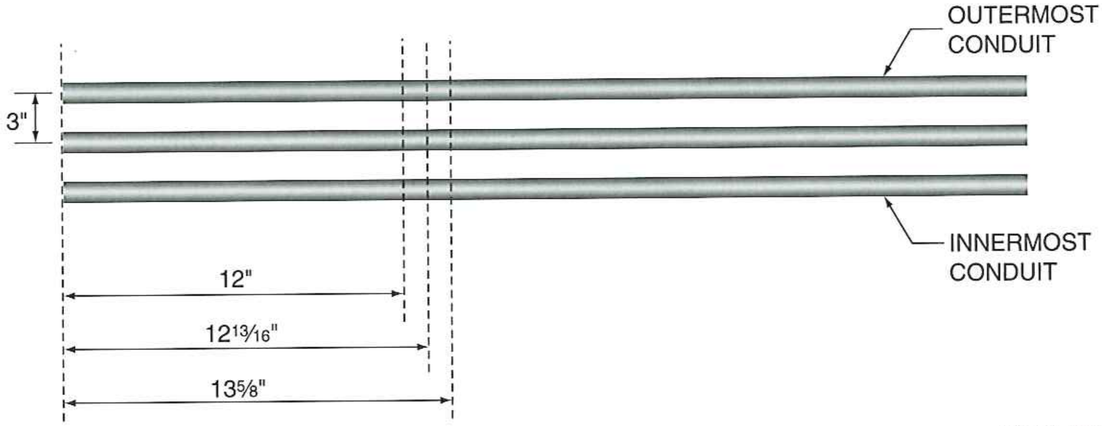


Figure 14 ◆ Successive centerlines.

THINK ABOUT IT

Equal Angles

Why is it important that the angles be identical when making an offset bend?

For example, *Figure 15* shows three pipes laid out as parallel and offset. The angle of the offset is 30°. The center-to-center spacing is 3". The start of the innermost pipe's first bend is 12".

The starting point of the second pipe will be:

12" + [center-to-center spacing × TAN (½ offset angle)]

12" + (3" × TAN 15°) = 12" + (3" × 0.2679) = 12" + 0.8037"

This is approximately $12\frac{13}{16}$".

The starting point for the outermost pipe is:

$12\frac{13}{16}$" + $\frac{13}{16}$" = $13\frac{5}{8}$"

2.7.0 Saddle Bends

A saddle bend is used to go around obstructions. *Figure 16* illustrates an example of a saddle bend that is required to clear a pipe obstruction. Making a saddle bend will cause the center of the saddle to shorten $\frac{3}{16}$" for every inch of saddle depth (see *Table 4*). For example, if the pipe diameter is 2 inches, this would cause a $\frac{3}{8}$" shortening of the conduit on each side of the bend. When making saddle bends, the following steps should apply:

Step 1 Locate the center mark A on the conduit by using the size of the obstruction (i.e., pipe diameter) and calculate the shrink rate of the obstruction (for example, if the pipe diameter is 2 inches, $\frac{3}{8}$" of conduit will be lost on each side of the bend for a total shrinkage of $\frac{3}{4}$"). This figure will be added to the measurement from the end of the conduit to the centerline of the obstruction (for example, if the distance measured from the conduit end to the obstruction centerline was 15", the distance to A would be $15\frac{3}{8}$").

Step 2 Locate marks B and C on the conduit by measuring $2\frac{1}{2}$" for every 1" of saddle depth from the A mark (i.e., for the saddle depth of 2 inches, the B mark would be 5" before the A mark and the C mark would be 5" after the A mark). See *Figure 17*.

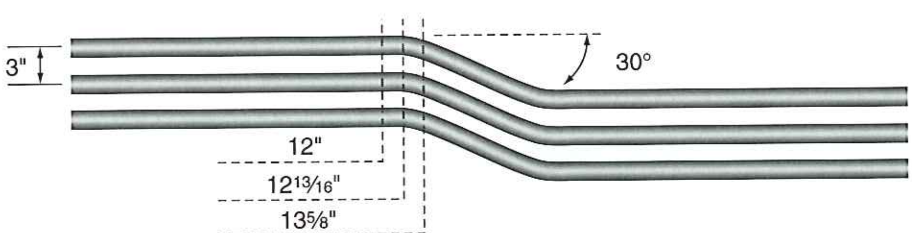


Figure 15 ◆ Parallel offset pipes.

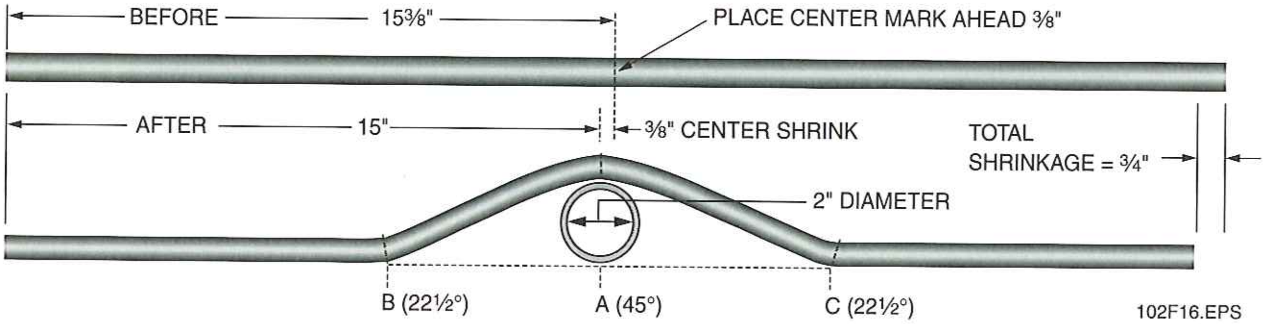
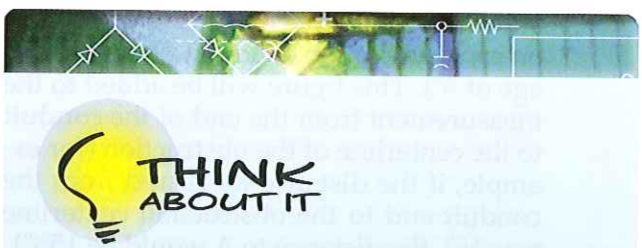


Figure 16 ◆ Saddle measurement.

Table 4 Shrinkage Chart for Saddle Bends with a 45° Center Bend and Two 22½° Bends

Obstruction Depth	Shrinkage Amount (Move Center Mark Forward)	Make Outside Marks from New Center Mark
1	3/16"	2½"
2	⅜"	5"
3	9/16"	7½"
4	¾"	10"
5	15/16"	12½"
6	1⅛"	15"
For each additional inch, add	3/16"	2½"



Calculating Parallel Offsets

You're making parallel offsets of 45° and the lengths of conduit are spaced 4" center to center. If the offset starts 12" down the pipe, what is the starting point for the bend on the second pipe?

Step 3 Refer to *Figure 18* and make a 45° bend at point A, make a 22½° bend at point B, and make a 22½° bend at point C. (Be sure to check the manufacturer's specifications.)

2.8.0 Four-Bend Saddles

Four-bend saddles can be difficult. The reason is that four bends must be aligned exactly on the same plane. Extra time spent laying it out and performing the bends will pay off in not having to scrap the whole piece and start over.

Figure 19 illustrates that the four-bend saddle is really two offsets formed back-to-back. Working left to right, the procedure for forming this saddle is as follows:

Step 1 Determine the height of the offset.

Step 2 Determine the correct spacing for the first offset and mark the conduit.

Step 3 Bend the first offset.

Step 4 Mark the start point for the second offset at the trailing edge of the obstruction.

Step 5 Mark the spacing for the second offset.

Step 6 Bend the second offset.

Using *Figure 20* as an example, a four-bend saddle using ½" EMT is laid out as follows:

- Height of the box = 6"
- Width of the box = 8"
- Distance to the obstruction = 36"

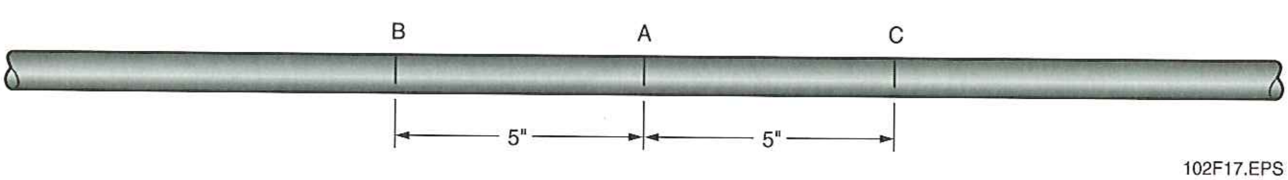


Figure 17 ◆ Measurement locations.

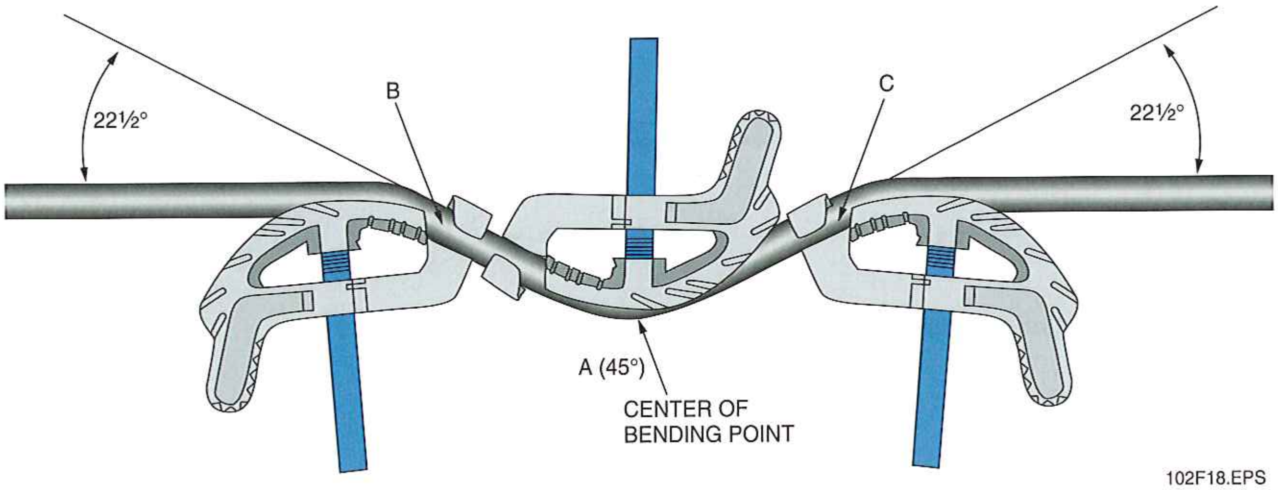


Figure 18 ◆ Location of bends.

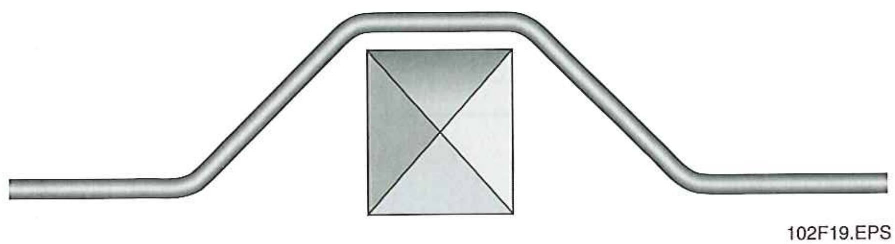


Figure 19 ◆ Typical four-bend saddle.

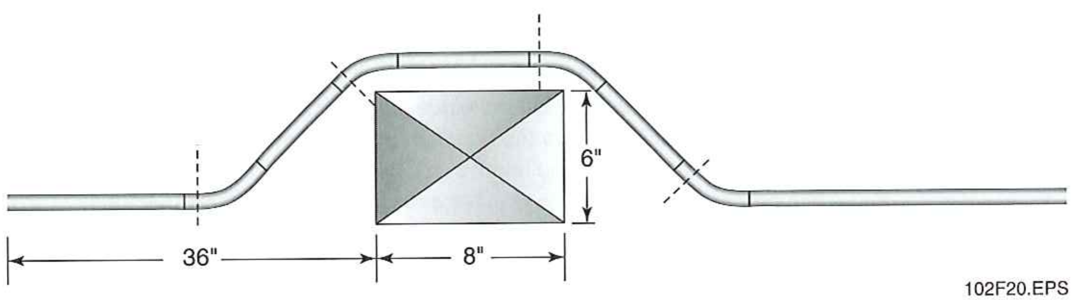


Figure 20 ◆ Four-bend saddle.

Two 30° offsets will be used to form the saddle. It is created as follows:

Step 1 See *Figure 21*. Working from left to right, calculate the start point for the first bend. The distance to the obstruction is 36", the offset is 6", and the 30° multiplier from *Table 2* is 2.0:

Distance to the obstruction − (offset × constant for the angle) + shrinkage = distance to the first bend

36" − (6" × 2.0) + 1½" = 25½"

Step 2 Determine where the second bend will end to ensure the conduit clears the obstruction. See *Figure 22*.

Distance to the first bend + distance to second bend + shrinkage = total length of the first offset

25½" + 12" + 1½" = 39"

Step 3 Determine the start point of the second offset. The width of the box is 8"; therefore, the start point of the second offset should be 8" beyond the end of the first offset:

8" + 39" = 47"

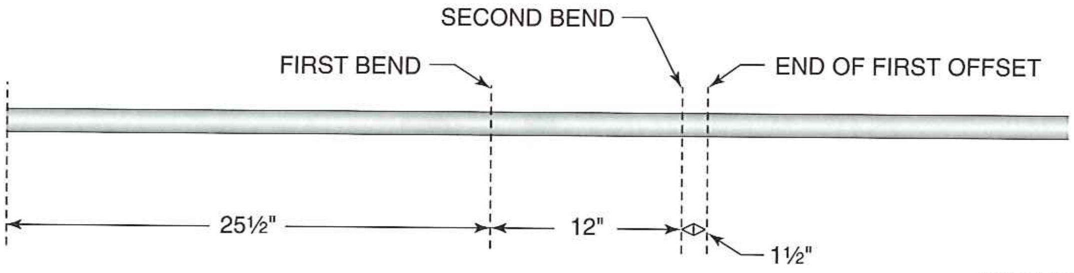


Figure 21 ◆ Four-bend saddle measurements.

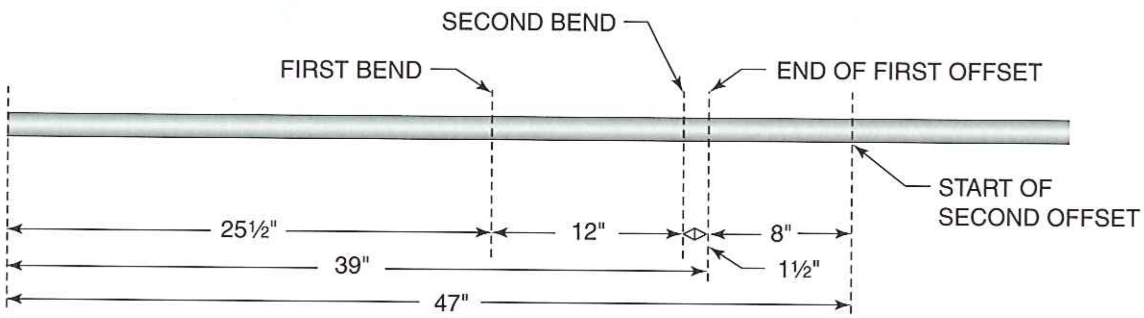


Figure 22 ◆ Bend and offset measurements.

INSIDE TRACK

Planning Bends

The more bends you make, the more difficult it is to pull the wires through the conduit. Therefore, plan your bends in advance, avoid sharp bends, and make as few bends as possible. The *NEC®* allows the bends in a single run of conduit to total 360°; however, 360° is not as much as you might think. For example, if you bend the conduit 90° for two corners of a room, with two 45° offsets where the conduit connects to a panelboard and junction box, you've used up your 360°.

INSIDE TRACK

Using Your Bender Head to Secure Conduit

To secure conduit while cutting, insert the conduit into one of the holes in the bender head, brace your knee against the bender to secure it, then proceed to cut the conduit.

Step 4 Determine the spacing for the second offset. Since the first and second offsets have the same rise and angle, the distance between bends will be the same, or 12".

3.0.0 ◆ CUTTING, REAMING, AND THREADING CONDUIT

RMC, IMC, and EMT are available in standard 10-foot lengths. When installing conduit, it is cut to fit the job requirements.

3.1.0 Hacksaw Method of Cutting Conduit

Conduit is normally cut using a hacksaw. To cut conduit with a hacksaw:

Step 1 Inspect the blade of the hacksaw and replace it, if needed. A blade with 18, 24, or 32 cutting teeth per inch is recommended for conduit. Use a higher tooth count for EMT and a lower tooth count for rigid conduit and IMC. If the blade needs to be replaced, point the teeth toward the front of the saw when installing the new blade.

Step 2 Secure the conduit in a pipe vise.

Step 3 Rest the middle of the hacksaw blade on the conduit where the cut is to be made. Position the saw so the end of the blade is pointing slightly down and the handle is pointing slightly up. Push forward gently until the cut is started. Make even strokes until the cut is finished.

CAUTION

To avoid bruising your knuckles on the newly cut pipe, use gentle strokes for the final cut.

Step 4 Check the cut. The end of the conduit should be straight and smooth. *Figure 23* shows correct and incorrect cuts. Ream the conduit.

3.2.0 Pipe Cutter Method

A pipe cutter can also be used to cut RMC and IMC. To use a pipe cutter:

Step 1 Secure the conduit in a pipe vise and mark a place for the cut.

Step 2 Open the cutter and place it over the conduit with the cutter wheel on the mark.

Step 3 Tighten the cutter by rotating the screw handle.

CAUTION

Do not overtighten the cutter. Overtightening can break the cutter wheel and distort the wall of the conduit.

Step 4 Rotate the cutter counterclockwise to start the cut. *Figure 24* shows the proper way to rotate the cutter.

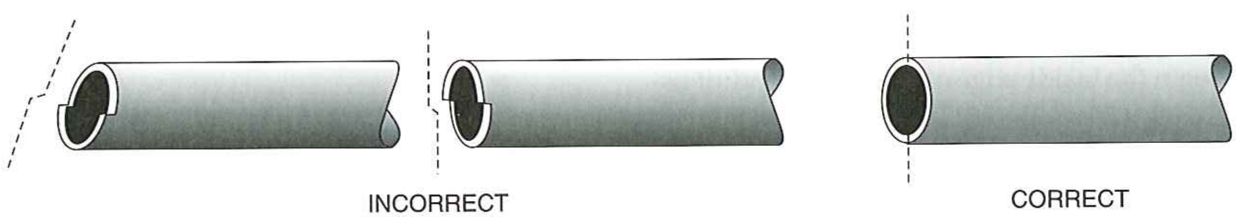
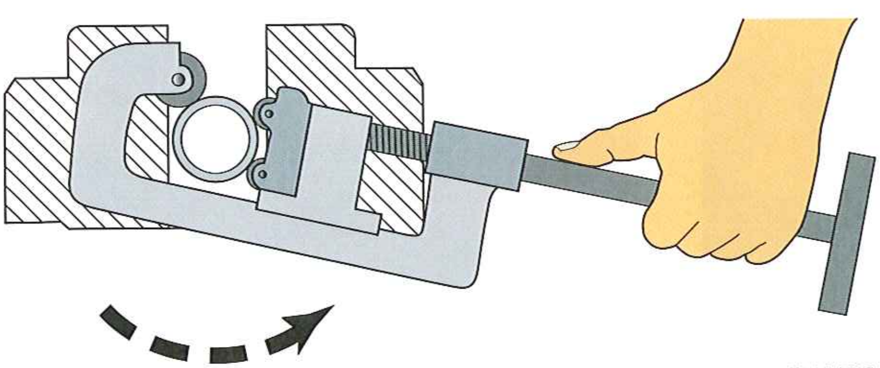


Figure 23 ◆ Conduit ends after cutting.



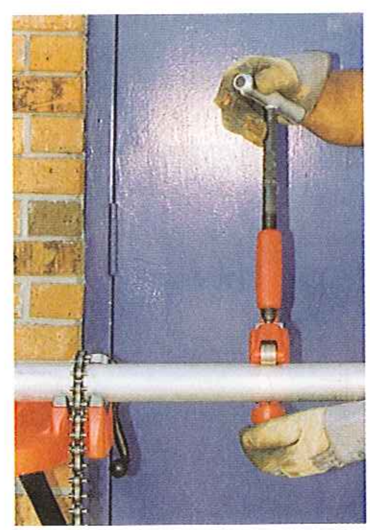


Figure 24 ◆ Cutter rotation.

Using Tape

INSIDE TRACK

Use a piece of tape as a guide for marking your cutting lines around the conduit. This ensures a straight cut.

Step 5 Tighten the cutter handle ¼ turn for each full turn around the conduit. Again, make sure that you do not overtighten it.

Step 6 Add a few drops of cutting oil to the groove and continue cutting. Avoid skin contact with the oil.

Step 7 When the cut is almost finished, stop cutting and snap the conduit to finish the cut. This reduces the ridge that can be formed on the inside of the conduit.

Step 8 Clean the conduit and cutter with a shop towel rag.

Step 9 Ream the conduit.

3.3.0 Reaming Conduit

When the conduit is cut, the inside edge is sharp. This edge will damage the insulation of the wire when it is pulled through. To avoid this damage, the inside edge must be smoothed or reamed using a reamer (*Figure 25*).

To ream the inside edge of a piece of conduit using a hand reamer, proceed as follows:

Step 1 Place the conduit in a pipe vise.

Step 2 Insert the reamer tip in the conduit.

Step 3 Apply light forward pressure and start rotating the reamer. *Figure 26* shows the proper way to rotate the reamer. It should be rotated using a downward motion. The reamer can be damaged if you rotate it in the wrong direction. The reamer should bite as soon as you apply the proper pressure.

Step 4 Remove the reamer by pulling back on it while continuing to rotate it. Check the progress and then reinsert the reamer. Rotate the reamer until the inside edge is smooth. You should stop when all burrs have been removed.

NOTE
If a conduit reamer is not available, use a half-round file (the tang of the file must have a handle attached). EMT may be reamed using the nose of diagonal cutters or small hand reamers.

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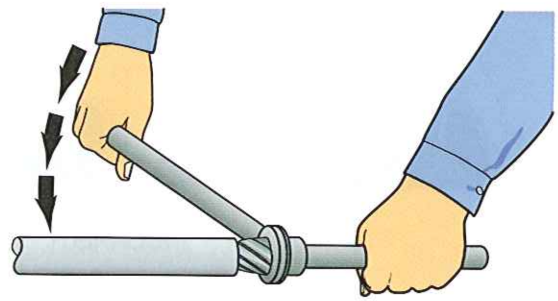
Figure 25 ◆ Rigid conduit reamer.



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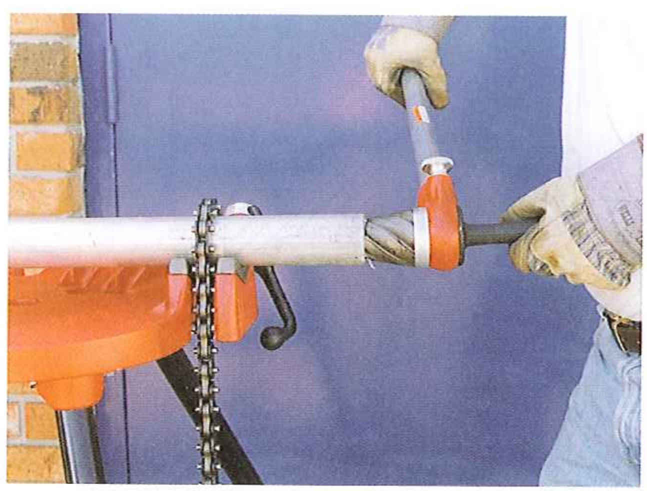

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Figure 26 ◆ Reamer rotation.

3.4.0 Threading Conduit

After conduit is cut and reamed, it is usually threaded so it can be properly joined. Only RMC and IMC have walls thick enough for threading.

The tool used to cut threads in conduit is called a die. Conduit dies are made to cut a taper of ¾ inch per foot. The number of threads per inch varies from 8 to 18, depending upon the diameter of the conduit. A thread gauge is used to measure how many threads per inch are cut.

The threading dies are contained in a die head. The die head can be used with a hand-operated ratchet threader (*Figure 27*) or with a portable power drive.

To thread conduit using a hand-operated threader, proceed as follows:

Step 1 Insert the conduit in a pipe vise. Make sure the vise is fastened to a strong surface. Place supports, if necessary, to help secure the conduit.

Step 2 Determine the correct die and head. Inspect the die for damage such as broken teeth. Never use a damaged die.

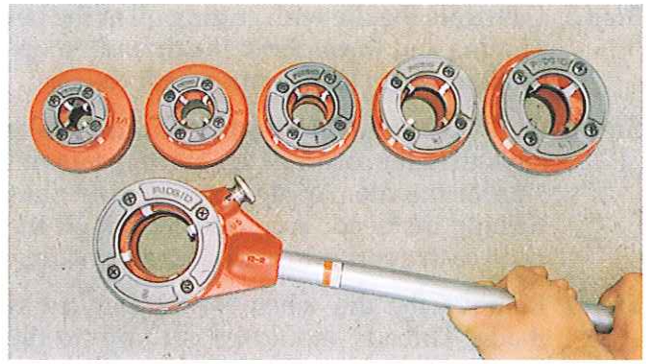

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Figure 27 ◆ Hand-operated ratchet threader.

Step 3 Insert the die securely in the head. Make sure the proper die is in the appropriately numbered slot on the head.

Step 4 Determine the correct thread length to cut for the conduit size used (match the manufacturer's thread length).

INSIDE TRACK

Oiling the Threader

For smoother operation, oil the threader often while threading the conduit.

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INSIDE TRACK

Threading Conduit

The key to threading conduit is to start with a square cut. If you don't get it right the first time, the fitting won't thread properly.

Step 5 Lubricate the die with cutting oil at the beginning and throughout the threading operation. Avoid skin contact with the oil.

Step 6 Cut threads to the proper length. Make sure that the conduit enters the tapered side of the die. Apply pressure and start turning the head. You should back off the head each quarter-turn to clear away chips.

Step 7 Remove the die when the proper cut is made. Threads should be cut only to the length of the die. Overcutting will leave the threads exposed to corrosion.

Step 8 Inspect the threads to make sure they are clean, sharp, and properly made. Use a thread gauge to measure the threads. The finished end should allow for a wrench-tight fit with one or two threads exposed.

> **NOTE**
> The conduit should be reamed again after threading to remove any burrs and edges. Cutting oil must be swabbed from the inside and outside of the conduit. Use a sandbox or drip pan under the threader to collect drips and shavings.

Die heads can also be used with portable power drives. You will follow the same steps when using a portable power drive. Threading machines are often used on larger conduit and where frequent threading is required. Threading machines hold and rotate the conduit while the die is fed onto the conduit for cutting. When using a threading machine, make sure you secure the legs properly and follow the manufacturer's instructions.

3.5.0 Cutting and Joining PVC Conduit

PVC conduit may be easily cut with a fine-tooth handsaw. To ensure square cuts, a miter box or similar device is recommended for cutting 2" and larger PVC. You can deburr the cut ends using a pocket knife. Smaller diameter PVC conduit, up to 1½", may be cut using a PVC cutter.

Use the following steps to join PVC conduit sections or attachments to plastic boxes:

Step 1 Wipe all the contacting surfaces clean and dry.

Step 2 Apply a coat of cement (a brush or aerosol can is recommended) to the male end to be attached.

Step 3 Press the conduit and fitting together and rotate about a half-turn to evenly distribute the cement.

Forming PVC in the field requires a special tool called a hot box or other specialized methods. PVC may not be threaded when it is used for electrical applications.

> **CAUTION**
> Solvents and cements used with PVC are hazardous. Wear gloves and follow the product instructions.

> **NOTE**
> Cementing the PVC must be done quickly. The aerosol spray cans of cement or the cement/brush combination are usually provided by the PVC manufacturer. Make sure you use the recommended cement.

INSIDE TRACK

PVC Cutters

A nylon string can be used to cut PVC in place in awkward locations. However, it is best to use a PVC cutter to cut smaller trade sizes of PVC.

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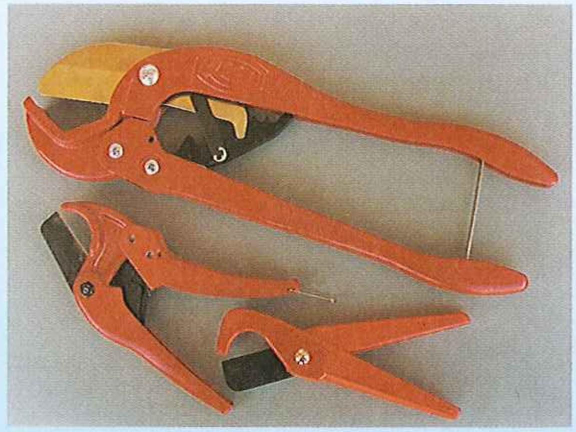

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THINK ABOUT IT

Putting It All Together

This module has stressed the precision necessary for creating accurate and uniform bends. Why is this important? What practical problems can result from sloppy or inaccurate bends?

Summary

You must choose a conduit bender to suit the kind of conduit being installed and the type of bend to be made. Some knowledge of the geometry of right triangles and circles needs to be mastered to make the necessary calculations. You must be able to calculate, lay out, and perform bending operations on a single run of conduit and also on two or more parallel runs of conduit. At times, data tables for the figures may be consulted for the calculations. All work must conform to the requirements of the *NEC®*.

Notes

Timothy Ely

Beacon Electric Company

Tim Ely is a man who believes in giving something back to the industry that nurtured his successful career. Despite working in a demanding executive position, he serves on many industry committees and was instrumental in the development of the NCCER Electrical Program.

What made you decide to become an electrician?
During my last two years of high school, I worked for a do-it-all construction company. We laid concrete, installed roofs, hung drywall, installed plumbing, and did electrical work. I liked the electrical work the best.

How did you learn the trade?
I learned through on-the-job training, hard work, and studying on my own. I had good teachers who were patient with me and took the time to help me succeed.

What kinds of jobs did you hold on the way to your current position?
I started out wiring houses and did that for the first two years. Then I switched over to commercial and industrial work, and worked as an apprentice in that area for two more years before becoming a journeyman. From there, I served as a lead electrician, then foreman, then city superintendent, then finally general superintendent before being promoted to my current job as vice president of construction.

What factor or factors have contributed most to your success?
Hard work helps a lot. I also try to bring a positive attitude to work with me every day. My family and friends have supported me throughout my career.

What does a vice president of construction do in your company?
In my job, I have responsibility for all the job sites, as well as the warehouse and service trucks. I also have responsibility for employee hiring, safety training, job planning and scheduling, quality control, and licensing. I personally hold 28 different state and city licenses, and I firmly believe that getting the training to obtain your licenses and then doing the in-service training to keep your licenses current are important factors in an electrician's success. For example, an electrical contractor can bid on jobs in a wide geographical area. Electricians working for that contractor can work on projects in different cities, even different states. Every place you go will require you to have a valid license.

What advice would you give to someone entering the electrical trade?
Work hard, treat people with respect, and keep an open mind. Be careful how you deal with people. Someone you offend today may wind up being your boss or a potential customer tomorrow.

Trade Terms Introduced in This Module

90° bend: A bend that changes the direction of the conduit by 90°.

Back-to-back bend: Any bend formed by two 90° bends with a straight section of conduit between the bends.

Concentric bends: 90° bends made in two or more parallel runs of conduit with the radius of each bend increasing from the inside of the run toward the outside.

Developed length: The actual length of the conduit that will be bent.

Gain: Because a conduit bends in a radius and not at right angles, the length of conduit needed for a bend will not equal the total determined length. Gain is the distance saved by the arc of a 90° bend.

Offsets: An offset (kick) is two bends placed in a piece of conduit to change elevation to go over or under obstructions or for proper entry into boxes, cabinets, etc.

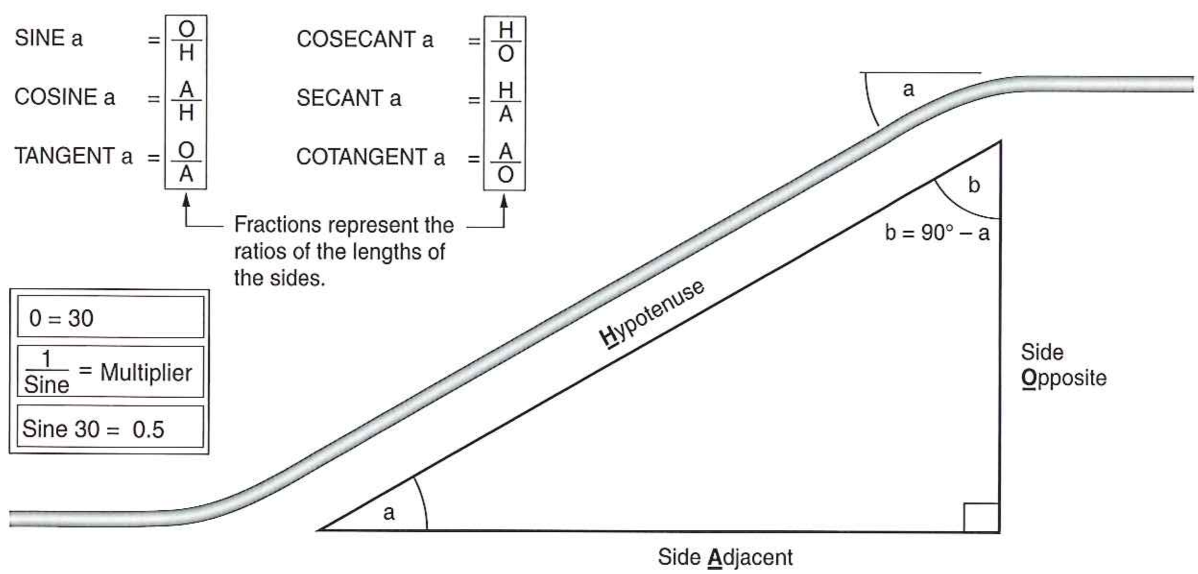
Rise: The length of the bent section of conduit measured from the bottom, centerline, or top of the straight section to the end of the bent section.

Segment bend: A large bend formed by multiple short bends or shots.

Stub-up: Another name for the rise in a section of conduit. Also, a term used for conduit penetrating a slab or the ground.

Using Trigonometry to Determine Offset Angles and Multipliers

You do not have to be a mathematician to use trigonometry. Understanding the basic trig functions and how to use them can help you calculate unknown distances or angles. Assume that the right triangle below represents a conduit offset. If you know the length of one side and the angle, you can calculate the length of the other sides, or if you know the length of any two of the sides of the triangle, you can then find the offset angle using one or more of these trig functions. You can use a trig table such as that shown on the following pages or a scientific calculator to determine the offset angle. For example, if the cosecant of angle A is 2.6, the trig table tells you that the offset angle is 22½°.



To determine the multiplier for the distance between bends in an offset:

1. Determine the angle of the offset: 30°
2. Find the sine of the angle: 0.5
3. Find the inverse (reciprocal) of the sine: $\frac{1}{0.5}$ = 2. This is also listed in trig tables as the cosecant of the angle.
4. This number multiplied by the height of the offset gives the hypotenuse of the triangle, which is equal to the distance between bends.

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ANGLE	SINE	COSINE	TANGENT	COTANGENT	COSECANT
1°	0.0175	0.9998	0.0175	57.3000	57.3065
2°	0.0349	0.9994	0.0349	28.6000	28.6532
3°	0.0523	0.9986	0.0524	19.1000	19.1058
4°	0.0698	0.9976	0.0699	14.3000	14.3348
5°	0.0872	0.9962	0.0875	11.4000	11.4731
6°	0.1045	0.9945	0.1051	9.5100	9.5666
7°	0.1219	0.9925	0.1228	8.1400	8.2054
8°	0.1392	0.9903	0.1405	7.1200	7.1854
9°	0.1564	0.9877	0.1584	6.3100	6.3926
10°	0.1736	0.9848	0.1763	5.6700	5.7587
11°	0.1908	0.9816	0.1944	5.1400	5.2408
12°	0.2079	0.9781	0.2126	4.7000	4.8097
13°	0.2250	0.9744	0.2309	4.3300	4.4454
14°	0.2419	0.9703	0.2493	4.0100	4.1335
15°	0.2588	0.9659	0.2679	3.7300	3.8636
16°	0.2756	0.9613	0.2867	3.4900	3.5915
17°	0.2924	0.9563	0.3057	3.2700	3.4203
18°	0.3090	0.9511	0.3249	3.0800	3.2360
19°	0.3256	0.9455	0.3443	2.9000	3.0715
20°	0.3420	0.9397	0.3640	2.7500	2.9238
21°	0.3584	0.9336	0.3839	2.6100	2.7904
22°	0.3746	0.9272	0.4040	2.4800	2.6694
23°	0.3907	0.9205	0.4245	2.3600	2.5593
24°	0.4067	0.9135	0.4452	2.2500	2.4585
25°	0.4226	0.9063	0.4663	2.1400	2.3661
26°	0.4384	0.8988	0.4877	2.0500	2.2811
27°	0.4540	0.8910	0.5095	1.9600	2.2026
28°	0.4695	0.8829	0.5317	1.8800	2.1300
29°	0.4848	0.8746	0.5543	1.8000	2.0626
30°	0.5000	0.8660	0.5774	1.7300	2.0000
31°	0.5150	0.8572	0.6009	1.6600	1.9415
32°	0.5299	0.8480	0.6249	1.6000	1.8870
33°	0.5446	0.8387	0.6494	1.5400	1.8360
34°	0.5592	0.8290	0.6745	1.4800	1.7883
35°	0.5736	0.8192	0.7002	1.4300	1.7434
36°	0.5878	0.8090	0.7265	1.3800	1.7012
37°	0.6018	0.7986	0.7536	1.3300	1.6616
38°	0.6157	0.7880	0.7813	1.2800	1.6242
39°	0.6293	0.7771	0.8098	1.2300	1.5890
40°	0.6428	0.7660	0.8391	1.1900	1.5557
41°	0.6561	0.7547	0.8693	1.1500	1.5242
42°	0.6691	0.7431	0.9004	1.1100	1.4944
43°	0.6820	0.7314	0.9325	1.0700	1.4662
44°	0.6947	0.7193	0.9657	1.0400	1.4395
45°	0.7071	0.7071	1.0000	1.0000	1.4142

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ANGLE	SINE	COSINE	TANGENT	COTANGENT	COSECANT
46°	0.7193	0.6947	1.0355	0.9660	1.4395
47°	0.7314	0.6820	1.0724	0.9330	1.3673
48°	0.7431	0.6691	1.1106	0.9000	1.3456
49°	0.7547	0.6561	1.1504	0.8690	1.3250
50°	0.7660	0.6428	1.1918	0.8390	1.3054
51°	0.7771	0.6293	1.2349	0.8100	1.2867
52°	0.7880	0.6157	1.2799	0.7810	1.2690
53°	0.7986	0.6018	1.3270	0.7540	1.2521
54°	0.8090	0.5878	1.3764	0.7270	1.2360
55°	0.8192	0.5736	1.4281	0.7000	1.2207
56°	0.8290	0.5592	1.4826	0.6750	1.2062
57°	0.8387	0.5446	1.5399	0.6490	1.1923
58°	0.8480	0.5299	1.6003	0.6250	1.1791
59°	0.8572	0.5150	1.6643	0.6010	1.1666
60°	0.8660	0.5000	1.7321	0.5770	1.1547
61°	0.8746	0.4848	1.8040	0.5540	1.1433
62°	0.8829	0.4695	1.8807	0.5320	1.1325
63°	0.8910	0.4540	1.9626	0.5100	1.1223
64°	0.8988	0.4384	2.0503	0.4880	1.1126
65°	0.9063	0.4226	2.1445	0.4660	1.1033
66°	0.9135	0.4067	2.2460	0.4450	1.0946
67°	0.9205	0.3907	2.3559	0.4240	1.0863
68°	0.9272	0.3746	2.4751	0.4040	1.0785
69°	0.9336	0.3584	2.6051	0.3840	1.0711
70°	0.9397	0.3420	2.7475	0.3640	1.0641
71°	0.9455	0.3256	2.9042	0.3440	1.0576
72°	0.9511	0.3090	3.0777	0.3250	1.0514
73°	0.9563	0.2924	3.2709	0.3060	1.0456
74°	0.9613	0.2756	3.4874	0.2870	1.0402
75°	0.9659	0.2588	3.7321	0.2680	1.0352
76°	0.9703	0.2419	4.0108	0.2490	1.0306
77°	0.9744	0.2250	4.3315	0.2310	1.0263
78°	0.9781	0.2079	4.7046	0.2130	1.0223
79°	0.9816	0.1908	5.1446	0.1940	1.0187
80°	0.9848	0.1736	5.6713	0.1760	1.0154
81°	0.9877	0.1564	6.3138	0.1580	1.0124
82°	0.9903	0.1392	7.1154	0.1410	1.0098
83°	0.9925	0.1219	8.1443	0.1230	1.0075
84°	0.9945	0.1045	9.5144	0.1050	1.0055
85°	0.9962	0.0872	11.4301	0.0880	1.0038
86°	0.9976	0.0698	14.3007	0.0700	1.0024
87°	0.9986	0.0523	19.0811	0.0520	1.0013
88°	0.9994	0.0349	28.6363	0.0350	1.0006
89°	0.9998	0.0175	57.2900	0.0180	1.0001
90°	1.0000	0.0000	0.0000	0.0000	1.0000

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Appendix B

Bending Radius Table

Radius (Inches)	Radius Increments (Inches)									
	0	1	2	3	4	5	6	7	8	9
0	0.00	1.57	3.14	4.71	6.28	7.85	9.42	10.99	12.56	14.13
10	15.70	17.27	18.84	20.41	21.98	23.85	25.12	26.69	28.26	29.83
20	31.40	32.97	34.54	36.11	37.68	39.25	40.82	42.39	43.96	45.83
30	47.10	48.67	50.24	51.81	53.38	54.95	56.52	58.09	59.66	61.23
40	62.80	64.37	65.94	67.50	69.03	70.65	72.22	73.79	75.36	76.93
50	87.50	80.07	81.64	83.21	84.78	86.35	87.92	89.49	91.06	92.63
60	94.20	95.77	97.34	98.91	100.48	102.05	103.62	105.19	106.76	108.33
70	109.90	111.47	113.04	114.61	116.18	117.75	119.32	120.89	122.46	124.03
80	125.60	127.17	128.74	130.31	131.88	133.45	135.02	136.59	138.16	139.73
90	141.30	142.87	144.44	146.01	147.58	149.15	150.72	–	–	–

Developed length for following angles use fraction of 90° chart.

For	15°	22½°	30°	45°	60°	67½°	75°	90°
Take	⅙	¼	⅓	½	⅔	¾	⅚	See Chart

For any other degrees: Developed length = 0.01744 × radius × degrees.

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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.

Benfield Conduit Bending Manual, 2nd Edition. Overland Park, KS: EC&M Books.

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

Tom Henry's Conduit Bending Package (includes video, book, and bending chart). Winter Park, FL: Code Electrical Classes, Inc.

The NCCER makes every effort to keep these textbooks up-to-date and free of technical errors. We appreciate your help in this process. If you have an idea for improving this textbook, or if you find an error, a typographical mistake, or an inaccuracy in NCCER's *Contren®* textbooks, please write us, using this form or a photocopy. Be sure to include the exact module number, page number, a detailed description, and the correction, if applicable. Your input will be brought to the attention of the Technical Review Committee. Thank you for your assistance.

Instructors – If you found that additional materials were necessary in order to teach this module effectively, please let us know so that we may include them in the Equipment/Materials list in the Annotated Instructor's Guide.

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