BENDING CONDUIT / TUBING USING HAND BENDERS

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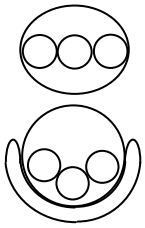
Provided by:

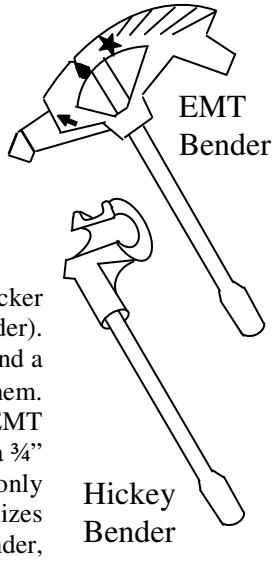
Wirelab Services

Resources for Electricians

The ability to bend conduit and tubing (raceways) is a requirement for all electricians. This document will step the beginner through the four main bends which are used by electricians. The electrician must use caution when bending raceways to make sure that it maintains it's round shape throughout the bent portion of the raceway, in order to help prevent "jamming" when pulling the wires into it (See NEC CH9 Table1 Note2).



EMT is very easy to bend by hand. It is a thin wall galvanized metal tubing which is used mostly for interior construction. Some electricians call it "Thinwall". EMT benders are full-sweep benders or one-shot benders. They have a curved track for the raceway to follow as the electrician bends the raceway. The raceway fits into a curved track or slot on the EMT bender which keeps the raceway from spreading out as it is bent. This keeps the raceway round in the bend. If it flattens out the wires can "jam" against the sides of the conduit as they are pulled into the round part of the raceway just past the curve.

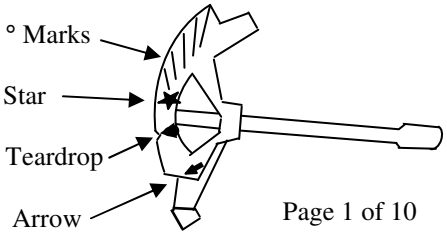


Rigid and IMC conduit are the hardest raceways to bend by hand because they have a much thicker and harder wall. ½" and ¾" rigid or IMC can be bent by hand using a hickey bender (or segment bender). A hickey bender is used to bend conduit in small bends with short segments. For instance, in order to bend a 90° bend with this type of bender you would bend 9 each 10° bends with short gaps in between them. Another way to bend rigid or IMC conduit by hand is to use a "rigid" full sweep bender or a steel EMT bender (don't try this with an aluminum bender). To use a steel EMT bender, the electrician would use a ¾" EMT bender for ½" rigid or IMC. For ¾" rigid or IMC, use a 1" EMT bender. The hickey bender is only used for Rigid or IMC, since it would normally kink EMT tubing (except for very small bends). Large sizes of raceways can be bent with hydraulic benders or with mechanical benders, such as a Chicago bender, which incorporates a ratcheting action.

PVC conduit is normally bent with heat. Heat benders are used on big jobs, but for smaller jobs, 45° and 90° elbows can be purchased and glued together to complete the run. However, in some cases, an EMT bender can be used to bend small degree bends or "kicks" in ½" or ¾" PVC . Double the degree of bend that you want for the PVC raceway. For instance, to create a 30° kick in the PVC, the raceway is bent to 60°, and then when the bender is removed, the conduit will "spring back" to 30°.

There are four major types of bends made in raceways: stub up bends, offset bends, back to back bends and saddle bends. There are two types of saddle bends: three-point and four-point saddles. This document will walk a beginning electrician through the steps to bend EMT tubing with a hand EMT tubing bender. These steps will produce consistent bends every time. Many electricians have developed their own technique for bending raceways and will skip many of the steps mentioned here. The least amount of measuring produces the fastest installation. However, when duplicate bends in raceways need to be run side by side, it is very difficult to produce parallel runs without measuring. That is when an experienced electrician will still need to mark the raceway in a manner similar to what is illustrated in this document. When following this document, pay close attention to marking the raceway and which direction the bend is made from that mark. Many of the bends require more than one mark. The bends are made on the conduit in the same order that the marks were placed on the conduit. Some electricians make a small model of the bend with a piece of solid copper wire. Practice makes perfect. You will never learn to bend raceways without doing it. Page nine of this article has tables needed to calculate the length that EMT will shrink from bending. Both shrinkage and gain values are needed to determine the final length of rigid or IMC conduit, so that it can be cut and threaded before it is bent.

The EMT bender has degree marks on it for making precise 10°, 22½°, 30°, 45° and 60° bends. There is not a 90° mark on the bender. The 90° bend is made by bending the raceway until it looks like the raceway is bent to 90°. This will get easier with experience. The EMT bender also has several marks that are used to line up various types of bends. These are the arrow, the star and the teardrop. The teardrop (notch or rim mark) is used for the center bend on 3 point saddles. The star is used on back to back bends. The arrow is used for all other bends covered in this manual.

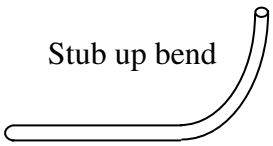


Some of the terms used when bending raceways are defined as follows:

"Back to Back bend" - a 90° bend located a short distance away from a box, a raceway fitting or another bend on the raceway.
"Box offset bend" - An offset bend that lifts the raceway up to the height of the knockout opening in the box so that the raceway enters the box in a straight direction instead of at a slight angle.
"Chicago Bender" - A ratcheting bender for larger raceways. This heavy bender is usually on wheels.
"Concentric bends" - bends in side by side conduit where each conduit is bent on the same centerline but with increasing radii.
"Dog Leg" - A mistake in bending when two bends in a raceway do not line up with each other.
"Foot" - The part on the bender where the electrician puts foot pressure to keep the raceway in the curved track of the bender.
"Gain" - The distance a raceway's path will shorten when it bends around a curve rather than going all the way into the corner. The gain can be calculated by taking 43% of the radius of the bend. See the table on page 9 of this handout.
"Jamming" - A problem that occurs while multiple wires are pulled through slightly flattened bends in a conduit (see NEC, Chapter 9, Table 1, Informational Note 2). The wires will move to a side by side position inside the bent part of the conduit and then will get stuck against the sides of the raceway as they are pulled into the non bent part of the conduit.
"Kick" - A bend in the raceway, usually less than a 45° angle that changes the direction of the run.
"Offset bend" - Two equal but opposite bends on a raceway that allow both ends of the raceway to remain parallel to each other.
"One Shot bender" - a bender that makes a complete bend in one step (not in segments) also called a "full sweep" bender.
"Reaming the conduit" – Deburing the jagged and sharp edges of a conduit which occurs in the process of cutting a pipe.
"Rise" - The distance that a raceway will offset or stub up.
"Run" - A term used for a complete path of raceway or cable between two points, usually between boxes and/or panels.
"Segment bend" - A large bend formed by a series of smaller bends.
"Sled-Runner" - A 90° segment bend made with a hickey bender which has unequal segment bends.
"Springback" - The amount a raceway will straighten out after the pressure of bending is released.
"Stub-up bend" - A 90° bend in a raceway that is located at or near the end of the raceway.

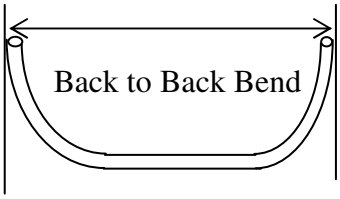
Introduction to the Bends

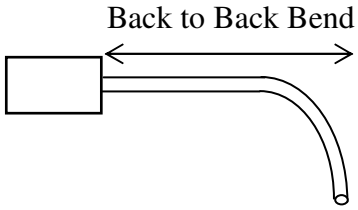
Use a ½" EMT bender to make all of the following bends. Marks are placed on the conduit and then the bender uses these marks to make the various bends.



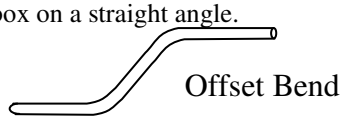
The Stub up bend. A stub up bend is a 90° bend used to bring a raceway from under the floor up to a receptacle box or into a panel or wireway. It is usually between 12" and 36" high. Because the stub up bend is so close to the end of the raceway, the bender must be placed on the back side of the mark which is placed on the raceway. The electrician will need to deduct 5" or 6" from the height of the stub up to compensate for bending in the "wrong" direction. Deduct 5" for ½" EMT tubing. Deduct 6" for ¾" EMT tubing, etc.

The Back to back bend. A back to back bend is any bend that needs a 90° bend located a predetermined distance away. This is probably the most common type of bend. A mark is made on the raceway at the exact distance that is needed for the 90° bend.



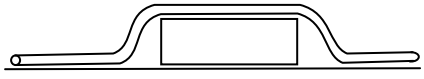


The offset bend. This bend is made up of two equal degree bends that are bent in opposite directions. This bend can be used when the run of raceway is changing elevations. Both marks are placed on the raceway before any bending takes place. A **box offset** is a small offset bend (usually two 10° bends) which is used to lift a raceway from the surface up to the height of the knockout of the box it is entering. This bend is usually made without marking the conduit. It allows the connector to enter the box on a straight angle.



The saddle bends. The **3 point saddle** is used to jump over small obstructions 6" or less, such as an installed raceway which is running perpendicular to the raceway you are installing. This bend is made by bending the middle bend twice the degree of the two side bends. All three marks are placed on the raceway before any bending takes place.

3 Point Saddle Bend

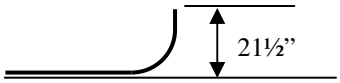


4 Point Saddle Bend

The **4 point saddle** is made up of two equal size offset bends, bent in opposite directions. This bend is used to jump over larger blockages than a 3 point saddle can handle. All four marks are placed on the raceway before any bending takes place.

Bending Stub Up Bends

1. Determine the height of the offset.

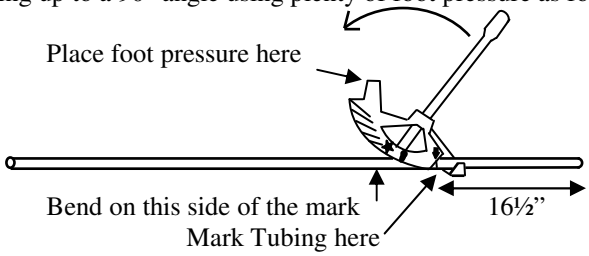


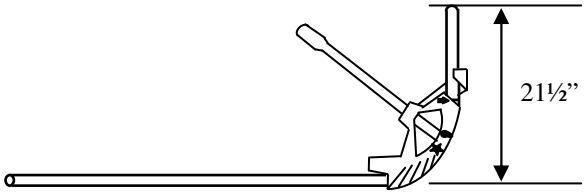
For example: This stub up bend will stop at a height of 21½”.

2. Subtract 5” from the height for ½” EMT or 6” from the height for ¾” EMT.

Using ½" EMT for example: 21½” - 5” = 16½”

3. Mark the tubing at the calculated distance from the end of the raceway and place the bender arrow on the mark. Then bend the tubing up to a 90° angle using plenty of foot pressure as follows:





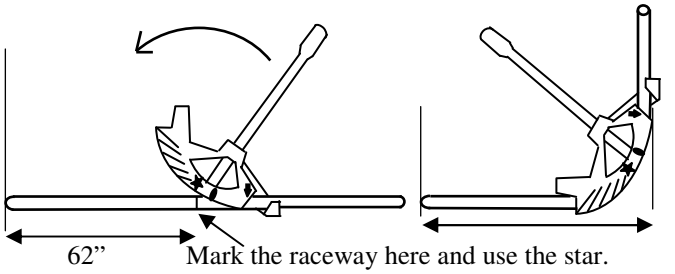
This should result in a stub up bend, 21 ½” high. This bend is made on the opposite side of the mark from the measured end of the tubing. Stub up bends are usually short 90° bends. Because the bend is near the end of the raceway, it is not practical to bend the raceway toward the end of the raceway. If we had placed the mark at exactly 21 ½” from the end, the result would be a stub up bend 26 ½” high. Therefore, we deleted 5” from the height when marking the ½” EMT tubing.

Bending Back to Back Bends

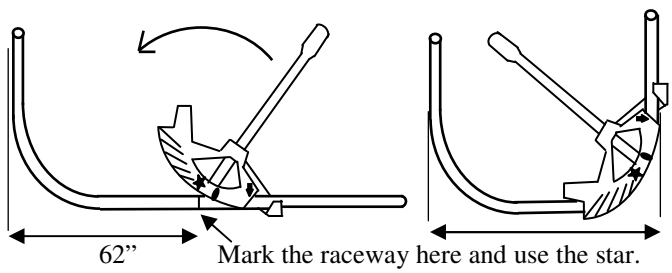
1. Determine the distance from the back side of one end of the ½” raceway to the back side of the other end.

Examples : These two back to back bends are both 62” wide: 62” from a box or coupling or 62” from another bend

2. Mark the raceway at the calculated distance and then place the raceway on the **star** and then bend the raceway up to a 90° angle using plenty of foot pressure as follows:

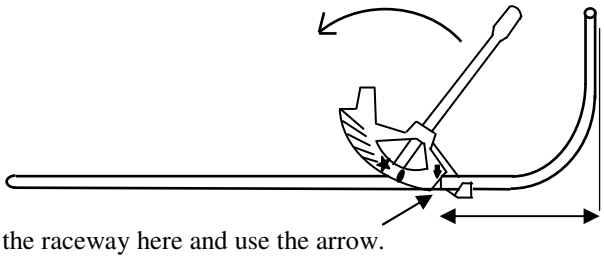


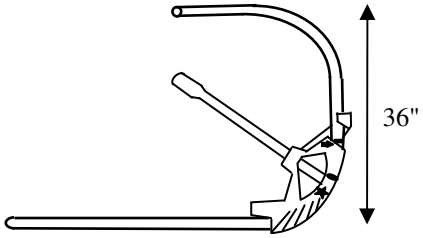
or



This should result in a back to back bend 62” wide. This bend is made using the **star** and in the direction of the measured end of the raceway. Because there was room to bend the raceway on that side of the mark, the bend could be placed on the **star**.

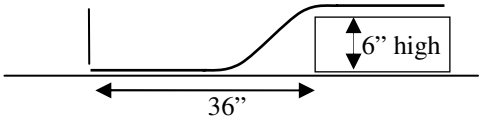
For **"short" back to back** bends, you can subtract 5” from the distance, mark the raceway and then bend the raceway on the **arrow** in the other direction from what is shown above. For instance for a 36” back to back bend on ½” raceway:





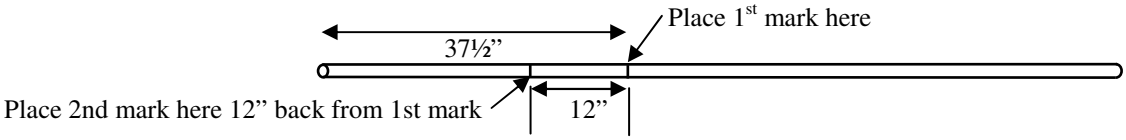
Bending Offset Bends

1. Determine the height of the offset and the distance from the end of the raceway. For example: This offset is 36” from the end of the raceway and is 6” high.

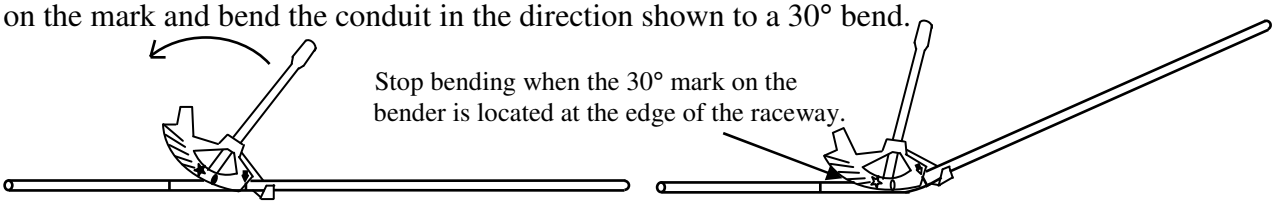


2. Determine the angle that will be used for the offset bends. Calculate the distance between bends and the shrinkage amount. Use the "**Offset Bend Table**” on page 9 of this document. In this example we will use 30°angles, so the distance between bends is 12” and the shrinkage amount is 1½”

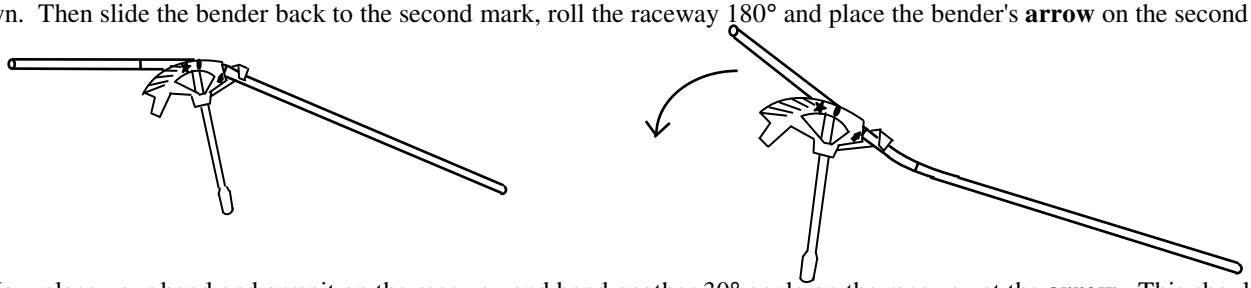
3. Place the first mark on the raceway a distance of 36” plus the shrinkage amount of 1½”. This will be 37½” away from the end of the raceway.



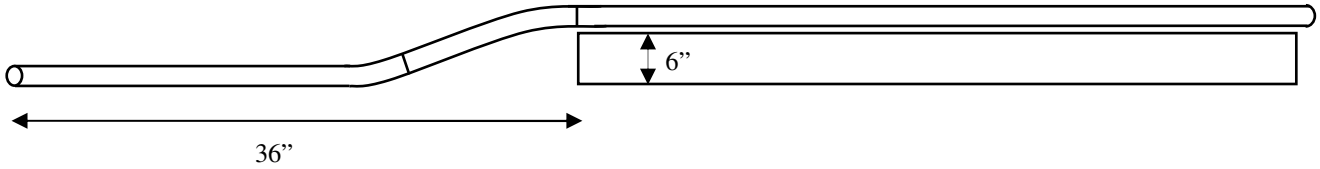
4. Place the second mark 12” back from the first Mark. Be sure to mark all the way around the raceway when placing marks on the raceway. Starting with the first mark placed on the raceway, place the bender **arrow** on the mark and bend the conduit in the direction shown to a 30° bend.



5. Leave the bender on the raceway and pick up both the raceway and the bender and stand the bender handle on the floor as shown. Then slide the bender back to the second mark, roll the raceway 180° and place the bender's **arrow** on the second mark.



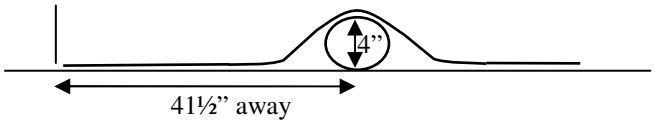
6. Now place your hand and armpit on the raceway and bend another 30° angle on the raceway at the **arrow**. This should give you a 6” offset 36” away from the end of the raceway. Because of the bends in the raceway, the first mark is now 1½” closer to the end of the conduit. That is why we had to add the shrinkage amount before we made these bends.



Note: This was done using 30° bends. 30° bends are easy to remember and calculate on the job without the use of charts. For other degree bends you will need to use the tables at the back of this handout to determine the shrinkage amount and the distance between bends. But for 30° bends, the distance between bends is twice the offset depth (2x6=12”) and the shrinkage amount is ¼ the offset depth (6/4= 1½”). You can simply calculate the first mark by adding ¼” to the length for each inch of offset rise. Then for the distance between marks, add 2” for each inch of offset rise. Example: For a rise of 10”, the shrinkage amount is 2½” and the distance between marks is 20”. Try to keep the total degree of bends to a minimum to allow ease in pulling wires through the run.

** **Warning 360°** ** The NEC does not allow the total amount of bends in a run to be more that 360° when using EMT (NEC 358.26). If more turns are required, a pull box must be added to the run or perhaps a different route can be taken. Don’t try to go beyond 360°, since you will not be able to pull wires into the conduit without extreme difficulty and then, if you do, the wires themselves could be damaged.

Bending Three Point Saddle Bends

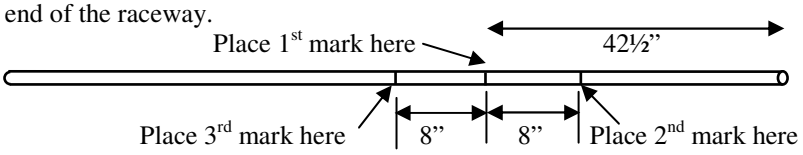


1. Determine the height of the Saddle and the distance from the end of the raceway. Note: measure to the centerline of the saddle.

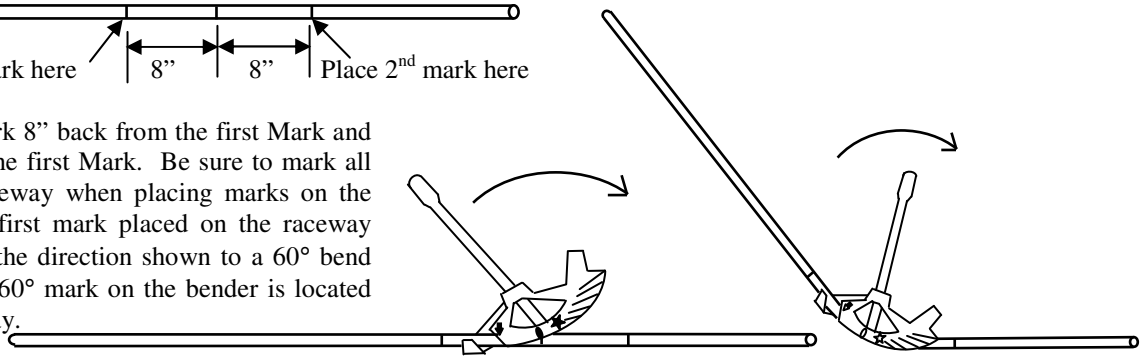
For example: This offset is 41½” from the end of the raceway and will clear an object 4” high.

2. Determine the angle that will be used for the offset bends. The center bend angle will be twice the other angles. Calculate the distance between bends and the shrinkage amount. Use the “**Three Point Saddle Bend Chart**” on page 9 of this document. In this example we will use a 60° center angle and two 30° outside angles, so the distance between bends is 8” and the shrinkage amount is 1”.

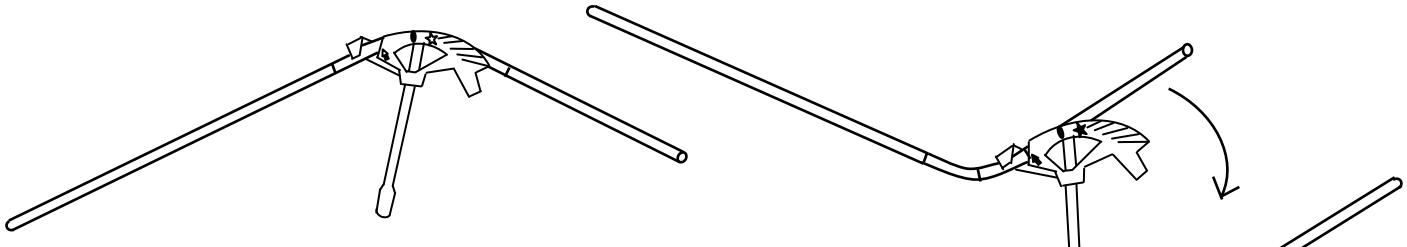
3. Place the first mark on the raceway a distance of 41½” plus the shrinkage amount of 1”. This will be 42½” away from the end of the raceway.



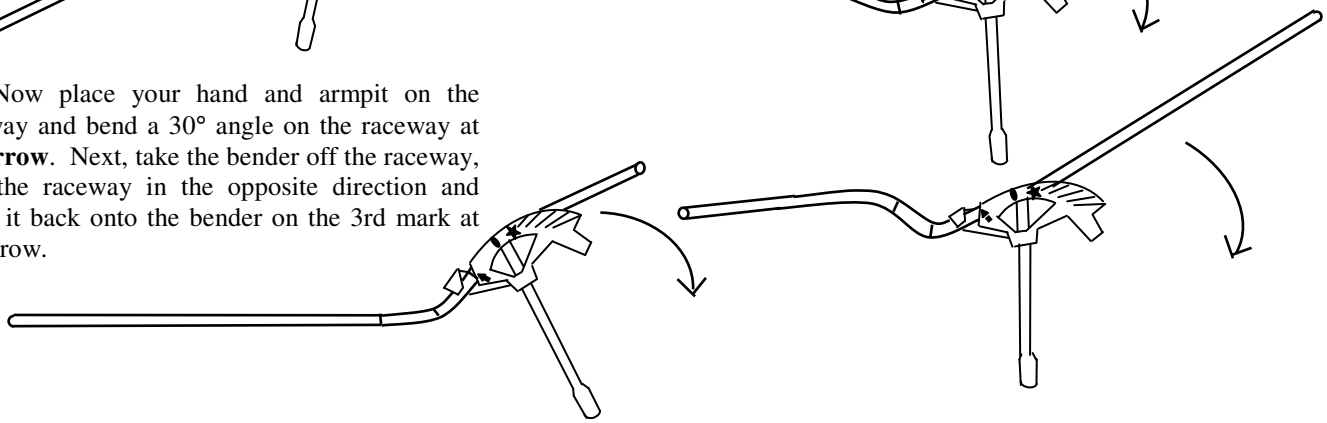
4. Place the second mark 8” back from the first Mark and the third mark 8” past the first Mark. Be sure to mark all the way around the raceway when placing marks on the raceway. Bend at the first mark placed on the raceway using the **tear drop** in the direction shown to a 60° bend Stop bending when the 60° mark on the bender is located at the edge of the raceway.



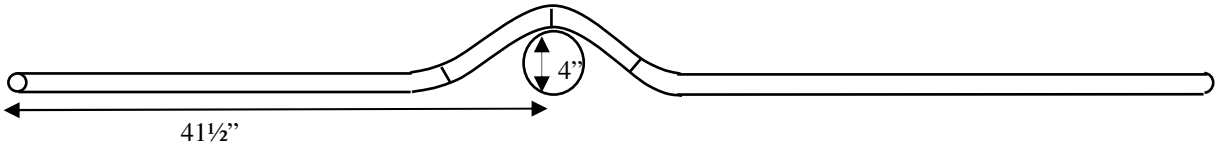
5. Leave the bender on the raceway and pick up both the raceway and the bender and stand the bender handle on the floor as shown. Then slide the bender back to the second mark and roll the raceway 180°.



6. Now place your hand and armpit on the raceway and bend a 30° angle on the raceway at the **arrow**. Next, take the bender off the raceway, turn the raceway in the opposite direction and place it back onto the bender on the 3rd mark at the arrow.



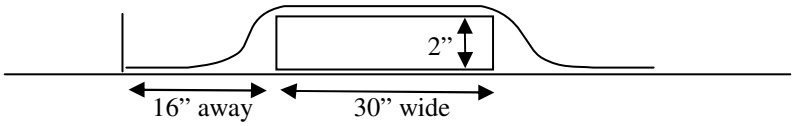
7. For the last bend, place your hand and armpit on the raceway and bend a 30° angle on the raceway at the **arrow**. This should give you a 4” high, 3 point saddle, 41½” away from the end of the raceway.



Note: This was done using one 60° and two 30° bends. This combination is easy to remember and calculate. The distance between bends is twice the offset depth and the shrinkage amount is ¼ the offset depth. Or you could say for the distance between bends you add 2” for each inch of offset rise and for the shrinkage amount you add ¼” for each inch of offset rise.

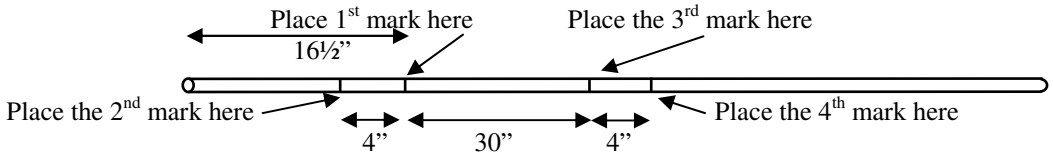
Bending Four Point Saddle Bends

1. Determine the height and width of the Saddle and the distance from the end of the raceway.

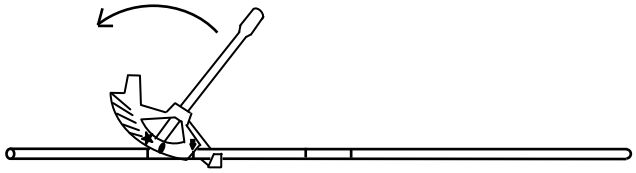


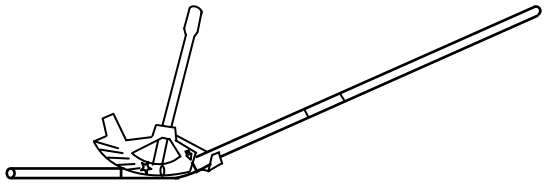
For example: This offset is 16” from the end of the raceway and will clear an object 2” high and 30” wide

2. Determine the angle that will be used for the bends. These bends are the same as two offset bends with the width of the object between them. Calculate the distance between bends and the shrinkage amount. Use the ”**Four Point Saddle Bend Chart**” on page 9 of this document. In this example we will use all 30° angles, so the distance between bends is 4” and the shrinkage amount is ½” and the width of the offset is 30”.

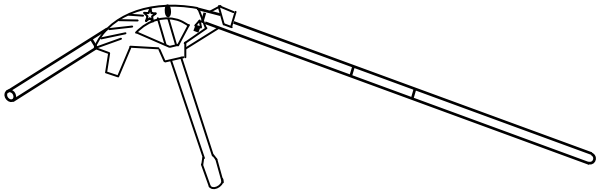


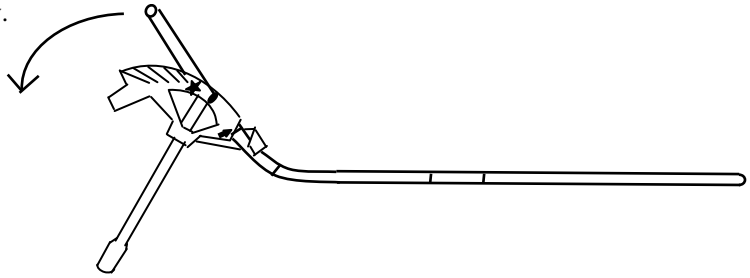
3. Place the first mark on the raceway a distance of 16” plus the shrinkage amount of ½”. This will be 16½” away from the end of the raceway. Place the second mark 4” back from the first Mark. Place the third mark 30” past the first Mark and the fourth mark 4” past the third mark. Be sure to mark all the way around the raceway when placing marks on the raceway. Bend at the first mark placed on the raceway on the **arrow** in the direction shown to a 30° bend. Stop bending when the 30° mark on the bender is located at the edge of the raceway.



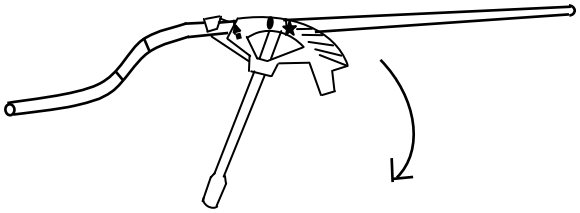


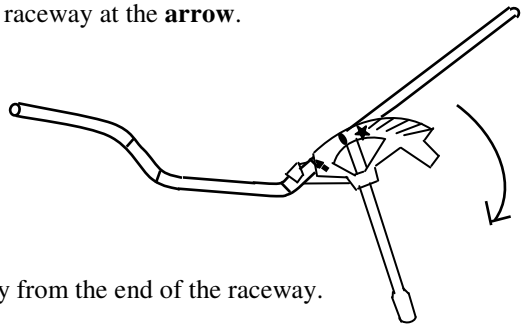
4. Leave the bender on the raceway and pick up both the raceway and the bender and stand the bender handle on the floor as shown. Then slide the bender back to the second mark and roll the raceway 180°. Now place your hand and armpit on the raceway and bend a 30° angle on the raceway at the **arrow**.



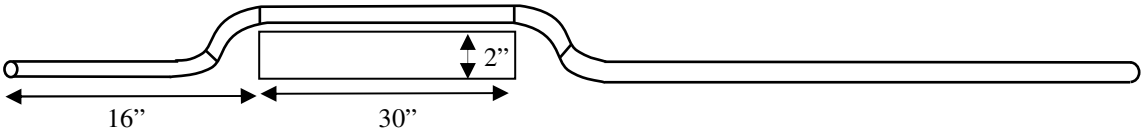


5. Next, take the bender off the raceway and turn the raceway in the opposite direction and place it on the bender on the third mark at the **arrow** and bend it to a 30° angle. Finally slide the bender back to the fourth mark and roll the raceway 180°. Now place your hand and armpit on the raceway and bend a 30° angle on the raceway at the **arrow**.



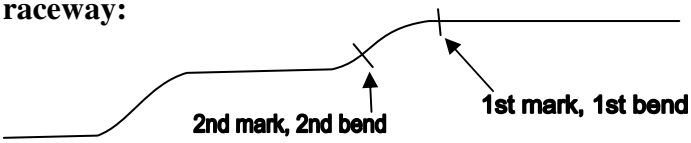


6. This should give you a 2” high and 30” wide 4 point saddle 16” away from the end of the raceway.

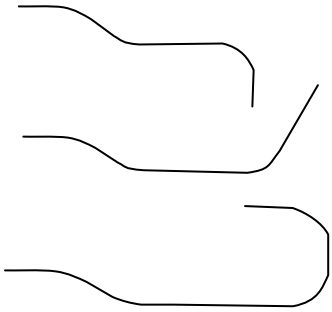


Note: This was done using 30° bends. This combination is easy to remember and calculate. The distance between bends is twice the offset depth and the shrinkage amount is ¼ the offset depth. Or you could say for the distance between bends you add 2” for each inch of offset rise and for the shrinkage amount you add ¼” for each inch of offset rise.

Determining the direction of multiple bends on a raceway:



Most of the time only one type of bend is placed on a 10' long raceway. However, quite often several types of bends will need to be placed on the same stick of conduit. When this happens, bending gets a little more complicated. Generally, the electrician will make all the measurements for the raceway and then mark and bend the first type of bend on the raceway. Then he will mark and bend the second type bend, then the third and fourth types of bends. Each type of bend may require several marks on the raceway. Whenever multiple bends are placed on the same raceway, it is very easy to create a dog leg. This is a condition where the multiple bends do not line up with each other (not all in the same plane). Take your time before you make the bend. Check the alignment in all directions and make sure the bender is placed on the correct side of the marks on the raceway.

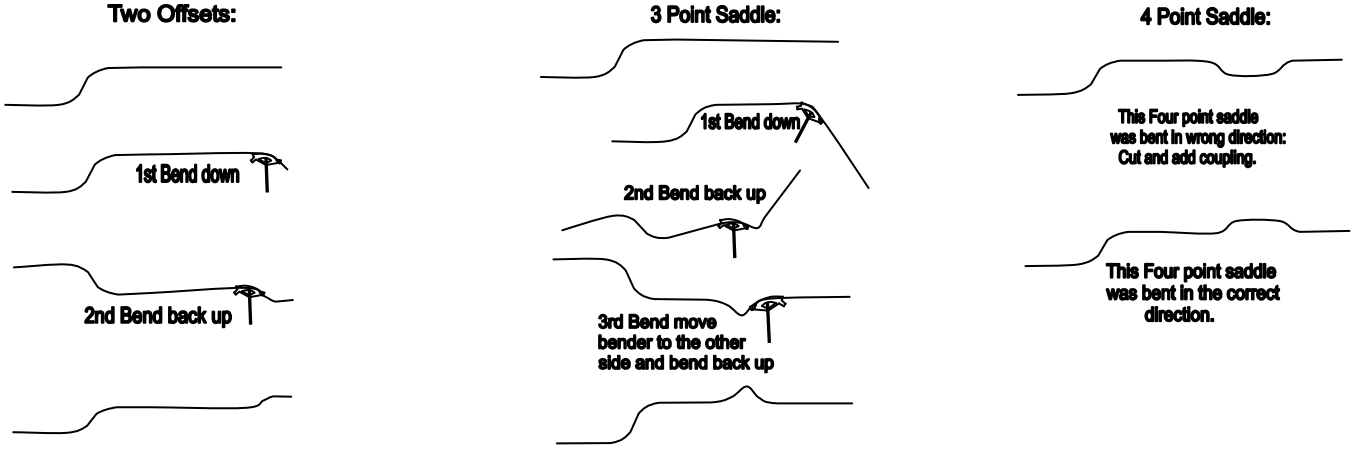


It is also very easy to make a mistake in direction when bending a second or third bend in the conduit. Bending raceways can be a confusing task when first learned. Once an electrician learns to make single bends, it would seem that making two of them on one raceway would be easy. And it is, for 90°s, kicks and back to back bends, you just bend the raceway in the direction you want the bend to go. All of the bends on the right were made after the original offset bend was done. Just make one bend in the direction you want the bend to go and your done. Making multiple bends on the same raceway will get easier with experience. If your bend winds up in the wrong direction, then just cut the raceway in two, ream the conduit ends and use a coupling to rotate and join the two pieces back together.

Bending offset and saddle bends require two to four steps each. Generally you will need to bend all these bends off the floor. They are confusing because most of these bends require the electrician to bend the first bend in the opposite direction of where it will end up. Bend the first bend down instead of up and then for your second bend, you slide the bender backwards and roll the pipe 180°s without lifting it from the raceway, then you bend the second bend. This requires you to make your bends off the floor. This can be confusing. If you try to bend the second bend first, then you will unbend this second bend when you try to bend the first bend. An easy way to know which way to first bend the pipe on offsets and saddle bends is to bend the first bend down into the surface you want to lift it up from. The second bend will lift the raceway back up. Most of these bends are bent upside down from the way they will wind up. Once you master which way to make the bends, you're on your way to becoming an expert bender.

The first mark on the raceway is where the first bend will take place. The second mark placed on the raceway is where the second bend will occur, and so on. You must learn first where to mark the raceway, second which direction to place the bender and third where to place the bender on the mark. After you learn these basic rules, then it becomes a matter of learning how much to bend the raceway to make the appropriate degree of bends. Remember, the only bend made with the tear drop mark on the bender is the middle bend of the three point saddle. The only bend made with the star is the back to back bend. All other bends used the arrow. Many bends can be made on the ground while the more complicated bends must be made off the floor. Study the following examples to see which way to place the bender and which bends to make first:

Note: In all of these examples, an offset bend was previously established on the raceway before the second type of bend was attempted. It is the offsets and saddles that are so confusing. Notice that each of the bends are made off the ground. The following examples show raceways with a second bend being performed after an offset bend was placed on the raceway:



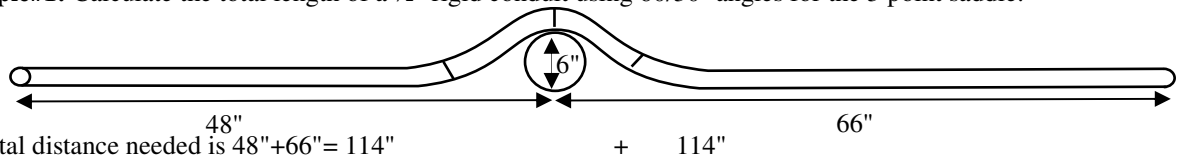
Practice is the only way to get better. Anything worth doing, is worth doing poorly, the first time. It's time to quit reading and get to bending! After you have practiced awhile, then reread this article. You'll be surprised at how fast you can learn.

Calculating the length of the entire raceway before bending:

Four conduit bending charts are located on page 9 of this document. These charts will allow the user to calculate both the shrinkage amount that is associated with offset bends, the distance between marks on the raceway for the bends and the bender gain. The shrinkage amount is the extra length needed in the raceway to raise or lower the raceway to a different elevation. If you don't have a copy of the "3 Point Saddle Bend Chart" or the "Offset bend and 4 point saddle bend chart" on the job, just make a shirt pocket copy of the "Offset Shrinkage Table" and then round the remainder to the nearest 1/16th of an inch.

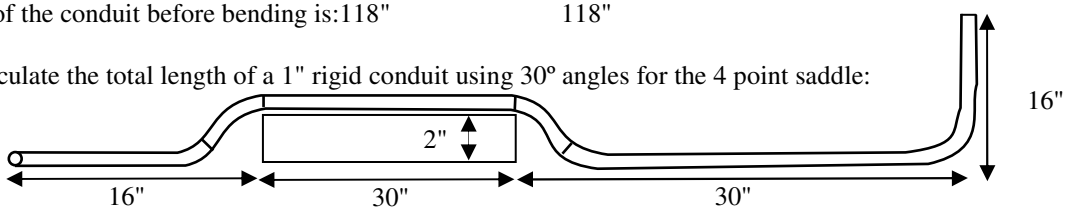
The "**Bender Gain**" table is use to measure the gain a rigid conduit makes when turning a 90º angle. Using both the "Offset shrinkage" table and the "Bender gain" table will allow the electrician to calculate the total length of a conduit before any bends are actually made in the conduit. This will allow the electrician to thread the conduit prior to bending the conduit. For 45º angles use half the 90º angle gain.

Example#1: Calculate the total length of a ½" rigid conduit using 60/30º angles for the 3 point saddle:



The total distance needed is 48"+66"= 114"	+	114"
The shrinkage amount for the first offset bend is: 1½"	+	1½"
The shrinkage amount for the second offset bend is: 1½"	+	1½"
Add 1/2" for threads inside of boxes on both ends: 1"	+	1 "
The total length of the conduit before bending is:118"		118"

Example#2: Calculate the total length of a 1" rigid conduit using 30º angles for the 4 point saddle:



The total distance needed is 16"+30"+30"+16"=92"	+	92"
The shrinkage amount for the first offset bend is : ½"	+	½"
The shrinkage amount for the second offset bend is: ½"	+	½"
The gain amount for the 90º angle is : 2 5/8"	-	2 5/8"
Add ½" for threads inside of boxes on both ends: 1"	+	1"
The total length of the conduit before bending is: 90"		91 3/8"

General Information for Installing Runs

The conduit run should follow the building structure as closely as possible. Don't take shortcuts up walls or on ceiling on 45º angles. Use the least amount of bends which allow the run to be installed in a neat and workmanlike manner (NEC 110.12). Make sure you size the conduit properly for the number of wires that will be installed (NEC Chapter 9 or Annex C). Try not to make bends in two alternate planes very close together. If you do, the wires can bend that way, but a steel fishtape may not be able to turn that sharp inside the conduit. If the fishtape has trouble being pushed through multiple bends, try using a fiberglass fish tape. Don't try to re-use conduit which has been located in wet or damp areas. The inside will be so rough, that the wires will have difficulty traveling through it, especially around bends. Use plenty of foot pressure when making bends on the floor so that the conduit will not be able to flatten in the bend. Don't make runs longer than your fishtape! Keep each run under 360º (NEC 358.26). Ream each cut to protect the wires from being damaged as they are pulled into the run.

Don't waste the conduit. Some bends can be completely undone. Otherwise, when a mistake can't be undone, cut that portion off the conduit, install a coupling, and continue from that point on. Install the conduit according to code. The minimum distance between straps for EMT is 10' and each run must be strapped within 3' of each termination. If there is no support within 3' for a strap, the distance from the termination can be up to 5' [NEC 358.30(A) exception 1] as long as there are no joints before the first strap. Other types of conduit have similar requirements. Be sure to check the NEC requirements for securing each type of conduit or tubing. Before installing, make sure that sand or any foreign objects do not remain in the conduit.

IMPORTANT - Make all connections tight and ream each cut. If you are installing a metal raceway, there needs to be a solid metal-to-metal connection between each raceway, fitting and box, all the way back to the panel. If a hot wire, within the conduit, inadvertently energized the conduit, a continuous metal-to-metal path back to the panel will provide enough current flow for the breaker to trip, thus removing the danger. Otherwise, when an electrician is called to diagnose the problem, he could be electrocuted! That could be you! Reaming the pipe and tightening EVERY locknut, coupling and connector is extremely important! Take pride in your work and the job will function properly and safely for many years to come.

Offset Shrinkage Table		
Angle	**Shrinkage of raceway per inch of rise**	**For distance between bends, multiply the offset depth by:**
10º	1/16"	5.7588
22 1/2º	3/16"	2.613
30º	¼"	2
45º	3/8"	1.4142
60º	½"	1.1547

Bender Gain Table		
Rigid Conduit	**NEC Radius**	**90º Gain**
½"	4"	2 5/8"
¾"	5"	3¼"
1"	6"	4"
1¼"	8"	5 5/8"

3 Point Saddle Bend Chart				
Degree of Bends	**One 45° Center Bend and two 22½ ° bends**		**One 60° Center Bend and two 30° bends**	
Obstruction Depth	Shrinkage Amount:	Distance between bends on both sides of center mark	Shrinkage Amount:	Distance between bends on both sides of center mark
1"	3/16"	2½"	¼"	2"
2"	3/8"	5"	½"	4"
3"	9/16"	7½"	¾"	6"
4"	¾ "	10"	1"	8"
5"	15/16"	12½"	1¼"	10"
6"	1 1/8"	15"	1½"	12"
For Each Additional inch Add:	3/16"	2½"	¼"	2"

Offset Bend and 4 point Saddle Bend Chart										
Degree of Bends	**10 º**		**22½º**		**30 º**		**45 º**		**60 º**	
Offset Depth	Shrink Amount	Distance Between Bends	Shrink Amount	Distance Between Bends	Shrink Amount	Distance Between Bends	Shrink Amount	Distance Between Bends	Shrink Amount	Distance Between Bends
½"	1/16	2 7/8	1/8	1 5/16	1/8	1	3/16	11/16	¼	9/16
1 "	1/16	5¾	3/16	2 5/8	¼	2	3/8	1 7/16	½	1 1/8
1½"	1/8	8 5/8	5/16	3 15/16	3/8	3	9/16	2 1/8	¾	1¾
2"	1/8	11½	3/8	5¼	½	4	¾	2 13/16	1	2 5/16
2½"	3/16	14 3/8	½	6 9/16	5/8	5	15/16	3 9/16	1¼	2 7/8
3"	3/16	17¼	9/16	7 13/16	¾	6	1 1/8	4¼	1½	3 7/16
3½"	¼	20 1/8	11/16	9 1/8	7/8	7	1 5/16	4 15/16	1¾	4 1/6
4"	¼	23 1/16	¾	10 7/16	1	8	1½	5 11/16	2	4 5/8
4½"	5/16	25 15/16	7/8	11¾	1 1/8	9	1 11/16	6 3/8	2¼	5 3/16
5"	5/16	28 13/16	15/16	13 1/16	1¼	10	1 7/8	7 1/16	2½	5¾
5½"	3/8	31 11/16	1 1/16	14 3/8	1 3/8	11	2 1/16	7¾	2¾	6 3/8
6"	3/8	34 9/16	1 1/8	15 11/16	1½	12	2¼	8½	3	6 15/16
6½"	7/16	37 7/16	1¼	17	1 5/8	13	2 7/16	9 3/16	3¼	7 ½
7"	7/16	40 5/16	1 5/16	18 5/16	1¾	14	2 5/8	9 7/8	3½	8 1/16
7½"	½	43 3/16	1 7/16	19 5/8	1 7/8	15	2 13/16	10 5/8	3¾	8 11/16
8"	1/2	46 1/16	1½	20 7/8	2	16	3	11 5/16	4	9¼
8½"	9/16	48 15/16	1 5/8	22 3/16	2 1/8	17	3 3/16	12	4¼	9 13/16
9"	9/16	51 13/16	1 11/16	23½	2¼	18	3 3/8	12¾	4½	10 5/8
9½"	5/8	54 11/16	1 13/16	24 13/16	2 3/8	19	3 9/16	13 7/16	4¾	11
10"	5/8	57 9/16	1 7/8	26 1/8	2½	20	3¾	14 1/8	5	11 9/16
11"	11/16	63 3/8	2 1/16	28¾	2¾	22	4 1/8	15 9/16	5½	12 11/16
12"	¾	69 1/8	2¼	31 3/8	3	24	4½	17	6	13 7/8
13"	13/16	74 7/8	2 7/16	34	3¼	26	4 7/8	18 3/8	6½	15
14"	7/8	80 5/8	2 5/8	36 9/16	3½	28	5¼	19 13/16	7	16 3/16
15"	15/16	86 3/8	2 13/16	39 3/16	3¾	30	5 5/8	21 3/16	7½	17 5/16
16"	1	92 1/8	3	41 13/16	4	32	6	22 5/8	8	18½
17"	1 1/16	97 7/8	3 3/16	44 7/16	4¼	34	6 3/8	24 1/16	8½	19 5/8
18"	1 2/8	103 11/16	3 3/8	47 1/16	4½	36	6¾	25 7/16	9	20 13/16
19"	1 3/16	109 7/16	3 9/16	49 5/8	4¾	38	7 1/8	26 7/8	9½	21 15/16
20"	1¼	115 3/16	3¾	52¼	5	40	7½	28 5/16	10	23 1/8
21"	1 5/16	120 15/16	3 15/16	54 7/8	5¼	42	7 7/8	29 11/16	10½	24¼
22"	1 3/8	126 11/16	4 1/8	57½	5½	44	8¼	31 1/8	11	25 3/8
23"	1 7/16	132 7/16	4 5/16	60 1/8	5¾	46	8 5/8	32½	11½	26 9/16
24"	1½	138 3/16	4½	62 11/16	6	48	9	33 15/16	12	27 11/16
25"	1 9/16	144	4 11/16	65 5/16	6½	50	9 3/8	35 3/8	12 1/2	28 7/8

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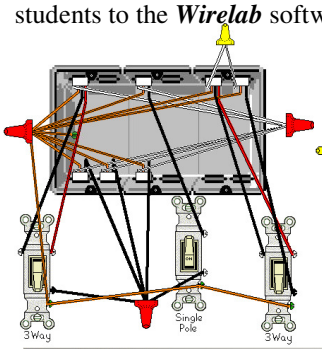
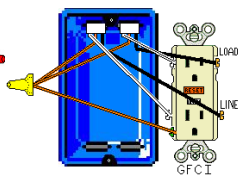
Wirelab Services

Resources for Electricians

Wirelab Services is an Orlando based company owned by Bill and Bobby Bamford. Bobby is an electrical engineer and Bill is a state licensed electrician who taught electrical classes at a technical college for eight years. Wirelab Services provides software, hardware and literature resources for electricians. This updated handout on bending conduit is one Bill wrote while teaching school.

Our newest product is an interactive software package for Technical Schools: "***Wirelab* - A Residential Wiring Course**". The course utilizes both textbook and software. The software allows the student to install panels, appliances, and cables on any residential floorplan, then call for a rough-in inspection. It then reports on any NEC discrepancies allowing the student to correct the floorplan. This continues until the house passes the rough-in according to code. Then, the student is allowed to trim-out the dwelling by double clicking on each box, appliance and panel and pulling the conductors from the cable ends to proper connections on receptacles, switches, fixtures, appliances and panels. When all connections are made, a trim out inspection is requested. Any discrepancies are addressed allowing the student to correct them until all trim-out tests pass. At this point the house is wired to code. The software and textbook are only available to those technical schools which teach residential wiring. It does not replace labs. A three year site license allows the school to provide unlimited access to their students to the ***Wirelab*** software. If your local school is interested in this residential wiring course, please contact:





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