Hand Bending — 90° Bends

CONDUIT BENDING and FABRICATION

2

A skilled electrician must be able to efficiently make conduit bends using a hand bender and hand tools. Hand benders are available to bend a variety of sizes of conduit, ranging from ½″ up to 1¼″ EMT or 1″ rigid.

All benders have similar components and markings that must be understood in order to make accurate bends. The various markings are used to align the correct part of a bender with a pencil mark on the conduit. The ability to read a tape measure or rule is very important because conditions in the field determine the type and size of bends to be made for a particular job.

The most common hand bends are stub-up, 90° bends, and back-to-back 90° bends. Fabricating these bends is an essential skill that must be mastered in order to become proficient at bending all types of conduit.

A stub-up bend requires the use of the bender take-up so that the stub extends the correct length from the back of the bend. A back-to-back bend requires the use of the bender gain when conduit must be cut and threaded before bending.

OBJECTIVES

1. *List the components of a hand bender.*
2. *List the shoe markings on hand benders.*
3. *Explain the use and practical limitations of hickeys.*
4. *Explain how to determine the take-up of a bender.*
5. *Demonstrate the basic arithmetic and take-up used when fabricating 90° bends.*
6. *Calculate the amount of gain in 90° bends and back-to-back 90° bends.*

Tech Tip

Using a larger bender on smaller conduit can cause the conduit to flatten because the shoe is designed for larger conduit and does not support the sides.

TOOLS

There are several tools required when making hand bends in conduit. Standard hand benders are used to make bends in conduit up to 1¼″ EMT. Hickeys are used to make bends in rigid conduit. Conduit reamers are used to remove any burrs from cut edges. Tape measures and rules are used to measure distances and lengths. Levels and protractors are used to check bends. Calculators are used in many applications.

Hand Benders

Standard hand benders are available from several manufacturers and come in sizes that can bend ½″ to 1¼″ EMT conduit. **See Figure 2-1.** The NEC® specifies a minimum bend radius for field bends depending on the conduit diameter. Benders are manufactured to deliver that particular radius. Generally, a particular bender size is used to bend the corresponding size of conduit. However, there are times when a smaller conduit should be bent on a bender one size larger, such as when a larger bend radius is used to match bends between adjacent pieces of conduit. A larger bender may also be used to increase the radius of bends in order to ease wire pulling.

Rigid conduit may also be bent with EMT benders. However, the next larger size bender must be used. For example, ½″ rigid conduit can be bent with a ¾″ EMT bender that is also designed to bend rigid conduit. When bending rigid conduit with an EMT bender, care should be taken to prevent damage.

Hand Benders

Figure 2-1. Standard hand benders are available from several manufacturers and come in a variety of sizes and configurations.

Occasionally a bender can be "sprung" when bending rigid conduit. This means that the hook becomes bent in relation to the shoe. If this occurs, the bender is ruined and should be thrown away.

Bender Classification. The two broad classifications of hand benders are plumb 30 benders and plumb 45 benders. These classifications are based on the angle generated when the bender handle is in the plumb (vertical) position. A plumb 30 bender produces a 30° angle when the handle is plumb. A plumb 45 bender produces a 45° angle when the handle is plumb. **See Figure 2-2.**

Plumb 30 and Plumb 45 Benders

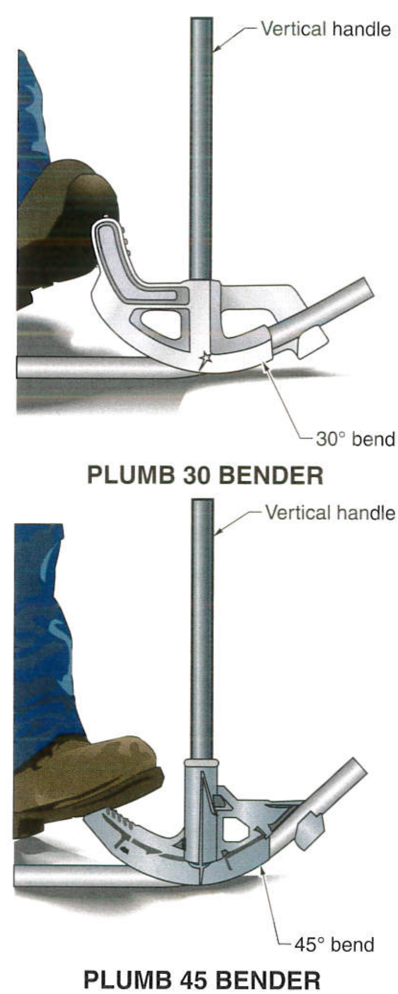


Figure 2-2. Different bender designs give different bends.

It should be noted that these statements are only approximately accurate. The handle of the bender must be moved past plumb before it is released. This allows for springback of the conduit. *Springback* is the property of conduit that causes it to unbend slightly after a bend is completed.

In addition, all benders are slightly different and the angle markings may be slightly off. Therefore, it is not sufficient to use a level to place the handle plumb to the floor. The conduit itself must be measured with a torpedo level or protractor level. An electrician must become familiar with the bender so that quick and accurate bends can be made.

Choosing a bender is often a matter of personal preference. The choice may also depend on the type of bender available at the job site. Since benders are sometimes used with a torpedo level, an electrician should consider the type of torpedo level that is best for the job. **See Figure 2-3.** In any case, it is a good idea to use the same bender whenever possible. Using the same bender allows the electrician to fabricate more consistent and accurate bends than if using different benders.

Bender Components. All benders have similar components. **See Figure 2-4.** Every bender has a shoe. A *bender shoe* is the curved part of a bender that forms the conduit during fabrication. The shoe is used to hold the conduit as it is wedged, or coined, to produce the bend.

A *bender handle* is a tube or lever used to hold the bender while in use. The handle can be factory made or it may be produced on the job by threading rigid conduit of the proper diameter and length into the bender shoe. A rule of thumb for handle length is that the combined length of the handle and bender should reach up to the electrician's elbow. It may be tempting to increase the length of the handle to gain mechanical advantage, but the extra handle length makes it cumbersome for many types of bends.

A *bender foot pedal* is the part of the bender where foot pressure is applied in order to bend the conduit. The foot pedal is designed to maximize the amount of foot pressure on the shoe. Foot pedals can be quite pronounced on some models and almost nonexistent on others.

A *bender hook* is the part of the bender shoe that holds the conduit in place during the bending process. The hook is used to determine the front of the bender and indicates which direction to point the bender. This distinction is critical when discussing three-bend saddles. Generally, the hook is the part of a bender that can be damaged, rendering the bender useless.

Bender Components

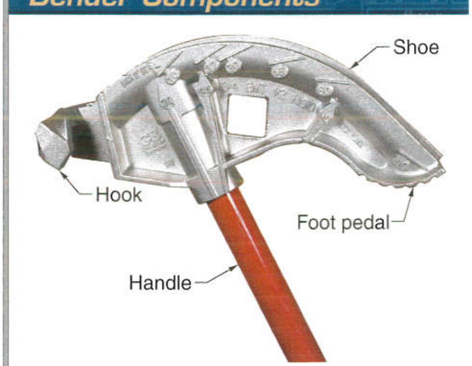


Figure 2-4. The primary bender components are the shoe, foot pedal, handle, and hook.

Torpedo Levels

Figure 2-3. A torpedo level can be used to check the angles of several types of bends.

Bender Shoe Markings. All benders have markings on the shoe. The arrow marking is the most used benchmark on any bender. **See Figure 2-5.** The arrow marking is used to make 90° bends and also as a benchmark on many other types of bends.

The star marking indicates the back of a 90° bend. Many benders also have rim notches located inside or outside of the shoe. These markings, which often look like file marks or teardrops, indicate the center of a 45° bend.

Angle markings vary greatly between manufacturers and in practical use. Some benders have built-in bubble levels that indicate 45° and 90° bends. Others use a pin and a graduated scale device that allow the operator to sight down the handle to determine the angle.

Some benders employ a series of markings on the outside of the shoe. When the conduit is parallel to a marking, that particular angle of bend has been achieved. Other benders use a small plumb bob to indicate the angle. Finally, some benders have no angle marks at all. Regardless of the type of bender used, an initial check should be made to determine the accuracy of the angle markings.

Bender Shoe Markings

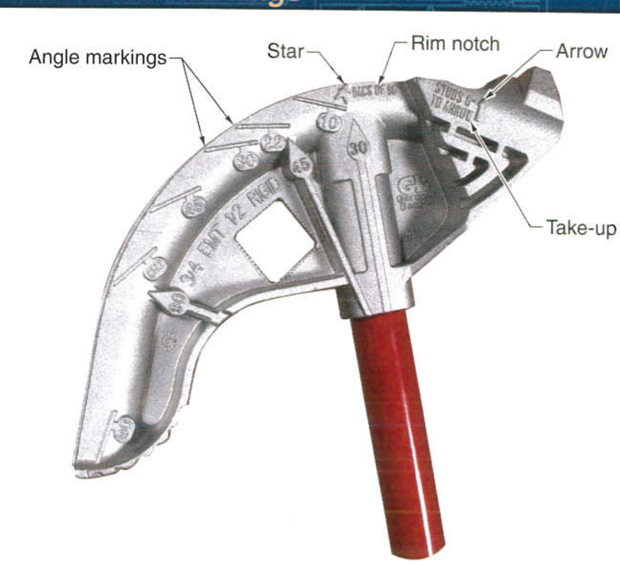


Figure 2-5. Common markings on a bender shoe include the angle markings, star, rim notch, and arrow. In addition, the take-up is often given on the bender.

When bending conduit, the conduit is formed in the shape of the shoe. Keeping the shoe in good shape is critical to the quality of the final product. Using a conduit bender to bend other products, such as rebar, or as a pry bar or lever will significantly reduce its life.

Hickeys

A *hickey* is a hand bender with a no-radius shoe. **See Figure 2-6.** Hickeys are effective only on heavy-walled rigid conduit. If hickeys are used on EMT, the wall will collapse and the pipe will kink. Hickeys are available in ½″, ¾″, and 1″ rigid pipe sizes.

Hickey Styles

Figure 2-6. A hickey is a hand bender with a no-radius shoe.

It is very difficult to make accurate repeatable bends with hickeys. However, they can be used in slab installations where radius is often irrelevant. They are also quite handy when making adjustments to conduits coming out of a slab.

The technique for using a hickey is quite different than for a hand bender with a shoe. Foot pressure is not used and the bends are all accomplished with upper body strength. A bend with a hickey is fabricated by making several short bends at different locations along the conduit. **See Figure 2-7.** If a tight radius is desired, the bends are made close to one another. If a long radius is desired, the distance between the bends is increased.

Conduit Reamers

A *conduit reamer* is a tool used to remove burrs and sharp edges from a piece of conduit after it has been cut to length. **See Figure 2-8.** Sharp edges can damage wire insulation and cause electrical shorts. A reamer is inserted into the cut end of the conduit and turned. The hooked edge of the reamer cleans up any roughness or burrs on the cut end. Burrs and sharp edges must be removed before conduit is installed.

Tape Measures and Rules

A *tape measure* is a measuring device with a metallic tape wound up in a coil that can be extended to take measurements. A *rule* is a rigid measuring tool. **See Figure 2-9.** Tape measures and rules are used to measure distances and lengths in many conduit-bending applications.

A tape measure is a fundamental tool for construction personnel. Reading a tape measure is a critical skill that every electrician must have. A tape measure has markings representing distances in feet, inches, and fractional parts of an inch.

The hook end of a tape is intentionally loose. It moves back-and-forth a distance equal to its thickness. This allows measurements to be made by pulling the tape, with the hook holding the end secure, or by pushing the tape against an edge. The hook end slides and allows a correct measurement to be made in either situation.

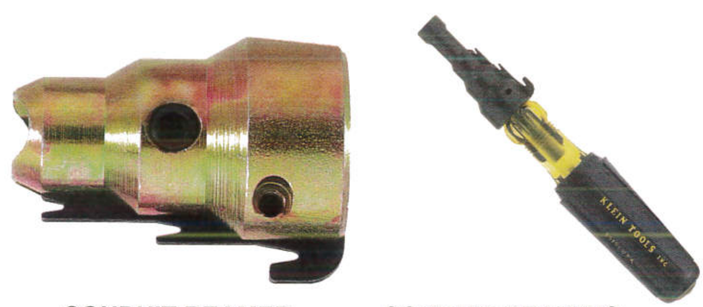
Tech Fact

Folding rules come in several varieties. The inside reading variety is the type most commonly used in electrical work. Tape measures also come in several varieties. In every case, the hook end must be protected. If the hook becomes bent, such as from a fall, any readings made using the hook will be in error. In addition, the only practical tape measures for fieldwork are 1″ or more in width. Narrower tapes are not rigid enough to be extended for a measurement.

Hickey in Use

Figure 2-7. *A bend with a hickey is fabricated by making several short bends at different locations along the conduit.*

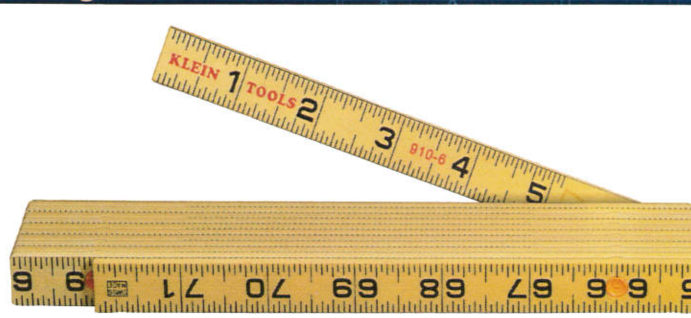
EMT Reaming Tools



Klein Tools, Inc.

Figure 2-8. *A conduit reamer is a tool used to remove sharp edges from a piece of EMT after it has been cut to length.*

Folding Rules



Klein Tools, Inc.

Figure 2-9. *A folding rule is a measuring device that folds up for easy handling.*

Converting between Fractions and Decimals. It is very useful to be able to convert between fractions of an inch and their decimal equivalents. Many calculations involving fractions are done on calculators. The fractions must be converted to decimal numbers to enter into the calculator. After the calculations are completed, the decimal number needs to be converted back to fractions in order to use a tape measure.

The simplest method for converting between decimals and fractions is to use a conversion table. **See Figure 2-10.** To convert from a fraction to a decimal, the fraction is located in the table and the equivalent decimal is found by following the line across in the table. To convert from a decimal to a fraction, the decimal number is found and the line followed back to its equivalent fraction.

Fraction and Decimal Conversions

Fraction	Decimal
1/16	0.0625
2/16, 1/8	0.125
3/16	0.1875
4/16, 2/8, 1/4	0.25
5/16	0.3125
6/16, 3/8	0.375
7/16	0.4375
8/16, 4/8, 2/4, 1/2	0.5
9/16	0.5625
10/16, 5/8	0.625
11/16	0.6875
12/16, 6/8, 3/4	0.75
13/16	0.8125
14/16, 7/8	0.875
15/16	0.9375
16/16	1

Figure 2-10. Some fractions can be represented in more than one way, and all fractions have an equivalent decimal value.

For example, from the table the fraction 5/16 is equal to 0.3125. Similarly, if the result of a calculation is 0.625, this is equal to the fraction 5/8. If the decimal number is not in the table, select the value in the table that is nearest to a decimal. If the result of a calculation is 0.6, the nearest decimal in the table is 0.625 and the equivalent fraction is 5/8.

If a calculator is available, any fraction can be converted to a decimal by dividing the numbers. For example, the fraction 3/4 can be converted to decimal by dividing the 3 by the 4, resulting in 0.75. Similarly, the fraction 5/16 can be converted to a decimal by dividing the 5 by the 16, resulting in 0.3125.

A calculator can also be used to convert a decimal number to a fraction. Simply multiply the decimal number by 16. This gives the number of 16ths in the fraction. For example, the decimal number 0.62 multiplied by 16 gives 9.92, or approximately 10. Therefore, the decimal number 0.62 is approximately equal to 10/16, or 5/8. **See Figure 2-11.**

For mixed numbers, care must be taken to multiply only the decimal part by 16. Multiplying the entire mixed number by 16 gives the wrong results. Only the part to the right of the decimal point is multiplied by 16. If a calculation result of 20.80″ is multiplied by 16, the result is 332.8, which has no meaning. If the part to the right of the decimal point, 0.80, is multiplied by 16, the result is 12.8, or about 13. This means that 20.80″ is approximately equal to 20 13/16″.

Calculator Conversions

CONVERT 0.62 TO A FRACTION

$$0.62 \times 16 = 9.92$$

$$0.62 = \frac{10}{16} \text{ (approximately)}$$

CONVERT 20.80 TO A FRACTION

$$20.80 \times 16 = 332.8 \text{ (no meaning)}$$

$$0.80 \times 16 = 12.8$$

$$0.80 = \frac{13}{16} \text{ (approximately)}$$

Figure 2-11. A calculator can be used to convert a decimal number to a fraction.

Mental Math

If a calculator or conversion table is not available, there are other simple methods that can be used to convert between decimals and fractions. These methods are not exact, but give results to the nearest 16th of an inch.

In the first method, the decimal value can be expressed in hundredths and divided by 6. The result is a close estimate of the number of 16ths. For example, the decimal 0.80 is 80⁄100, or 80 hundredths. Dividing the 80 by 6 results in 13.3. Rounding 13.3 gives 13, indicating that 0.80 is approximately equal to 13⁄16. For example, a calculation result of 20.80″ is approximately equal to 20 13⁄16″.

The second method requires memorizing the decimal equivalents for all of the 1⁄8″ values in their 100ths form and then simply adding or subtracting 6 to come up with the nearest corresponding 1⁄16″ equivalent. For example, 3⁄8″ (0.375″) is approximately equal to 0.38, or 38 hundredths. Therefore, the value of the next highest 16th, 7⁄16, can be determined by adding 6 to the 38. The sum of 38 and 6 is 44, indicating that 7⁄16 is fairly close to 0.44. The actual value is 0.4375.

The value of the next lowest 16th, 5⁄16, can be determined by subtracting 6 from the 38. The difference between the 38 and 6 is 32, indicating that 5⁄16 is fairly close to 0.32. The actual value is 0.3125.

Conversions without Calculator

$$0.80 = \frac{80}{100}$$

$$\frac{80}{6} = 13.3$$

$$0.80 = \frac{13}{16}$$
(approximately)

DIVIDING BY 6

Eighths	Decimal	Hundredths
1⁄8	0.125	13
2⁄8	0.25	25
3⁄8	0.375	38
4⁄8	0.5	50
5⁄8	0.625	63
6⁄8	0.75	75
7⁄8	0.875	88
8⁄8	1	100

$$\frac{3}{8} = 38 \ (hundredths)$$

$$\frac{7}{16} = 38 + 6 = 44 \ (hundredths)$$

$$\frac{7}{16} = 0.44 \ (approximately)$$

$$\frac{5}{16} = 38 - 6 = 32 \ (hundredths)$$

$$\frac{5}{16} = 0.32 \ (approximately)$$

ADDING AND SUBTRACTING 6

BASIC BENDS

A 90° bend is the first bend learned by an electrician. The techniques used in making this basic bend are used in many other types of bends. Take-up is an adjustment made to a measurement when making bends.

Tech Fact

The thin walls of EMT can easily kink and bend out of shape when bent with a hickey.

Take-up

Every bender has a take-up, or deduction. *Take-up* is the value that is used to determine where to place the bending marks. The take-up is often stamped on hand benders. The take-up can also be determined from the bender manual or chart provided with a new bender. **See Figure 2-12.** An electrician should not assume that the take-up is the same for all benders of the same size. In addition, the take-up may vary from one manufacturer to another.

Take-up	
Bender Size	Typical Take-up
½″	5″
¾″	6″
1″	8″
1¼″	11″

Figure 2-12. Every bender has a specific take-up. This value is used to determine where to place pencil marks on the conduit before it is bent.

90° Bends

In order to place the bending mark in the correct position on the conduit, the take-up must first be subtracted from the desired stub length. A pencil mark is then placed on the conduit where the bend is to be made. A soft lead pencil is recommended so that the mark can be easily removed if necessary. Marks made with a permanent marker can be an unnecessary distraction on exposed conduit and are considered unprofessional. The pencil mark should be drawn entirely around the conduit. This makes it much easier to find the mark when making multiple bends in low lighting conditions, or when the conduit is rotated during the bending process.

A bend is made using heavy foot pressure. The handle is used only to guide the bend. If bends in EMT are made using the handle to apply pressure to the shoe, the conduit can rise up from the bending surface. This creates either a distorted curve in the bend or a kink in the conduit. When bending heavier-walled rigid conduit, foot pressure is just as critical; however, some force will need to be applied with the handle to complete the bend.

Making Stub-up Bends. A *stub-up bend* is a 90° bend in conduit made perpendicular to the original length of the conduit, with the conduit extending a specified length from the back of the bend. **See Figure 2-13.** A stub-up bend can be used whenever conduit has to make a 90° turn. However, a stub-up bend still requires a simple calculation to determine where to place the bend mark in order to reach a desired stub length.

A stub-up bend is created as follows:

1. Measure the length of the required stub-up. This is the distance from the back edge of the conduit out to where the conduit should end. **See Figure 2-14.**
2. Subtract the take-up from the stub length measurement. Place a pencil mark on the conduit at the calculated distance.
3. Place the bender on the conduit and align the arrow benchmark on the bender with the pencil mark on the conduit. Make certain the bender hook is facing toward the end of the conduit from which the measurement was taken.
4. Place the conduit and bender on a hard level surface. Place one foot on the bender foot pedal and grasp the handle of the bender with both hands. The other foot may remain on the ground or may be placed on the conduit to help steady it. Use the handle to guide the bender while using heavy foot pressure to make the bend.
5. Once the bend approaches 90°, check your progress with a torpedo level, making sure the surface on which you are working is level. Some fine-tuning is often necessary to make a perfect 90° bend. Bending slightly past 90° is usually required to compensate for springback.
6. Check the completed stub length against the desired length. It is often a result of poor foot pressure if the completed stub length is longer than the desired length.

90° Stub-up Length

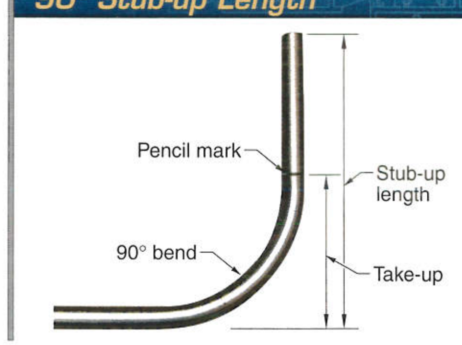


Figure 2-13. A stub-up bend is fabricated to a precise stub-up length.

90° Stub-up Bending

1. Measure stub-up length.

2. Mark the conduit.

3. Align the arrow with pencil mark.

4. Use heavy foot pressure to make bend.

5. Check bend with torpedo level.

6. Install conduit.

Figure 2-14. *A stub-up bend is started at the pencil mark.*

For example, a ½″ EMT bender with a 5″ take-up is used to make a stub-up bend. **See Figure 2-15.** In the first step, the length of the stub is measured at 10″. Next, the take-up of 5″ is subtracted from the 10″ length of the stub-up, which results in 5″. A pencil mark is placed on the conduit at a distance of 5″ from the end.

The bender is placed on the conduit and the arrow is aligned with the pencil mark. After the bender is placed on the conduit, heavy foot pressure is used to make the bend. The finished bend is checked with a torpedo level and the overall length is checked against the desired length.

Stub-up Bend

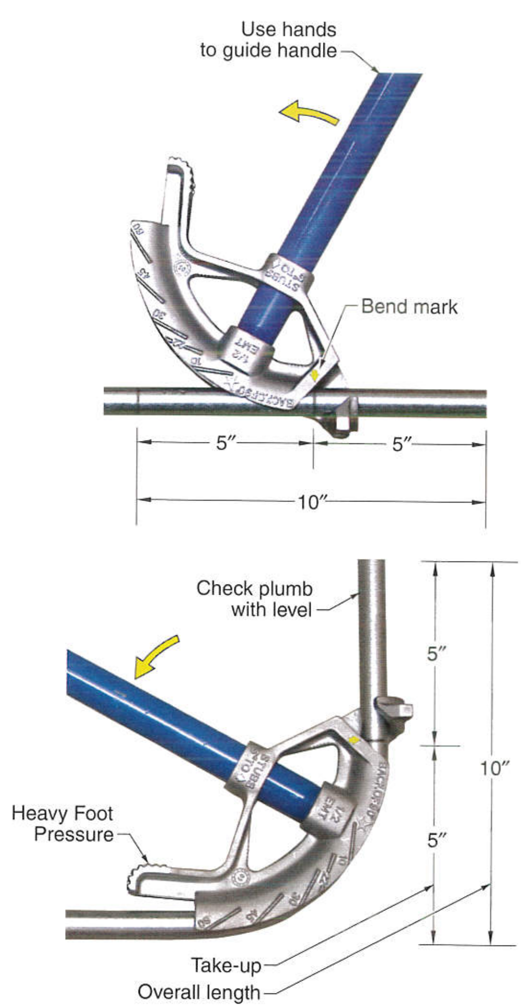


Figure 2-15. The pencil mark is placed 5″ from the end when the stub-up length is 10″ and the take-up is 5″.

Measuring Shortcuts. There are two simple shortcuts that can be used when working with take-up to eliminate the possibility of the arithmetic errors. **See Figure 2-16.**

The first shortcut is to place the measuring tape with the take-up length at the end of the conduit and place the pencil mark at the tape marking for the stub-up length. For example, if the measured stub-up length is 15″ and the take-up is 7″, the end of the conduit is placed at the 7″ marking and the pencil mark is placed at the 15″ marking.

The second shortcut consists of positioning a measuring tape with the stub-up length measurement at the end of the conduit and placing the pencil mark at the tape marking for the take-up.

For example, if the measured stub-up length is 15″ and the take-up is 7″, the end of the conduit is placed at the 15″ marking on the tape. The pencil mark is placed on the conduit at the 7″ marking.

Determining an Unknown Take-up. There are situations where the take-up for a bender is not known. In this case, an electrician can determine the actual take-up of a bender by using a scrap piece of conduit. The actual take-up measurement is found by placing a pencil mark on the scrap conduit at any convenient location and making a 90° bend with the arrow at that mark.

The distance from the back of the bend to the pencil mark is the take-up. The distance is measured by laying the conduit flat on the ground and placing a straight edge against the back of the bend and measuring to the pencil mark. This is a universal method of finding take-up. It works for all types of benders and shoes.

Bend Corrections

There are occasions when an error has been made in bending conduit. When a bend ends up being less than the required 90°, the bend can be fixed by placing the bender back on the conduit at the same benchmark and bending slightly more. If the bend ends up being bent past 90°, the bend can be fixed by placing the handle of the bender over the stub gently bending it backward. This requires that the handle be placed as far down the stub as possible to avoid a kink in the bend. One foot should be placed on the conduit to steady it during the straightening.

Back-to-Back 90° Bends

Fabricating back-to-back 90° bends is the next skill to be mastered. Back-to-back 90° bends consist of two 90° bends fabricated on the same length of conduit. The bends may be required to be in the same direction, 90° to the left or right, or in the opposite direction. Back-to-back 90° bends can be used to fit conduit within a space between obstructions or to connect two boxes a known distance apart.

Making Back-to-Back Bends in the Same Direction. There are three measurements for any back-to-back 90° bend. **See Figure 2-17.** The first two measurements are the lengths of the two stubs. The third measurement is the back-to-back distance (distance from the back of one bend to the back of the other). The back-to-back bend is fabricated as follows:

1. Measure the two stub-ups and the required back-to-back distance. **See Figure 2-18.**
2. Use the first measured stub-up length and the bender take-up to make the first bend. This is the same procedure as discussed previously.
3. Subtract the bender take-up from the measured back-to-back distance. This difference is the distance from the back of the first bend to the pencil mark for the second bend. Place a straightedge along the first stub to extend the back of the first 90° bend. Measure from the straightedge away from the first bend and place a pencil mark at the calculated distance.
4. Place the bender on the conduit and align the arrow with the pencil mark. It is very important to keep the two bends in the same plane. Carefully sight along the bender and conduit to make sure that the second bend is aligned with the first. Make certain the bender hook is pointing toward the first bend and make the second bend.
5. Check the bend with a level. Measure the length of the second stub-up and place a pencil mark on the conduit. The stub length is measured from the ground or from a straightedge placed on the back of the second bend.
6. Once the bends are complete, the conduit can be cut to length, reamed, and installed.

Tech Fact

A dogleg is an undesirable bend that is not in line with other bends in the same conduit. A conduit with a dogleg does not lie flat against the wall or ceiling. A dogleg is sometimes called a "wow".

Measuring Shortcuts

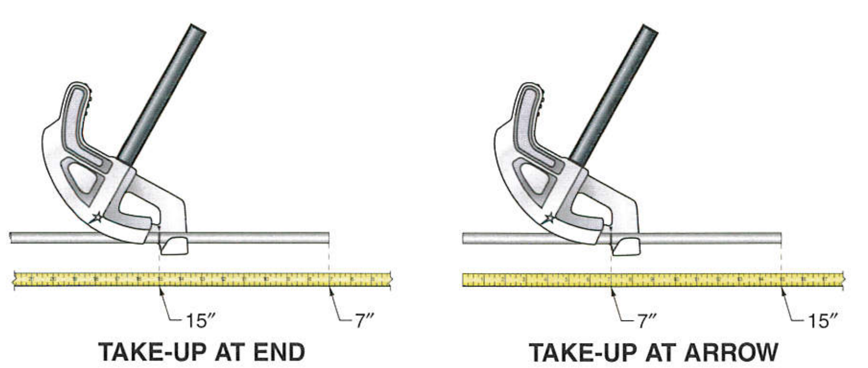


Figure 2-16. Simple measuring shortcuts can be used to eliminate arithmetic errors.

Reverse Method for 90° Bends

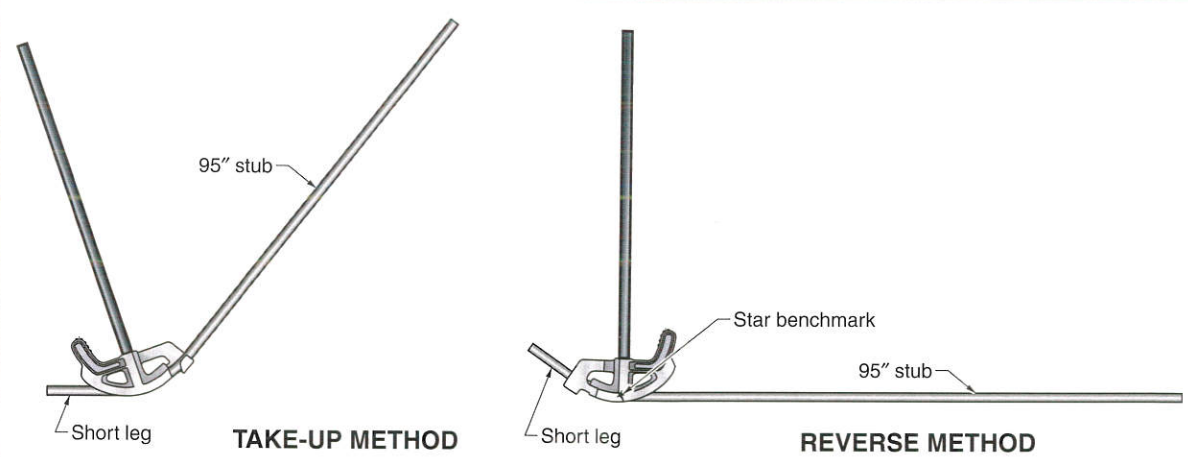
Another method for laying out and forming a 90° bend is called the reverse method or the B method. When using this method to form a 90° bend, the take-up for the bending shoe is no longer a consideration. The reverse method is often used when forming 90° bends with long leg lengths. Forming 90° bends with long leg lengths can be accomplished with the standard take-up method; however, it can be awkward or difficult to control the conduit in the bender during the bending process.

The reverse method forms the short leg as if it were a stub while leaving the long stub on the ground as if it were a leg. For example, if the desired stub of a 90° bend is 95″ long, the leg remaining on the floor is only 25″ long plus the gain. A stub of this length is difficult to handle, so the bend can be made in reverse. When this bend is complete, a leg length is formed that is 95″ long from the end of the conduit to the back of the 90° bend. The reverse method can be used to form a 90° bend as follows:

1. Measure 95″ from one end of the conduit and place a pencil mark.
2. Place the bender on the conduit with the hook pointing towards the opposite end of the conduit (the short end). Align the pencil mark and the point of the star.
3. Fabricate the 90° bend, bending the short end in the air.

The reverse method of fabricating 90° bends can also be used in concrete slab or pan applications. This method can be used when the conduit is in place and the partition is marked on the deck. The bend is made by aligning the star with the partition mark.

Reverse Method



Making Bends at Right Angles. If the situation calls for the two 90° bends to be at right angles to each other, the procedure is very similar to that for back-to-back bends in the same direction. This situation may occur when conduit is run along one wall, makes an elevation change at a corner (the first 90° bend), and then makes another 90° bend to run along another wall.

The only difference between this procedure and making a standard back-to-back bend is the angle of the second bend relative to the first bend. **See Figure 2-19.** For best accuracy, the bender is placed on the conduit and the conduit rotated until a level shows that the first bend is parallel to the floor. The arrow benchmark and the pencil mark are aligned and the second bend is then completed in the normal manner.

Tech Fact

Take-up is the distance measured from the arrow on the bender to the back side of the conduit after making a 90° bend.

BEND PRE-POSITIONING

There are many situations where it is desirable to measure and cut the conduit to the proper length before fabricating a 90° bend. It is far easier to thread a straight length of conduit than conduit that has been bent. The principle of gain allows a section of conduit to be cut to the proper length before bending.

Gain

Because conduit is required to be bent with a radius, the actual length of the conduit will be less than the sum of the horizontal and vertical distances as measured in the run. *Gain* is the difference between the sum of the straight distances and the actual length of conduit. **See Figure 2-20.** In other words, gain is the "shortcut" provided by following the arc of the curve instead of the straight distance.

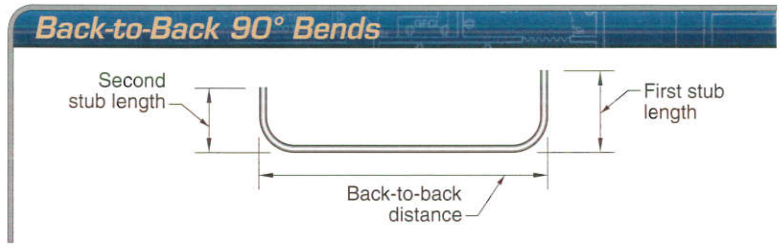


Figure 2-17. *A back-to-back bend requires three measurements.*

Figure 2-18. *When back-to-back bends are made in the same direction, the bend is fabricated on the floor.*

Back-to-Back Bends at Right Angles

Figure 2-19. Back-to-back bends are often made at right angles to each other.

Gain

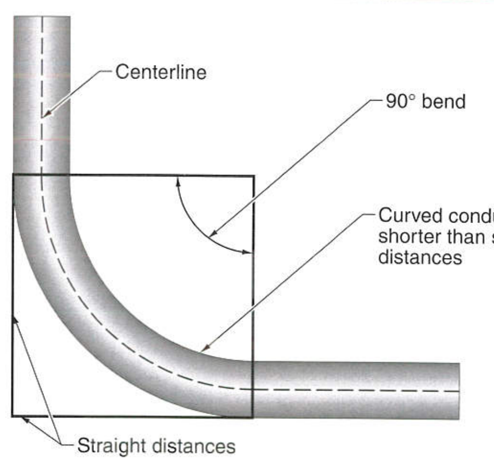


Figure 2-20. Gain is the shortcut provided by following the arc of a bend instead of the straight distances.

Tech Fact

A larger bend radius allows the wire to be pulled more easily than a smaller bend radius. However, a smaller bend radius allows the bend to fit tighter in a corner.

To find the length of straight conduit needed to complete a run, the straight distances are added and the gain is subtracted from this sum. The difference is the linear length of conduit required. The amount of gain for conduit of different sizes may be available from the bender manufacturer. **See Figure 2-21.**

For example, a run of ¾″ EMT has a leg of 37½″ and a stub of 33½″. The gain from the table is 3″. **See Figure 2-22.** The needed length of conduit before making the bend is 68″ (37½ + 33½ – 3 = 68).

Measuring Gain. Generally speaking, there is no standard value for typical gain. Gain should be determined the first time a particular bender is used. In this situation, gain can easily be measured by using a scrap piece of conduit. Gain can be measured as follows:

1. Measure the length of a scrap piece of conduit.
2. Fabricate a 90° bend and verify that the bend is accurate.
3. Measure the stub and leg lengths.

The sum of the stub and leg lengths is the completed length of the 90° bend in the conduit. The difference between the completed length and the original length is the gain for that bender.

For example, ¾″ EMT is being used on a job. A scrap piece of conduit measuring 36⅝″ long is used to determine gain. After fabricating a 90° bend, the stub is 15⅝″ long and the leg is 24⅛″ long. The completed length is 39¾″ (15⅝ + 24 ⅛ = 39¾). Since the gain is the difference between the completed length and the original length, the gain is 3⅛″ (39¾ – 36⅝ = 3⅛).

Back-to-Back Gain. The principle of gain can be used when bending back-to-back 90° bends. Each of the two bends has an equal amount of gain, so the total amount of gain is twice the gain of a single bend. To find the total precut length of conduit for a back-to-back installation, simply add the length of the two 90° stubs to the distance between the backs of the 90° bends and subtract twice the gain. If the run has three 90° bends, subtract three times the gain. The required length of conduit for a two-bend back-to-back 90° bend is calculated as follows:

$$l = S_1 + S_2 + D - (gain \times 2)$$

where

l = precut length, in inches
S_1 = length of stub-up 1, in inches
S_2 = length of stub-up 2, in inches
D = distance between backs of the bends, in inches
$gain$ = gain, in inches

For example, a back-to-back 90° bend is made in ½″ EMT. **See Figure 2-23.** The length of one stub-up is 13¾″ and the length of the other stub-up is 22¼″. The distance between the backs of the bends is 41″. For ½″ EMT, the gain is 2½″. The required length of conduit is calculated as follows:

$$l = S_1 + S_2 + D - (gain \times 2)$$

$$l = 13\tfrac{3}{4} + 22\tfrac{1}{4} + 41 - (2\tfrac{1}{2} \times 2)$$

$$l = 77 - 5$$

$$l = \mathbf{72''}$$

APPLICATION—THREE-BEND BACK-TO-BACK BENDS

An electrician needs to bend conduit around several obstacles and decides to use a three-bend back-to-back 90° bend. **See Figure 2-24.** The conduit is ½″ rigid bent on a ¾″ EMT bender with a gain of 3$\frac{1}{16}$″ and a take-up of 6″. The two stubs are 12″ and 16″, with back-to-back distances of 21″ and 36″, with the stubs at a right angle to the legs.

Tech Fact

Threadless couplings and connectors used with conduit shall be made tight. Where buried in masonry or concrete, they shall be concrete tight. Threadless couplings and connectors shall not be used on threaded conduit ends unless listed for the purpose. Running threads shall not be used on conduit for connection at couplings.

Hand Bending Gain

Conduit Size	Typical EMT Bend Radius	EMT Gain	Typical Rigid Bend Radius	Rigid Gain
½″	4$\frac{3}{16}$″	2½″	5⅛″	3$\frac{1}{16}$″
¾″	5⅛″	3″	6½″	3$\frac{13}{16}$″
1″	6½″	3$\frac{15}{16}$″	9⅝″	5$\frac{7}{16}$″
1¼″	8″	4$\frac{15}{16}$″	–	–
	9⅝″	5⅝″	–	–

Figure 2-21. *The amount of gain depends on the conduit size and the bend radius. These values are approximate and should be verified for each bender.*

¾″ EMT Gain

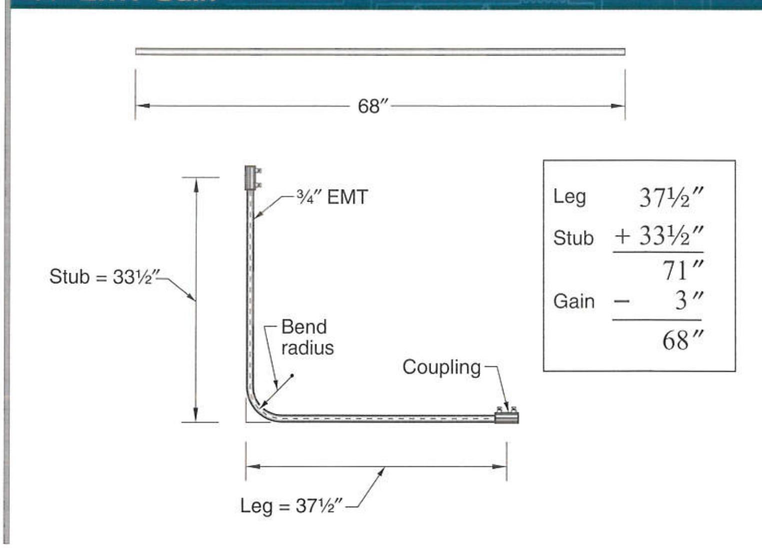


Figure 2-22. *The conduit length is calculated from the horizontal and vertical distances and the gain.*

Back-to-Back Gain

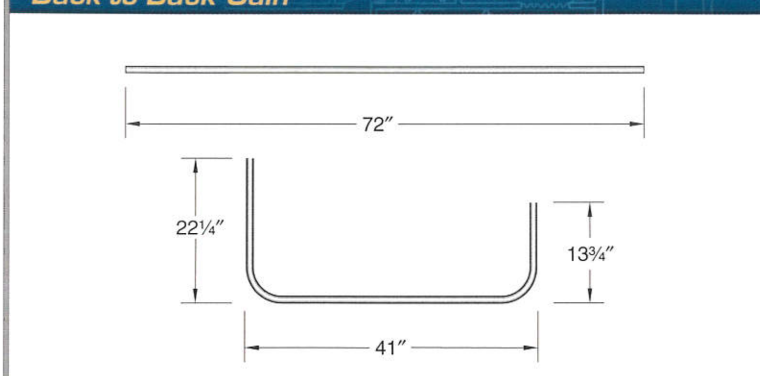


Figure 2-23. *The gain is doubled in the calculation for a back-to-back bend.*

Calculating Conduit Length

The method used to calculate prebend length needs to be modified slightly for a three-bend back-to-back gain calculation. The total back-to-back distance needs to include both the legs and the gain needs to be multiplied by three because there are three bends. The required length of conduit is calculated as follows:

$$l = S_1 + S_2 + D_1 + D_2 - (gain \times 3)$$
$$l = 12 + 16 + 21 + 36 - (3\tfrac{1}{16} \times 3)$$
$$l = 85 - 9\tfrac{3}{16}$$
$$l = \mathbf{75\tfrac{13}{16}}$$

The total required conduit length is 75$\tfrac{13}{16}$″. Therefore, a 10′ length needs to be cut down to 75$\tfrac{13}{16}$″ and threaded.

Back-to-Back Bend Layout and Fabrication

A three-bend back-to-back bend is laid out in a manner similar to a two-bend back-to-back bend. The bender take-up needs to be used to determine the correct location for the pencil marks. A three-bend back-to-back bend is fabricated as follows:

1. Use the bender take-up of 6″ to calculate the distance to the first pencil mark. Since the first stub is 12″, the pencil mark is placed 6″ (12 – 6 = 6) from one end of the conduit.
2. Place the bender on the conduit and align the arrow benchmark with the pencil mark and make a 90° bend.
3. Use the bender take-up to calculate the distance to the second pencil mark. Since the first leg is 21″, the pencil mark is 15″ (21 – 6 = 15) from the back of the bend. Use a straightedge to place a pencil mark 15″ from the back of the bend.
4. Place the bender on the conduit and align the arrow benchmark with the new pencil mark and make a 90° bend. Be very careful to make sure that the bends are in the correct plane so a dog-leg is not created.
5. For the third bend, align the first leg (21″) with a straight edge and measure 36″ from the back of the second bend. Place a pencil mark at that point.
6. Turn the bender around, facing the far end of the conduit (16″ stub), and align the star benchmark on the bender with the pencil mark on the conduit. This is the reverse method. Pull up on the 16″ stub while using the previous bend to stabilize the conduit on the floor. By keeping the 21″ leg flat on the floor it will be easier to finish the 16″ stub and have it be perpendicular to the previous bend.

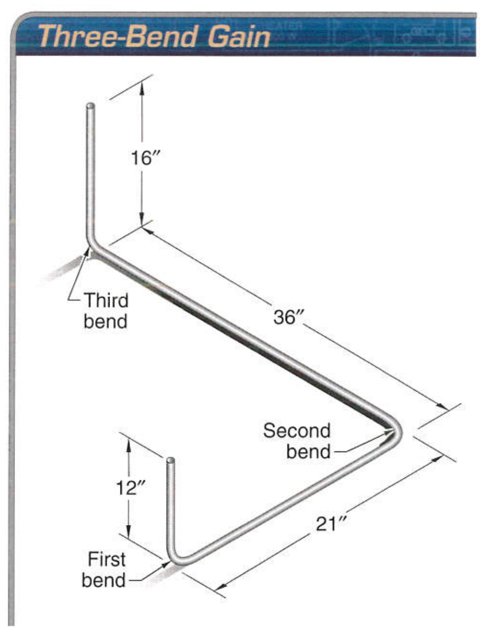


Figure 2-24. *The gain is multiplied by three in the calculation for a three-bend back-to-back bend.*

Back-to-Back Bend Pre-positioning

Gain can be used to pre-position back-to-back 90° bends. This eliminates the need to measure the back-to-back distance while making bends. The gain for different types of conduit is available in tables. For ½″ rigid conduit bent on an EMT bender, the take-up is 6″ and the gain is 3⅟16″. For example, a three-bend back-to-back bend is needed with a 12″ stub, a 21″ leg, a 36″ leg, and a 16″ stub. The bends are fabricated as follows:

1. Use the bender take-up of 6″ to calculate the distance to the first pencil mark. Since the first stub is 12″, place the first pencil mark 6″ (12 – 6 = 6) from one end of the conduit.
2. The first leg is 21″. Taking the gain into account, place the second pencil mark 17¹⁵⁄16″ (21 – 3⅟16 = 17¹⁵⁄16) from the first pencil mark.
3. The second leg is 36″. Taking the gain into account, place the third pencil mark 32¹⁵⁄16″ (36 – 3⅟16 = 32¹⁵⁄16) from the second pencil mark.
4. Align the arrow benchmark with the first pencil mark and fabricate the 12″ stub.
5. Align the arrow benchmark with the second pencil mark and fabricate the 21″ leg.
6. Align the arrow benchmark with the third pencil mark and fabricate the 36″ leg.

The bender must face the starting end (12″ stub) for all three bends. The third bend may be difficult to fabricate unless the bender is turned around. This problem can be solved by simply marking the far end of the conduit at 10″ (16 – 6 = 10), reversing the direction of the bender, and bending the 16″ stub using the arrow benchmark.

SUMMARY

- Standard hand benders are available from several manufacturers and come in sizes that bend ½″ to 1¼″ EMT conduit.
- Rigid conduit may also be bent with EMT hand benders. However, the next larger size bender must be used.
- A bender shoe is the curved part of a bender that holds the conduit during fabrication.
- A bender foot pedal is the part of the bender where foot pressure is applied in order to bend the conduit.
- A bender hook is the part of the bender shoe that holds the conduit in place during the bending process.
- A bender take-up, or deduction, is a value that is used to determine where to place the bending marks when making a stub-up or 90° bend.
- Back-to-back 90° bends consist of two or more 90° bends fabricated on the same length of conduit.
- Gain is the difference between the sum of the straight distances and the actual length of conduit.