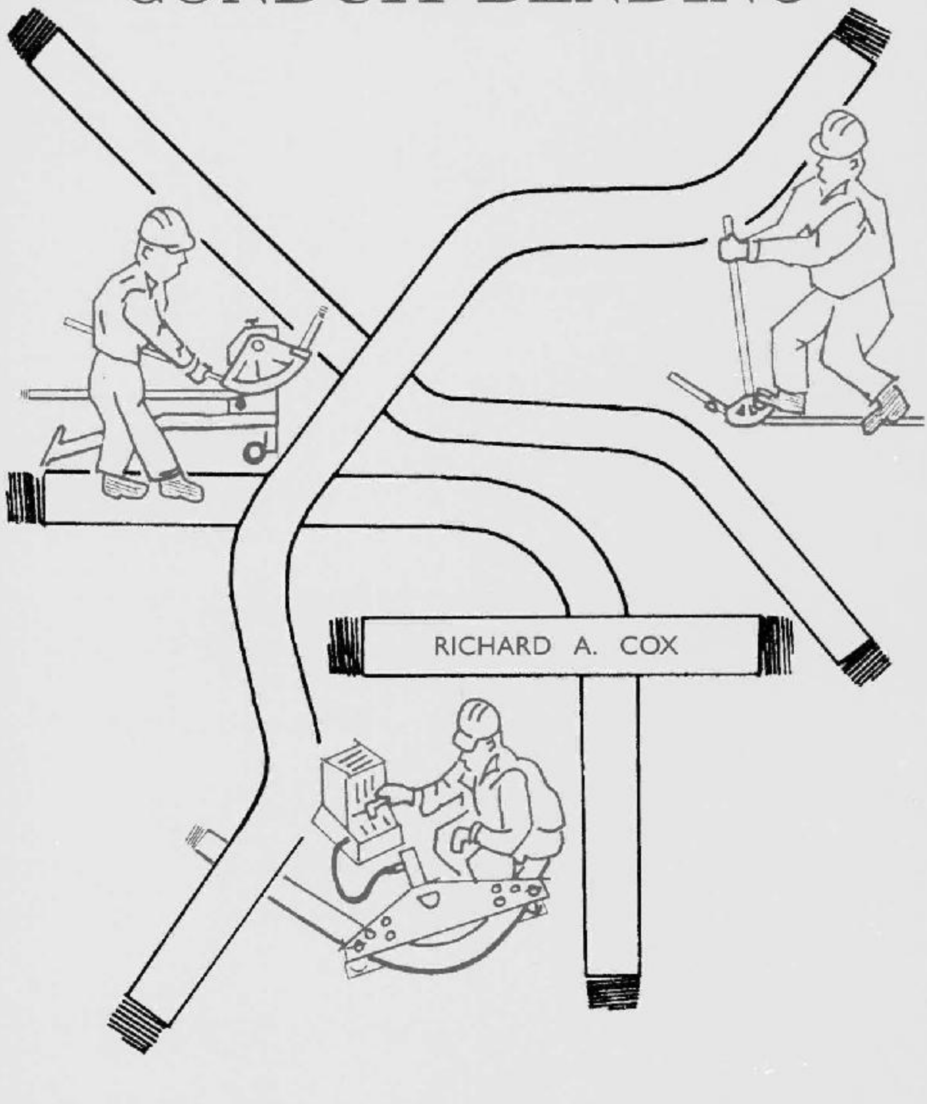
THIRD EDITION

# ELECTRICIANS GUIDE TO CONDUIT BENDING



**Third Edition**

# ELECTRICIANS GUIDE TO CONDUIT BENDING


**RICHARD A. COX**
Journeyman Electrician—Retired IBEW Local 73
Retired—Chairman Electrical Robotic Department
Spokane Community College
AAS Occupational Education
BS University of the State of New York
MS Eastern Washington University



COXCO

www.coxco.net

**1-800-257-0941**

**THIRD EDITION**

# ELECTRICIANS GUIDE TO CONDUIT BENDING


11501 W Highland Rd. Nine Mile Falls, WA 99026
www.coxco.net

Library of Congress Catalog Card Number—82-81759



Special thanks to the following companies who furnished photographs, diagrams and/or technical data.

ENERPAC
Milwaukee, WI

Greenlee Textron Inc.
Southaven, MS

Allied Tube and Condit Corp.
Harvey, IL

Gardner Benders
Milwaukee, WI

Graphics:
Inland Northwest Industrial Training
Newman Lake, WA

Lindseen
Hayesville, NC

2/13

Printed and Bound in the United States of America
National Color Graphics, Inc.
Spokane, WA 99201

For my wife and best friend

**PATRICIA**

# INTRODUCTION

The purpose of this text is to assist the reader—Apprentice or Journeyman—with developing the techniques required to accurately and efficiently bend conduit.

Exposed conduit work is one area of an electrician's job that puts their skill on display. Exposed conduit is there for all to see and directly reflect on the knowledge and workmanship of the installer. With these thoughts in mind, it then will benefit all electricians to learn one of several methods of bending conduit that will assure accurate and precision bent conduit. Conduit, that you can step back and look at with pride and the knowledge that it was bent right the first time.

The formula methods that the text will deal with at first will seem slow and time consuming, but as you learn the method and become confident with the bender and your own abilities, it will be quicker and less time consuming than any other ***ABOUT*** methods in use by many electricians in the field today.

Some explanations of mathematical or trigonometric functions have been over simplified so the reader may understand the principles and relationships without an extensive math background.

Terms and terminology used in the text, as with any trade, may be regional. A "WOW " in Chicago, IL, may be a "Hoop-De-Do" in Butte, MT. For this reason, a complete glossary of terms is included with definitions. The reader, therefore, need only pick the definition that fits the term used and your area and the text will be understandable.

The text will lead you through the steps of procedure for formulated bending, and then let you apply what you have read with sample problems. The correct answers for each problem can be found at the back of the book. It is intended that these sample problems will enable the reader to gain confidence in the system and themselves.

For the best understanding of the material, read the Chapters in order. Reference is made back to preceding Chapters as to the methods and techniques and continuity will be lost if you attempt to "skip around".

It should be stated, that with few exceptions, the methods and procedures outlined in this text are not original with the author, but a culmination of ideas, techniques, and methods of many fine electricians from throughout the United States and Canada, men and women that I had the pleasure of working with and sharing ideas on conduit bending. Although I would like to give individual credit, the list is too innumerable and I will simply say "Thank You" to those involved.

Richard A. Cox

***"It is difficult to climb the ladder of success with your hands in your pockets"***

Author Unknown

# TABLE OF CONTENTS


## CHAPTER 1

**Basic Trigonometry**....................1
Right Triangles—1 Pythagorean Theorem—9

## CHAPTER 2

**Electrical Metallic** Conduit....................10
Bending EMT—10 Hand Benders—11

## CHAPTER 3

**Ninety Degree Bends**....................16
Finding Bender Take-Up—16

## CHAPTER 4

**Back-To-Back 90° Bends**....................20

## CHAPTER 5

**Kicks**....................23

## CHAPTER 6

**Offsets**....................25
Offset Multipliers—29

## CHAPTER 7

**Predetermining Offset Location**....................34
Predetermining Offsets Location Method #1—34
45° Offset Constant Table—36 EMT Offset Constant Table—40
Offset Multiplier Table—41 Offset Location Multiplier Table—42
Predetermining Offsets Location Method #2—43
Shrink Value Table—44

## CHAPTER 8

**Parallel Offsets**....................48

## CHAPTER 9

**Four Bend Saddles**....................52
Predetermining Saddle Location—53
Method #1 for Predetermining Saddle Location—54
Method #2 for Predetermining Saddle Location —55

## CHAPTER 10

**Three Bend Saddles**....................58
Predetermining Saddle Location Using Shrink—62

## CHAPTER 11

**Bending Around a Corner**.......................................................65
Round Obstruction—65 Square Obstruction—66
Rectangular Obstruction—67
Predetermining Bend Marks Round Obstructions—68
Predetermining Bend Marks Square Obstructions—69
Predetermining Bend Marks Rectangular Obstruction—70

## CHAPTER 12

**Rigid Metal Conduit** .......................................................71
Types of Rigid Conduit Benders—73
Manually Bending Rigid Using a Hickey—73
Mechanical Benders—75 Electrical Benders—75
Hydraulic Benders—76

## CHAPTER 13

**Bending With a Mechanical Style Bender** ..................................77
Amount of Travel Method—79
Finding Total Pipe Length Required—81
Push-Through Bending—89
Locating Bend Mark from the Opposite End of The Pipe—90
Predetermining Saddle Location —100
Three Bend Saddles Using "Chicago" Style Benders—101
General "Chicago" Bending Tips—103

## CHAPTER 14

**Hydraulic Benders**.......................................................105
Bending Tips for Aluminum Pipe—108

## CHAPTER 15

**Layout for Segment Bending**.......................................................109

## CHAPTER 16

**Segment Bending Techniques**.......................................................117
Bend Degree Protractor—117 Magnetic Angle Finder—118
Amount of Travel Method—119 Number of Pumps Method—121
Segment Offsets—124 Segment Saddles—126

## CHAPTER 17

**Concentric Bending**.......................................................128
Concentric 90° Bends—128 Concentric Offsets—131
One-Shot Parallel Offsets—133

## CHAPTER 18

**Intermediate Metal Conduit (IMC)**.......................................................134
Bending IMC—135

**CHAPTER 19**
**Rigid Nonmetallic Conduit (RNC)** ........ 137
Bending PVC—137
**CHAPTER 20**
**Finding an Unknown Radius** ........ 141
Alternate Methods—143
**CHAPTER 21**
**Bending Pipe With Larger Than Normal Radius** ........ 145

**Tables and Charts** ........ 149
**Conduit Trade Sizes and Dimensions** ........ 152
**Conduit Spacing Chart** ........ 155
**Glossary** ........ 156
**Answers to Problems** ........ 159
**Other Books and Tools** ........ 165

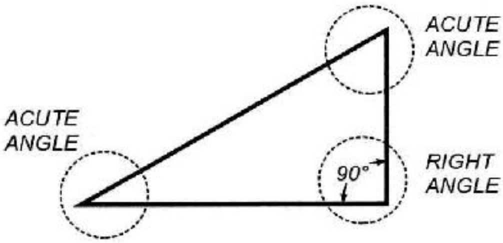
# BASIC TRIGONOMETRY 1

A very basic understanding of trigonometry is needed to fully understand and appreciate ***Formula Conduit Bending***. Once the basic relationships of the ***Right Triangle*** are understood, the serious student of conduit bending can then fully understand ***how*** and ***why*** the methods work, and will be able to develop their own formulas or tricks to make the job easier.

## RIGHT TRIANGLES

Right triangles will have one angle that is 90° and two other angles that when added together will equal 90°, for a total of 180° for the ***three*** angles. The 90° angle is called a ***right angle***, while the other two angles of less than 90°, are called ***acute angles*** as shown in Figure 1-1.

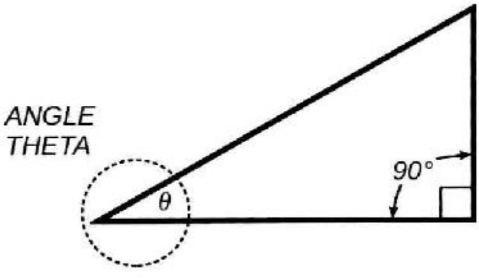
**Figure 1-1**




It is important to identify the angles of a right triangle. The 90° angle is identified with a square as shown in Figure 1-2. Of the two acute angles one must be identified so we can use it as a reference when naming the sides of the right triangle. The reference angle in Figure 1-2 is called ***Angle Theta***.

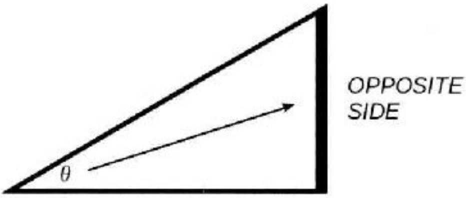
***Angle Theta*** is identified by using the Greek letter $\theta$, as shown in Figure 1-2.

**Figure 1-2**



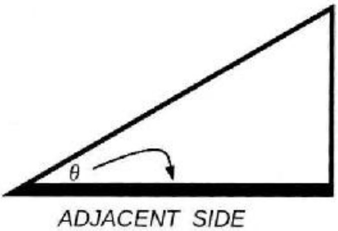
The side opposite Angle Theta (***θ***) is called the ***Opposite side***, as shown in Figure 1-3.

**Figure 1-3**



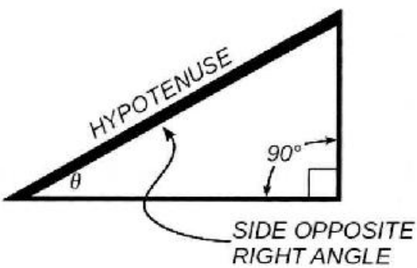

The side next to, or adjacent to, angle ***θ*** is called the ***Adjacent side*** as shown in Figure 1-4.

**Figure 1-4**




The remaining side of the right triangle, which is opposite the right angle and touches both acute angles, is called the ***Hypotenuse***, as shown in Figure 1-5.

**Figure 1-5**




Mathematicians have been impressing laymen with strange sounding terms for a long time. Even if the terms are strange sounding, they should not cause panic. Three such alien terms are: ***Sine***, ***Cosine***, and ***Tangent***. These terms quite simply are numerical values/constants for given angles of a right triangle. These numerical values are found in the Trigonometric Function Table located in back of the book.

These terms: ***Sine***, ***Cosine***, and ***Tangent*** give us the ***ratio*** between any two sides of a right triangle. The ratios may be stated in formulas:

**Sine of angle** $\theta = \frac{O}{H}$

**Cosine of angle** $\theta = \frac{A}{H}$

**Tangent of angle** $\theta = \frac{O}{A}$

**O** = Opposite Side
**H** = Hypotenuse
**A** = Adjacent Side

By using the formulas, we can find any side of a right triangle, or the unknown value of angle Theta.

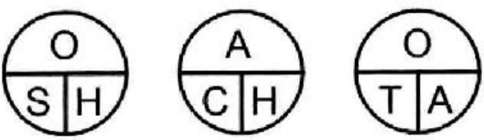
As with any formula of this type, ***two*** values ***must be known*** to find the third or unknown value.

Using the formula **Sine** = $\frac{O}{H}$ as an example:

If the Sine of the angle is known, and the Hypotenuse is known, only the Opposite side and Adjacent sides remain to be found. To find the Opposite side, the original formula Sine = $\frac{O}{H}$ would have to be Transposed algebraically.

By placing formulas in so-called ***"Magic Circles"***, they are easier to handle and ***transposition*** is not necessary, greatly simplifying the math. Figure 1-6 shows the three formulas; Sine, Cosine, and Tangent converted into "Magic Circles".

**Figure 1-6**

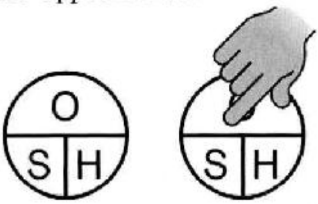



Sine = $\frac{O}{H}$ Cosine = $\frac{A}{H}$ Tangent = $\frac{O}{A}$

In a Magic Circle letters separated by a vertical line | are multiplied, while letters that are separated by a horizontal line — are divided.

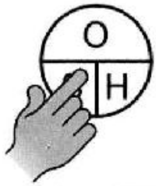
**EXAMPLE:** If we know the Hypotenuse and wanted to find the Opposite side we can use the Sine formula shown in Figure 1-7. Simply place your forefinger over the unknown value O (Opposite). The vertical line between the S and the H in the circle tells us to multiply the Sine of the angle (angle Theta) by the value of the Hypotenuse to find the Opposite side.

**Figure 1-7**




Had we known the measurements of Hypotenuse and the Opposite side and wanted to find the Sine of the angle, we would cover the unknown Sine and the circle tells us to divide the Opposite side by the Hypotenuse to find the Sine of angle Theta, as shown in Figure 1-8.

**Figure 1-8**

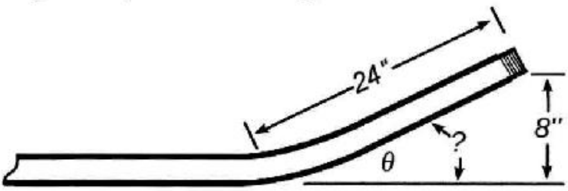



This is a very basic presentation of Trigonometric (Trig) functions, but should be adequate enough to understand the relationship that exists between the Opposite side (O); the Adjacent side (A); the Hypotenuse (H); and angle Theta ($\theta$). Reference will be made throughout the text to these relationships and if you can understand the relationships you will be able to develop your own formulas. Trig functions will also be used to determine where bends are to be made, and also to determine the degree of bend.

Let's try some examples to see how this works.

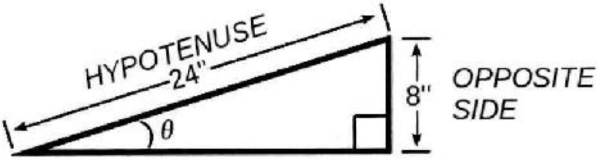
**EXAMPLE:** Assuming we want to bend a piece of conduit at 24" and want it to raise 8". What degree of bend will be required?

1. First draw the problem, as shown in Figure 1-9



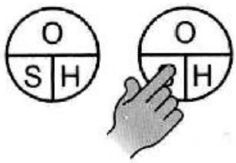
2. Look at it now as a right triangle, redraw and label the Hypotenus and Opposite sides, as shown in Figure 1-10.

**Figure 1-10**




3. Select a formula that has the two known values Hypotenuse and Opposite side. The Sine formula, as shown in Figure 1-11 meets our needs.

**Figure 1-11**




4. Replace letters with the measurements from the problem and divide as indicated in the formula. Sine = $\frac{8}{24}$ **Sine = .333**

5. Using the partial Trigonometric Table shown in Table 1-12 we see that the closest angle to a sine of .333 is 19 degrees, so we can say that the angle will be ≈ 19°.

**PARTIAL TRIGONOMETRIC TABLE**

**Table 1-12**

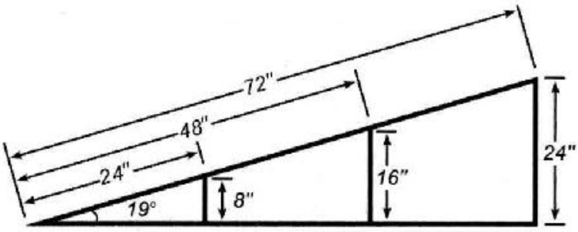
| ANGLE | SINE | COSINE | TANGENT |
|---|---|---|---|
| 17° | .2924 | .9563 | .3057 |
| 18° | .3090 | .9511 | .3249 |
| 19° | .3256 | .9455 | .3443 |
| 20° | .3420 | .9397 | .3640 |

The approximate symbol ≈ will be used in the text to indicate an answer that is close to, or is an ***approximate*** number or value.

We could now place the center of a bender shoe on the 24" mark on the pipe and using a protractor level or other device bend the conduit to 19° knowing ahead of time that we would get the desired rise and length. In reality, we would not go to all this trouble for such a simple bend, but did so only to try out the formulas. This was not all wasted time and effort, however, for this is the procedure to determine rate of rise of a conduit.

The ratio of the sides of the triangle, to a given angel Theta, remains ***constant***, even if the size of the triangle ***increases***, as shown in Figure 1-13.

**Figure 1-13**




Notice that if the Hypotenuse doubles in length from 24" to 48" the dimension of the Opposite side also ***doubles*** from 8" to 16", but the angle of Theta remains unchanged.

$\text{Sine} = \frac{O}{H}$ $\quad$ $\text{Sine} = \frac{16}{48}$ $\quad$ Sine = .333 $\quad$ or $\approx 19^{o}$

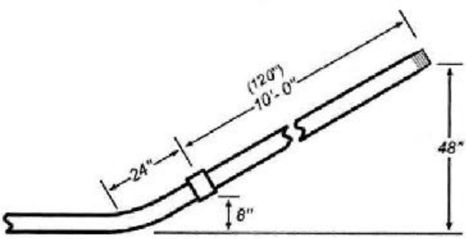
If the Hypotenuse is tripled in length, the Opposite side also triples, yet angle Theta ($\theta$) remains the same.

$\text{Sine} = \frac{O}{H}$ $\quad$ $\text{Sine} = \frac{24}{72}$ $\quad$ Sine = .333 $\quad$ or $\approx 19^{o}$

The ratio between the Hypotenuse and the Opposite side will hold true no matter how large the triangle becomes.

So in a practical sense, we could say that if we bend our conduit 19° at 24" it will rise 8", or the rate of rise is 4" per foot of length. If a 10' (120") section of conduit was added, we know the rise would increase 4" times 10, or 40". Add this amount to the original 8" rise for a total of 48", as shown in Figure 1-14.

**Figure 1-14**



To prove our figures and check the rise again, let's use the formula

$$\text{Sine} = \frac{O}{H}$$

We know the angle of the bend is 19° and that the Hypotenuse is now 144" (24" plus 120" for the 10' piece of conduit that was added). The unknown then would be the Opposite side, which will be the rise of the conduit. Cover the Opposite side of the Magic Circle as shown in Figure 1-15. The Circle tells us to multiply the Sine of the angle (.333) by the length of the Hypotenuse (144).

**O** = .333 × 144
**O** = 47.952* or ≈ 48"

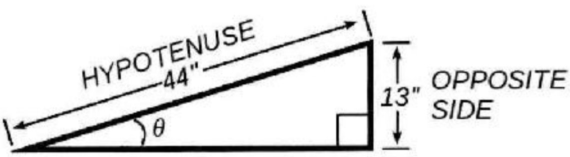

**Figure 1-15**

* The small error is caused by selecting the closest degree for a Sine of .333 at the beginning of the problem. But this is certainly close enough as we can only expect accuracy in conduit bending to within ± 1/8" or .12500".

**EXAMPLE:** A pipe must be bent at 44" and have a rise of 13". What angle of bend will be required?

Draw the problem and label it as a right triangle, as shown in Figure 1-16.

**Figure 1-16**




Use the formula $S = \frac{O}{H}$ Substitute values $S = \frac{13}{44}$

**Solve.** Sine = .2954

From Table 1-17 the closest angle to a Sine of .2954 is 17°, which has a Sine of .2924. The conduit is then bent to 17° to get a rise of 13".

**Table 1-17 PARTIAL TRIGONOMETRIC TABLE**

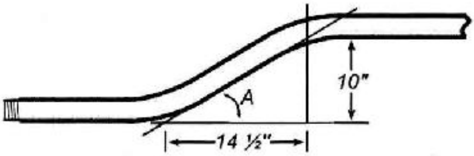
| ANGLE | SINE | COSINE | TANGENT |
|---|---|---|---|
| 16° | .2758 | .9613 | .2867 |
| 17° | .2924 | .9563 | .3057 |
| 18° | .3090 | .9511 | .3249 |

**PROBLEMS:**

1. How far will a pipe rise if it is bent 30° at 48"? What is the rise per foot?

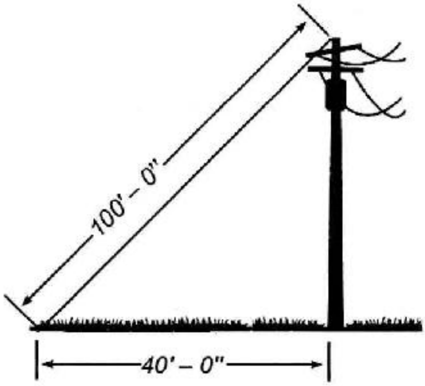
2. An electrician has bent a piece of conduit, as shown in Figure 1-18, what is the angle of bend A?

**Figure 1-18**




3. A guy wire 100' long is attached at the top of a pole and secured to the ground 40' from the base of the pole as shown in Figure 1-19. A) What angle does the wire make with the ground?
   B) How tall is the pole?

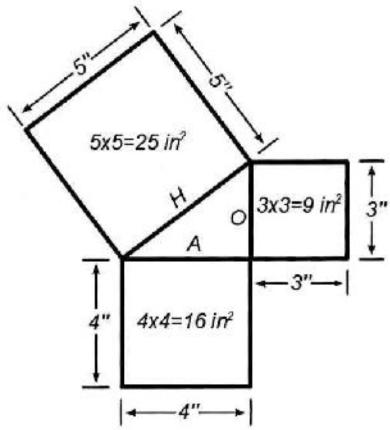
**Figure 1-19**



## PYTHAGOREAN THEOREM

Another method of solving problems dealing with right triangles that does not require you to know angle Theta, is called Pythagorean Theorem and was developed over 2500 years ago. Pythagoras was a Greek scholar who found that the square areas of two legs, or sides of a right triangle (Adjacent and Opposite), when added together, exactly equaled the square area of the Hypotenuse, as shown in Figure 1-20.

**Figure 1-20**




The theorem simply stated, gives us the formula $A^2 + O^2 = H^2$.
By transposing the formula we get the following three formulas:

$$H = \sqrt{A^2 + O^2} \qquad O = \sqrt{H^2 - A^2} \qquad A = \sqrt{H^2 - O^2}$$

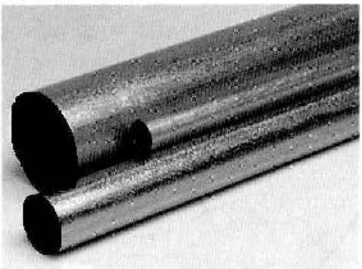
**Example:**
To find the Hypotenuse of a right triangle the H formula requires you to find the ***square root*** of $A^2 + O^2$. While it would be very difficult to solve this formula long hand; it can be done quickly using a pocket calculator.

$$H = \sqrt{A^2 + O^2} \qquad H = \sqrt{16 + 9} \qquad H = \sqrt{25} \qquad H = 5$$

On your calculator the key strokes would be:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ( | 4 | $X^2$ | + | 3 | $X^2$ | ) | $\sqrt{X}$ | 5 |

# ELECTRICAL METALLIC TUBING 2



Electrical Metallic Tubing, or ***EMT***, is also referred to as ***Steel Tube*** or ***Thin Wall***. Article 358 of the National Electrical Code7 covers the installation and use of EMT. EMT is a listed metallic tubing approved for the installation of electrical conductors when joined together with listed fittings. EMT is relatively easy to bend, cut, and ream, and because it is not threaded, all connectors and couplings are of the threadless type.

Standard trade sizes for EMT are: ½", ¾", 1", 1¼", 1½", 2", 2½", 3" and 4" and are manufactured in standard 10' lengths.

Bending qualities will be effected by the ***ductility****, uniformity, and surface treatment of the conduit and these qualities will vary with each manufacturer.

*Ductility is the ability of a material to be bent or formed.

**BENDING EMT**

EMT may be bent with hand benders, "Chicago" style mechanical benders, electric, and hydraulic benders.

**Hand benders** are usually restricted to ½", ¾", 1" and 1¼" conduit sizes. Over 1¼" would require physical strength not possessed by most electricians.

**"Chicago" style mechanical benders** vary with the manufacturer, but most will bend up to 2" EMT.

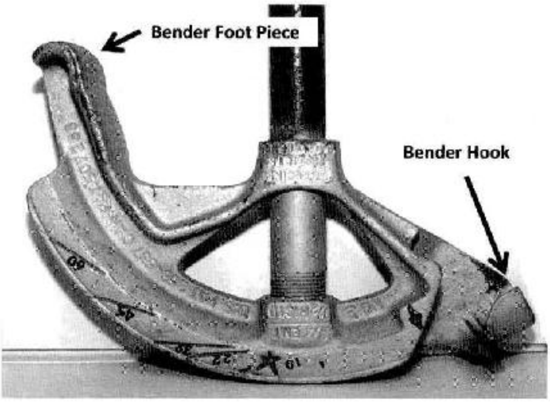
**Electric and Hydraulic benders** are available that will bend ½" through 4" EMT.

Only hand bending techniques will be discussed for EMT. "Chicago" style mechanical, electric, and hydraulic bending methods are covered under rigid conduit, and the techniques as outlined there will also apply to EMT.

**HAND BENDERS**

All hand benders will have a curved ***shoe*** that will be used to form the conduit, a ***hook*** that will hold the pipe at the front of the shoe, and a ***back*** or ***foot piece*** for applying pressure to keep the pipe in the shoe while the pipe is being bent. Figure 2-1 shows a Benfield bender head.

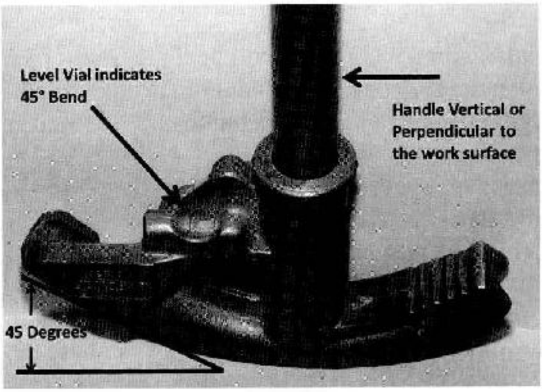
**Figure 2-1**




Hand benders are offered by many manufacturers and are basically of two types. Benders that will have bent a 45° bend when the handle is vertical or perpendicular to the work surface (floor) as shown in Figure 2-2 and benders that have bent a 30° bend when the bender handle is vertical as shown in Figure 2-3. 30° and 45° bends are used frequently when bending offsets. Offsets will be covered in Chapter 6.

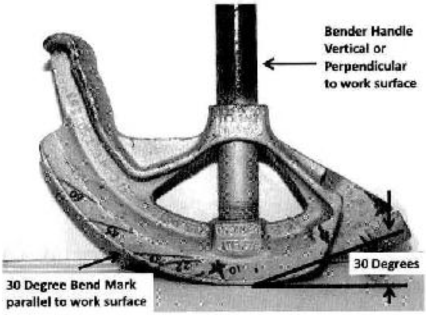
The handle of the Gardner bender (as shown in Figure 2-2) will be ***perpendicular*** (plumb) or ***vertical*** to the work surface when a 45° degree bend has been achieved.

**Figure 2-2**




The Benfield bender head Shown in Figure 2-3 has angle indicating marks of 10°, 22°, 30°, 45° and 60° on the side of the bending shoe. When an angle mark is parallel to the work surface that angle of bend has been achieved. This bender handle will be perpendicular (plumb) or vertical to the work surface when a 30° bend has been achieved.

**Figure 2-3**




Each manufacturer puts marks, arrows, stars, letters, etc. on the bending head to locate, or indicate starting points for bending 90° bends, offset bends, center of bend, make adjustment for back-to-back bends, etc.

Take the time to read the instructions that come with each bender head. If no literature is available, make some sample bends with scrap pipe to familiarize yourself with the bender and its marks. The time will be well spent, and will pay dividends in time and material saved when the actual bending is started.

Benders normally ***do not*** come with a handle. The handle is cut from standard size Rigid or IMC conduit, and then screwed into the bender head. To save back strain, and to gain mechanical advantage, the top of the bender handle after it has been screwed into the bender head should reach the center of the elbow of the user when stood upright on the floor next to the body, as shown in Figure 2-4.

**Figure 2-4**

The key to accurate bending with a hand bender is ***constant and heavy*** foot pressure on the ***back piece, or foot piece*** of the bender. Failure to keep constant pressure on the back/foot piece will allow the conduit to rise off the floor and bend outside the bending shoe. Proper body positioning when bending conduit will give added leverage and make the job easier.

Figure 2-5 shows the proper stance for initial bending of a 90° bend. Hold this position while pulling the handle back toward the chest with ***constant heavy foot pressure*** on the foot piece until the handle is well past vertical. Change body positioning, spacing feet further apart, while still maintaining good pressure on the foot piece. The bend can now be completed by pushing down on the bender handle, as shown in Figure 2-6.

**Figure 2-5**

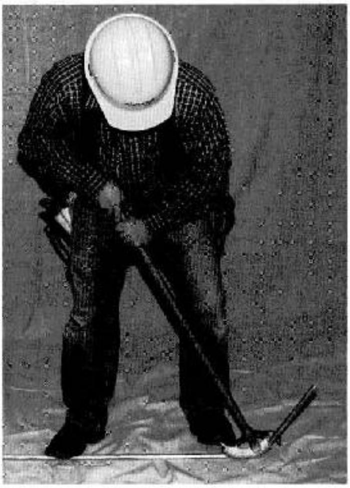


**Figure 2-6**

For hand bending 1¼" EMT a two-step bender like the Greenlee Site-Rite shown in Figure 2-7 will be required. The bender head is available in either an aluminum or iron alloy and features a two-step oversized foot piece that allows more foot pressure and better control during the two-step bending process.

**Figure 2-7**

Many manufacturers indicate that their EMT benders can be used to bend the next smaller sized Rigid pipe, i.e. 1" EMT bender can also bend ¾" Rigid, ¾" EMT bender can also bend ½" Rigid. The author's experience has been that when bending rigid conduit with a bender head made of aluminum, the rigid conduit may distort the bending shoe and ruin the bender. If you want to bend rigid conduit with an EMT bender use an iron alloy bending head, not an aluminum head.

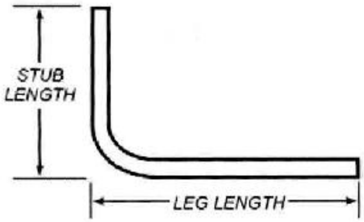
Trying to bend IMC pipe with an aluminum EMT bender will usually break the front hook of the bender.

An EMT bender can also be ruined by loaning the bender to an Iron Worker to bend re-bar. It is also important to keep the bending shoe clean, as dirt or build-up on the shoe can cause the bender to kink the pipe.

# NINETY DEGREE BENDS 3

Ninety degree bends are called ***stubs***, or ***stub-ups***. The stub or stub-up length is measured from the back of the completed bend to the end of the pipe, as shown in Figure 3-1. The length of pipe left after the stub has been bent is called the ***leg*** length.

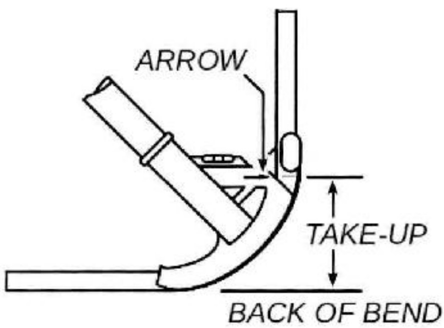
**Figure 3-1**




The 90° bend is the most frequent bend the electrician will make, and also one of the easiest. To bend stubs to a given dimension, the ***take-up*** of the bender being used must be known.

Take-up is the distance from the arrow, star, or other mark on the bender, to the back of the completed bend, as shown in Figure 3-2.

**Figure 3-2**

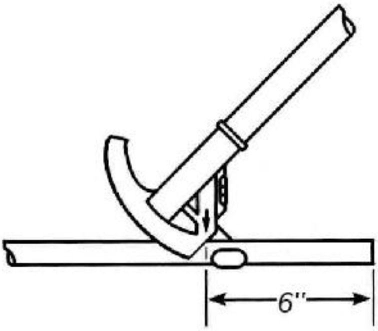



## Finding Bender Take-Up

To find the take-up, or to check the take-up printed on the bender, proceed as follows:

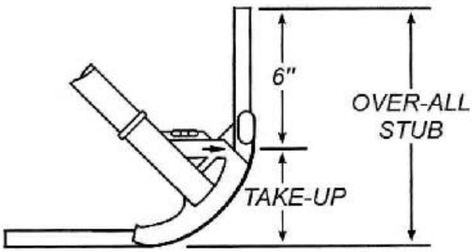
1. Measure 6" from the end of a scrap piece and place a mark.
2. Place the arrow, star, or other mark on the bender on the 6" mark as shown in Figure 3-3 and bend a full 90° bend. Accuracy at this point is very important, so check your bend with a level.

Figure 3-3




3. Measure the over-all stub length and deduct 6". The remainder is the ***take-up*** for that bender, as shown in Figure 3-4.

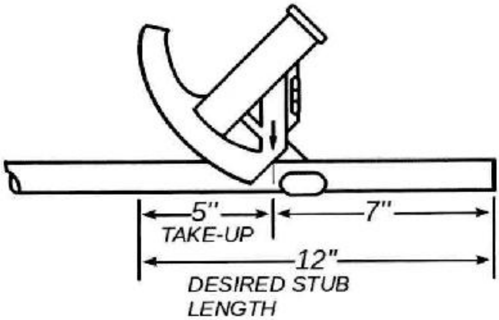
Figure 3-4




Take-up then is the measurement from the arrow to the back of the bend, or by subtracting 6" from the overall stub length. If the overall stub length is 11", subtracting 6" would give us a take-up value of 5". Once the take-up for a given bender has been found the take-up value can be used to bend perfect 90° stubs to any stub length you need.

**EXAMPLE:** We want to bend a 12" stub using ½" EMT. We have determined that the ½" EMT bender we are using has a take-up of 5". All we need to do to bend a 12" stub then is to subtract the bender take-up of 5" from the 12" stub length, leaving 7". Place a mark 7" from the end of the pipe and then place the arrow of the bender on the mark, as shown in Figure 3-5. Next make a 90° bend. The result will be a perfect 12" stub.

Figure 3-5

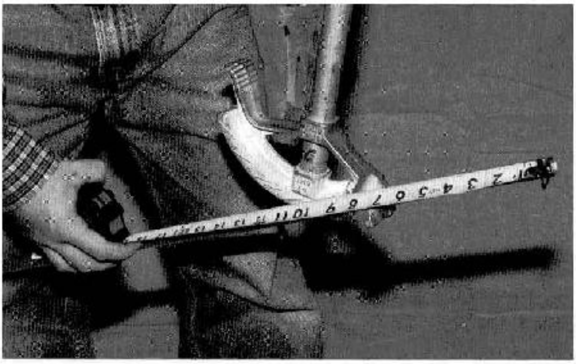


In embedded or underground conduit work where accuracy and appearance is not so important, a quick method of bending 90° stubs is by sighting down the back of the bender foot piece. Notice in Figure 3-5 that the back of the bending shoe lines up with the 12" measurement for the desired stub length. If a 12" stub is required, measure 12" from the end of the conduit and place your thumb there as a reference. Place the bender shoe on the conduit and sight the back of the bender foot piece. Move the conduit in the bender until the back of the foot piece (back of bender shoe) is lined up with the thumb mark (12"). Set the bender down and bend a 90° stub. This is called an ***about*** method and is ***not*** accurate enough to be used for exposed conduit runs.

**RULE:** When bending stubs using the take-up method, the bender is always placed on the pipe and the bend is made facing the end of the pipe the measurement was taken from.

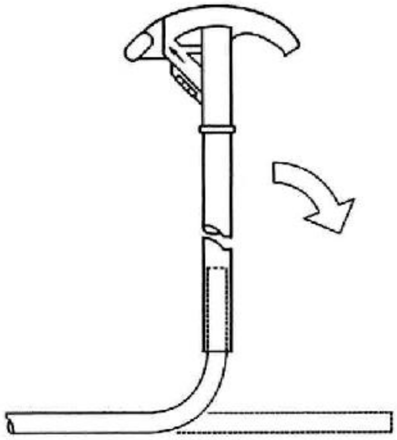
**TIP:** Once the length of the stub has been determined, deduct take-up in your head to find the bend mark. Do not mark the pipe. Instead, place the bender on the conduit in the approximate area where the mark should be. Support the conduit in the bender with one hand, hook the end of a steel tape over the end of the conduit and then slide the bender until the arrow of the bender is on the proper measurement, as shown in Figure 3-6. Set the bender down and bend a 90° stub. This eliminates fumbling for a pencil and saves time.

**Figure 3-6**



To straighten a stub that has been over bent, place bender handle (or any close fitting pipe) over the stub, as shown in Figure 3-7, and push down and away. For larger sizes of EMT, a close fitting pipe that will fit inside the pipe will also work.

**Figure 3-7**

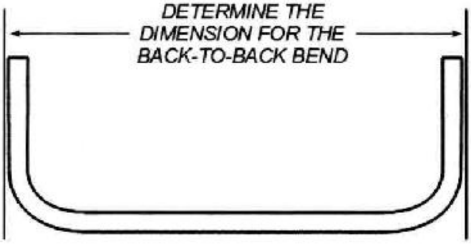


This method can be used to remove the whole bend. As part of the bend is removed, move the bender handle further down and continue to remove the bend. Success with this method depends greatly on the ductility of the EMT. The pipe will show that a bend has been removed. This method is O.K. for buried work, but ***not*** for exposed conduit runs.

# BACK-TO-BACK BENDS 4

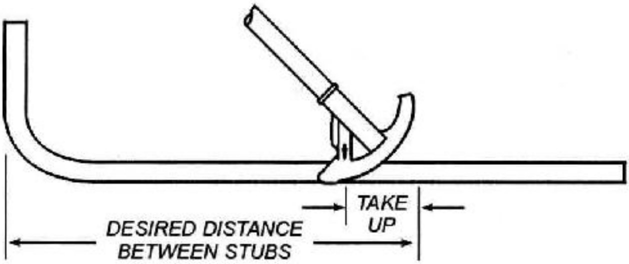
For making ***back-to-back*** 90° stubs, or "U" bends, first determine the distance needed for the back-to-back bends as shown in Figure 4-1.

**Figure 4-1**



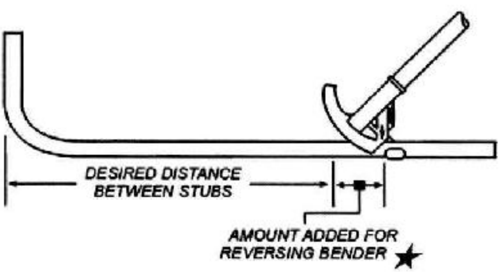

Bend the first stub as outlined in Chapter 3. To make the second bend, measure required distance between stubs from the back of the first stub that was bent, as shown in Figure 4-2. Deduct take-up and bend as shown.

**Figure 4-2**




If the distance between the two stubs is quite long or if there is not enough pipe left after deducting take-up to make the bend, reverse the bender and bend the second stub facing the ***opposite*** direction, as shown in Figure 4-3. Bending the second stub in this manner requires only bending up the short end of the pipe, rather than bending and lifting the full length of pipe.

**Figure 4-3**

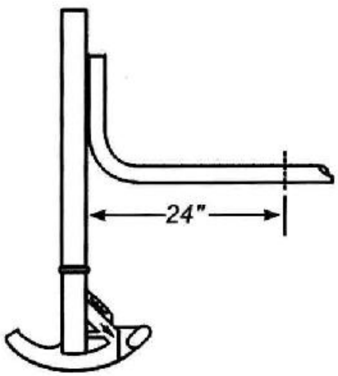


★ When you turn your back on the end of the pipe that you originally measured from, take-up is not used. Instead an amount must be ***added*** to the desired distance between the stubs for the back-to-back bends to come out right.

Most benders have a mark that may be used when the bender has been reversed to bend back-to-back bends, while other benders have the amount that must be added printed on the bender head.

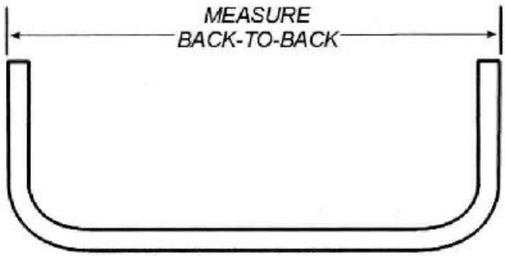
If your bender has no marks or information printed on the bender head, you can bend a scrap piece of pipe to find the amount that must be added. To determine the amount that must be added for reversing the bender, bend an 8" stub in a scrap piece of pipe. Using the bender handle as a straight edge, measure over 24" and place a mark on the conduit, as shown in Figure 4-4.

**Figure 4-4**




Reverse the bender on the pipe, your back is now to the first stub you just bent. Place the arrow or other mark on the 24" mark and bend a 90° stub. Measure the ***back-to-back*** dimension of the two stubs measuring from outside-to-outside, as shown in Figure 4-5.

**Figure 4-5**



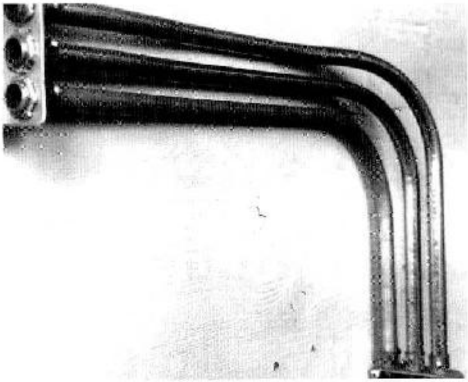

The outside-to-outside measurement between the stubs will be less than 24". The amount that the measurement is short of 24" is the amount that must be ***added*** to the desired measurement between the stubs for accurate back-to-back bends. The amount that must be added will ***vary*** with each pipe size and bender used.

**TIP:** When bending stubs, if you must ***turn your back*** on the first stub to bend the second stub you must ***ADD*** to the desired measurement, ***do not*** subtract take-up.

# KICKS 5

The term ***Kick*** is applied to any bend of ***less than*** 90°. Its primary use is for direction changes, and works exceptionally well for entry into boxes and/or cabinets, as shown in Figure 5-1.

**Figure 5-1**



The degree of bend for a given amount of kick will depend on bender placement on the conduit. Bending close to the 90° stub requires more angle of bend for a given kick height, while bending further away from the stub will require less angel of bend to achieve the same kick height, as shown between Figure 5-2.

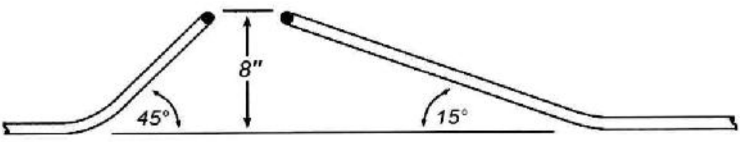



**Figure 5-2**

Installation requirements will usually dictate where the conduit is to be ***kicked***. If possible use the smallest amount of angle to achieve the necessary kick—that will make wire pulling easier.

The easiest method of hand bending kicks after the initial stub has been bent is to place the conduit in the bender and level the stub horizontally, as shown in Figure 5-3. Holding a rule next to the leveled stub, measure to the top of the conduit. Mentally add the amount of kick that is needed to this measurement and start bending until the stub reaches the required height on the tape, as shown in Figure 5-4.

**Figure 5-3**

**Figure 5-4**

# OFFSETS 6

Offsets are used to change conduit elevation, to go over or under an obstruction, or for entry into boxes, cabinets, etc. The offset is achieved by bending two bends of ***equal*** degrees. The first bend is made and then the conduit is rotated 180° and then the second bend is made. Figure 6-1 shows an offset with two bends having the same degree of bend (A and B).

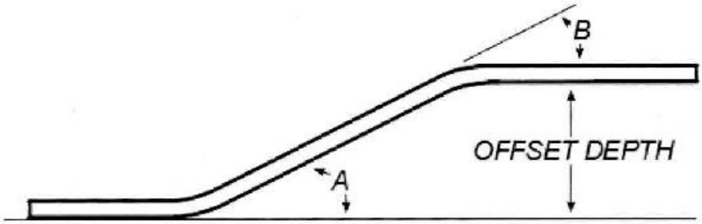



**Figure 6-1**

Perfectly fitting offsets can be easily and quickly made if a few basic rules are understood and followed.

The degree of bend is dictated by the space requirements. The smaller the angle of bend, the larger the space needed to complete the elevation change as illustrated in Figure 6-2.

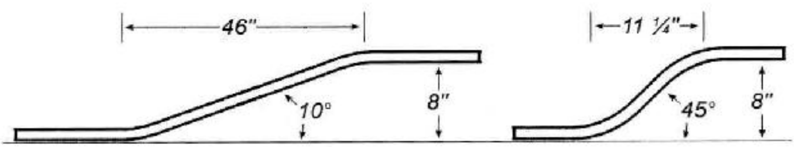
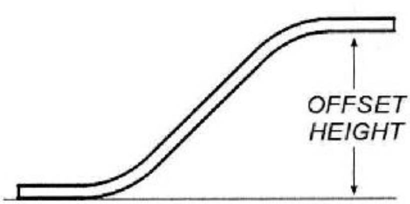



**Figure 6-2**

If space is no problem, the angle of bend should be kept small to make wire pulling easier.

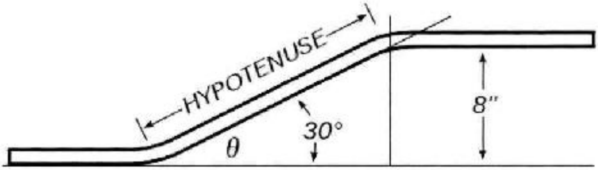
Unlike the 90° stub that is measured over-all, the offset is measured ***bottom*** to ***bottom***, as shown in Figure 6-3.

**Figure 6-3**



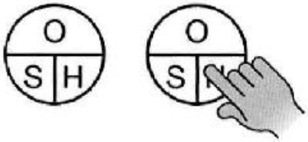
Once the angle of bend has been decided and the required height of the offset determined, only the spacing between the bends is needed to start bending. This spacing is found by using Trig functions. Assume an 8" offset is needed and 30° bends are to be used, as shown in Figure 6-4.

**Figure 6-4**




The Figure forms a right triangle, with an angle Theta of 30°, and opposite side of 8". The Hypotenuse would represent the distance between the two 30° bends. As we know the Opposite side and can find the Sine for 30° we can use the **Sine = O ÷ H** formula to find the dimension of the Hypotenuse (Figure 6-5).

**Figure 6-5**




Using the ***Magic Circle*** and covering the unknown value, we can find the Hypotenuse by dividing the Opposite side (8") by the Sine of 30°. From the partial Trig table shown, we find that the Sine of 30° is .500.

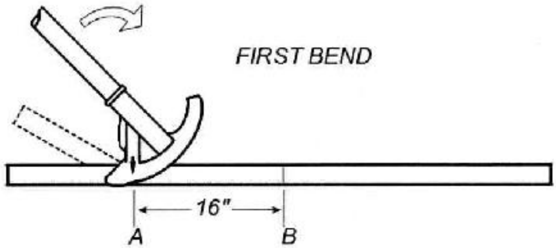
| ANGLE | SINE | COSINE | TANGENT |
|---|---|---|---|
| 28° | .4695 | .8892 | .5317 |
| 29° | .4848 | .8746 | .5543 |
| 30° | .5000 | .8660 | .5774 |
| 31° | .5150 | .8572 | .6009 |

H = O ÷ Sine     H = 8" ÷ .500     H = 16"

Place a mark on the conduit where you want the offset to start. From this mark measure over 16" and place a second mark on the conduit. Marks placed on the conduit for bending offsets should be drawn ***completely around*** the conduit. This will keep the mark from going out of sight when the pipe is rolled 180° for the second bend.

Put the conduit into the bender shoe and line the first mark up with the arrow, as shown in Figure 6-6.

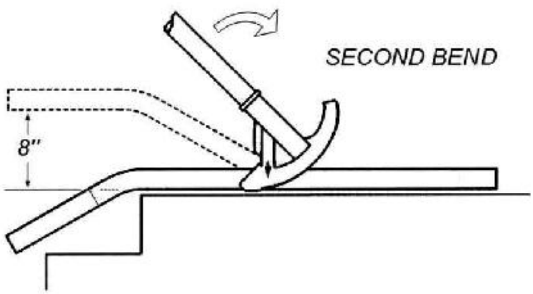
Figure 6-6




**NOTE:** The arrow, the front hook of the bender, or any point on the bender can be placed on the bending marks for bending, but the same point or reference must be used for ***both*** the first and second bend. It is assumed, however, that most hand benders have an arrow or star and all diagrams and descriptions in this book will use the arrow as a reference.

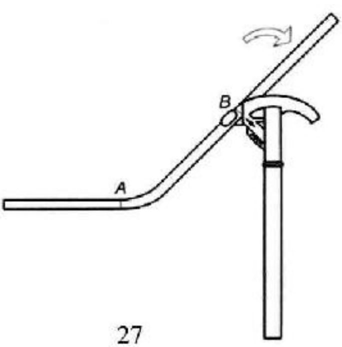
Bend the first 30° bend. Then roll the conduit 180° making sure to line the second bend up with the first bend to avoid misalignment of the two bends. Use an elevated platform or stairway, if available, to make the second bend, as shown in Figure 6-7. Bend the second 30° bend and a perfect 8" offset has been achieved.

Figure 6-7




If an elevated platform or stairway is not available, invert the bender handle and place the handle on the floor to complete the bend as shown in Figure 6-8. Use your foot to keep the inverted handle from slipping.

Figure 6-8



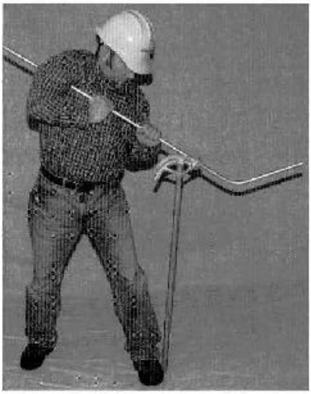
Pull down with the hands, keeping one hand as close to the bender head as possible holding the pipe down in the bending shoe as the pipe is bent, as shown in Figure 6-9.

**Figure 6-9**

**TIP**: If you are making several bends with the bender handle inverted and are having trouble with the handle slipping, buy a crutch tip at a local hardware store and install in on the end of the bender handle. This will give added traction, even on slick concrete floors.

Another technique for bending with the bender handle inverted is to place the pipe under your armpit and use the weight of your body and you hands to form the pipe in the bender shoe, as shown in Figure 6-10. This technique works well with ¾" and 1" EMT.

**Figure 6-10**



Care must be taken when the bends are made if perfect results are to be expected. A few degrees too much will make the offset to high and bending less than the required degrees will make the offset too low.

As we have seen, the spacing between marks can be found using Trig formulas. This is time consuming though and is not necessary. A quicker, more practical method uses the ***Cosecant*** of the offset angle. The Cosecant is the ***ratio*** of the Hypotenuse to the Opposite side. The Cosecant number can be used to determine the spacing between the offset bend marks. The Cosecant by degrees is listed in the Trig Chart at the back of the book.

A 10° angle has a Cosecant of 5.7588. This tells us that the length of the hypotenuse will be 5.7588 times the height of the Opposite side (the obstruction). In other words, if we multiply the height of the obstruction by 5.7588 we can determine the length of the Hypotenuse, which gives us the spacing between the offset bend marks.

A 30° angle has a Cosecant of 2.000, or the Hypotenuse is 2 times as long as the Opposite side is tall. Multiplying the height of the obstruction by 2.000 would give us the spacing between the offset bend marks.

The Cosecant of the any angle can be used to determine the spacing between the offset bend marks. Determine at what angle the offset is to be bent and simply multiply the Cosecant of the offset angle times the height of the offset to find the spacing between the bends, which is the Hypotenuse. When the Cosecant of the angle is used in this manner it is called the ***Offset Multiplier***.

To save time, Table 6-11 lists ***common angles*** used when bending offsets and their ***Offset Multipliers*** (Cosecant) rounded to three digits. These values should be committed to memory, if not cut and fold the Trig Table on the green card at the end of the book and carry it in your wallet.

**OFFSET MULTIPLIERS**
**TABLE 6-11**

| OFFSET ANGLE | OFFSET MULTIPLIER |
|---|---|
| 10° | 5.759 |
| 22½° | 2.613 |
| 30° | 2.000 |
| 45° | 1.414 |
| 60° | 1.155 |

**EXAMPLE:** Layout a 12" offset using 45° bends. The offset multiplier (Cosecant) for 45° is 1.414 as shown in Table 6-11. Multiply 1.414 times the height of the offset which is 12".
$1.414 \times 12" = 16.968"$, or just under 17". As we only expect accuracy to within ⅛" we will round up and make the spacing between the bend marks for our 12" offset at 17", as shown in Figure 6-12.

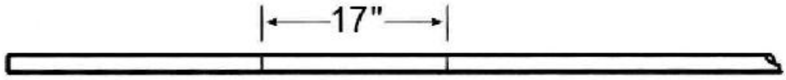



**Figure 6-12**

When converting decimal numbers to fractions when bending offsets always ***round*** the number ***up*** to the nearest ⅛". As conduit is usually marked with a wide pencil or felt-tip marker, the marks themselves are almost ⅛" wide. There is no need to try and measure to within a 1/16th or 1/32nd of an inch.

By rounding up to the next closest ⅛" the offsets will always be tall enough to clear the obstruction. With offsets it is better to be a bit high, than to come up short and not clear the obstruction. While the pipe can be bent again to gain the necessary clearance it will require extra work, which wastes time.

**Math Tip:** To convert your calculator answer to the closest ⅛" multiply the fractional numbers by 8. If the answer is 16.968, as in the previous example, multiply the fractional portion .968 times 8. Your answer will be 7.744. This means that there are 7.744 eighths. Round the 7.744 up to 8 and we get 8 eighths, or a whole number value of 1. One is then added to the 16" to get a measurement between the bend marks of 17".

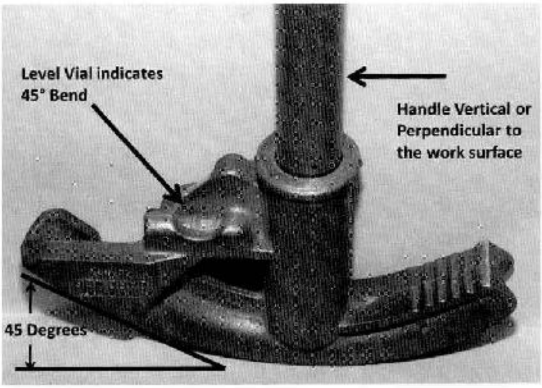
If the answer you are trying to round is 14.334, multiply the .334 times 8 for a value of 2.672. 2.672 eighths rounded up will be three eights. The ⅜" is added to the 14" making the spacing between the bend marks 14⅜".

The method for determining the spacing between bend marks for bending offsets, as shown in Table 6-11 will work for any size conduit, using any type of bender; hand, "Chicago" style, electric, or hydraulic.

**TIP:** For conduit that will be painted after installation, ***Do Not*** use a permanent ink marker, as the marker ink will bleed through the paint.

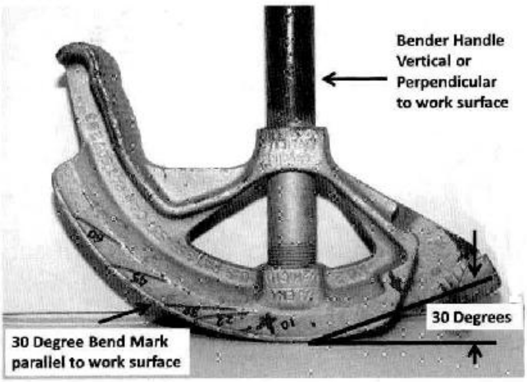
What angle of offset is the most common when hand bending EMT? It depends on the individual and the tools available. Some EMT benders are designed so that when a 45° bend has been achieved, the bender handle will be vertical, other benders have a built in level vile to indicate 45° (Figure 6-13), while other benders have raised lines cast into the bender head that when lined up indicate various degrees of bend

**Figure 6-13**




Other benders are designed so that a 30° bend has been achieved when the handle is vertical (plumb) and the line for 30° is parallel with the work surface, as shown in Figure 6-14.

**Figure 6-14**




Note that other angles 10°, 22°, 45°, and 60° can be determined when the line for each degree is parallel with the work surface.

$30^o$ offsets are popular with electricians because the ***Offset Multiplier*** is 2.0. An Offset Multiplier of 2 simplifies the math necessary as we can usually figure offset spacing using a multiplier of 2 in our head. For finding other angles, use a protractor level with a magnetic base like the one shown in Figure 6-15.

**Figure 6-15**

Johnson Level & Tool 700 Magnetic Angle Locator

**PROBLEMS:** Determine the spacing between the bend marks for a 22" offset using: (a) $45^o$ bends (b) $30^o$ bends (c) $15^o$ bends.

**BOX OFFSETS:** Box offsets are the most used offset application. It is not practicable, however, to mark and layout normal box offsets in smaller sized EMT. These offsets are achieved only by practice and for this reason will not be covered. For accurate box offsets in larger conduit sizes, normal offset procedures are required.

When bending offsets for buried work or for installations where the finished offset will be covered, an alternate, but less accurate, method of bending offsets may be used. This alternate method does not use offset multipliers as previously discussed, but rather uses a measurement for offset height, after the first bend has been made.

**EXAMPLE:** To bend a 6" offset using the ***alternate*** method proceed as follows:

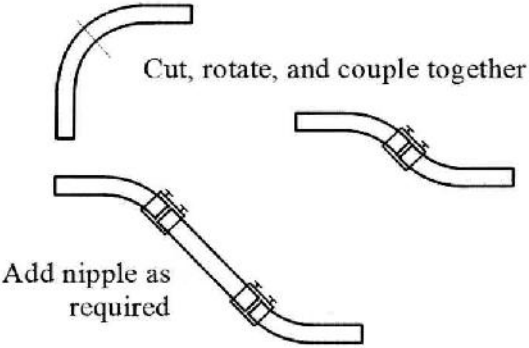
1. After the first bend of the offset has been made, lay the bender handle next to the pipe, as shown in Figure 6-16.

**Figure 6-16**

2. Using your tape measure at 90° from the end of the bender handle, measure out 6" and mark the pipe for the second bend of the offset.
3. Put the pipe back in the bender, align the pipe and bend the second bend of the offset. The results will be an offset of ***approximately*** 6".

**TIP:** For offsets in larger sized EMT that can not be bent using hand benders, usually 1¼" and above, or when a bender is not available, factory sweeps or factory bent 90° pipes can be cut in half, rotated and coupled together to form an offset. Greater offset depth can be obtained by adding a short piece of conduit of the required length, as shown in Figure 6-17.

**Figure 6-17**



# PREDETERMINING OFFSET LOCATION 7

The hardest part about bending an offset is properly aligning the pipe in the bender to avoid any misalignment between the two offset bends. The misalignment of the bends is called a ***Dog-Leg***, or in some parts of the country it is called a ***Wow***. As with any skill, proficiency comes with experience.

Once proficiency has been achieved, the next step is to learn how to locate the marks on the pipe so the location of the offset can be determined ***prior*** to bending. By knowing that the offset will be in the right location after the offset is bent will save time and avoid having to cut the pipe to fit, or having to add extra pipe and a coupling to make it fit.

Predetermining offset locations is an easy procedure requiring little additional time, but will pay large dividends in material and labor units saved.

Two methods for ***predetermining offset location*** will be discussed. Study both methods, then use the one that you find easiest to apply for a given set of circumstances.

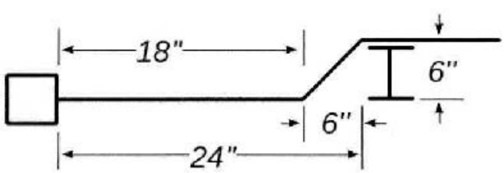
## Predetermining Offset Location Method #1

The key to this method is establishing ***Constants*** for the different pipe sizes, and angle of offset bends.

This method can be used for any angle offsets and any pipe size.

Figure 7-1 shows an offset that is to be bent with two $45^0$ bends. Notice, that both the Opposite and Adjacent side of the right triangle are 6", or are equal, or have a ratio of 1:1.

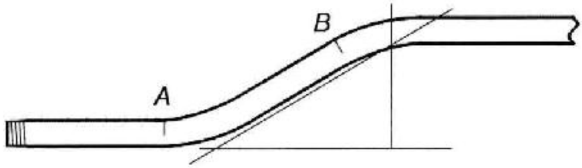
**Figure 7-1**



If the pipe was bent like the drawing, to locate the center of Bend A, we would need to subtract 6", the length of the Adjacent side from 24", the distance from the box to the obstruction to get a value of 18". This value, 18", is the distance from the end of the conduit to bend mark A, the first bend of the offset. (As shown in Figure 7-1)

Of course, in reality conduit is bent to the radius of the bending shoe, as shown in Figure 7-2, not at right angles, as shown in Figure 7-1.

**Figure 7-2**

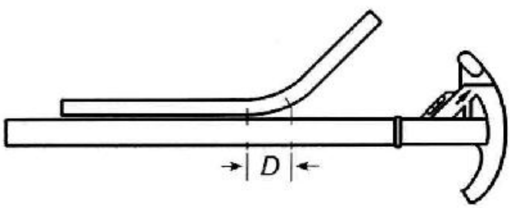



Notice, that for a short distance before the right triangle formed at bend A, and after bend B, the conduit is not straight. This is caused by the radius of the bend. For the offset to fit properly over the obstruction, the offset must be shifted to the left (toward the box) so the pipe is straight and no part of the bend is touching the obstruction.

We need to locate the bend marks so that when the offset is completed there is straight pipe at the edge of the obstruction. To accomplish this, an amount is added to the height of obstruction (opposite side) measurement before subtracting the value from the distance from the box to the obstruction. The amount that must be added for 45° offsets can be found as follows.

1. Bend a 45° bend in a scrap piece of pipe.
2. Remove the pipe from the bender, locate and mark the center of the 45° bend.
3. Using the bender handle as a straight edge, measure from the center of the bend to a point where the conduit is straight on the bender handle measurement D, as shown in Figure 7-3.

**Figure 7-3**



As there are two bends in each offset, the measurement (D) is doubled, and this amount must be added to the height of the obstruction (H); the total of the two measurements (2D + H) is then subtracted from the distance from the box to the edge of the obstruction to locate bend mark A. This adjustment compensates for bending on a radius and assures the pipe will be straight when it passes over the obstruction.

The amount that must be added is called an ***Offset Constant*** and will be different for each pipe ***size*** and ***angle*** of offset.

Table 7-4 lists ***Offset Constants*** that have been established for ½", ¾", and 1" EMT to compensate for the radius of both bends of a 45° offset.

**TABLE 7-4**
**Offset Constants for**
**45° Offsets Using EMT**

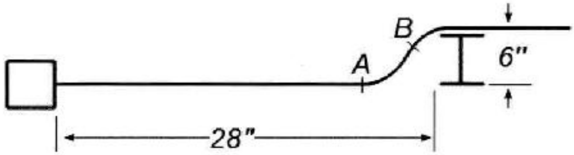
| EMT Size | Add |
|---|---|
| ½" | 5" |
| ¾" | 6¼" |
| 1" | 7½" |

For 45°offsets, the height of the obstruction (Opposite side) is equal to the Adjacent side, giving a ratio of **1:1**. With this fact in mind we can add the 5" ***Offset Constant*** for ½" EMT to the height of the obstruction and subtract the combined measurement from the distance from the box to the obstruction to locate ***bend mark A***.

**NOTE:** For simplicity, examples and problems will be drawn in one line form, and box offsets will not be included.

**EXAMPLE:** A 45° offset is to be bent using ½" EMT to clear a 6" "I" beam that is located 28" from a box, as shown in Figure 7-5. Using Method #1, locate bend marks A and B.

**Figure 7-5**

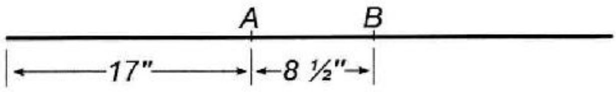



| | | |
|---|---|---|
| Height of obstruction (H) | | 6" |
| Offset Constant for ½" EMT | | +5" |
| | Total | 11" |

| | |
|---|---|
| Distance from box to Obstruction | 28" |
| Subtract H + Offset Constant | −11" |
| | 17" |

Measure 17" from the end of the conduit and mark bend mark A as shown in Figure 7-6. Multiply 1.414 (Offset Multiplier for 45° offsets) times 6" (Height of the obstruction) to find the spacing between bend mark A and bend mark B. 1.414 × 6" = 8.484", or ≈ 8½". This is the spacing from bend mark A to bend mark B, as shown in Figure 7-6.

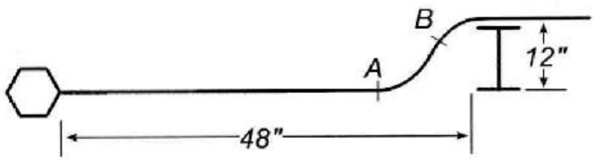
**Figure 7-6**




**NOTE:** See the ***Decimal to Fraction Conversion Table*** in back of book if you need help converting decimal numbers to their fractional equivalent. You can also find the fractional equivalent using your calculator. Multiply the value after the decimal times 8 to find the equivalent in eighths. In the previous example the value was 8.484. Multiplying .484 (the value after the decimal) times 8 give us 3.872 eighths. Rounding up to the next eighth would be 4/8 or ½".

**EXAMPLE:** Bend a 12" offset using 45° bends with ¾" EMT as indicated in Figure 7-7. Locate bend marks A and B.

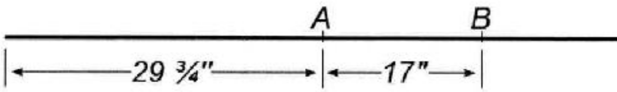
**Figure 7-7**




1. Add the 12" height of obstruction to the ¾" EMT Offset Constant of 6¼" for a total of 18¼".
2. Subtract 18¼" from the 48" distance from the box to the obstruction for a value of 29¾".
3. From the end of the pipe measure 29¾" and mark bend A.
4. Multiply the height of the obstruction by 1.414 to find the spacing between bend marks A and B, as shown in Figure 7-8.

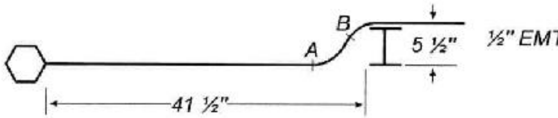
12" × 1.414 = 16.968 or ≈ 17"

**Figure 7-8**

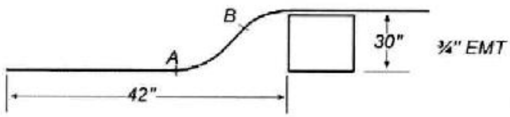



**PROBLEMS:** Layout bend marks A and B for the following offset projects. All offsets are 45°, the EMT pipe size are as listed.

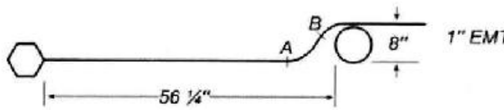
1.



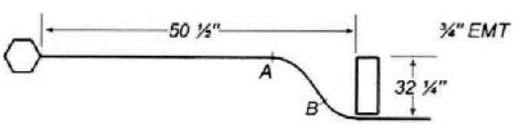

2.



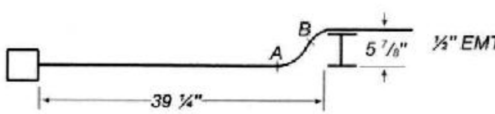

3.




4.




5.



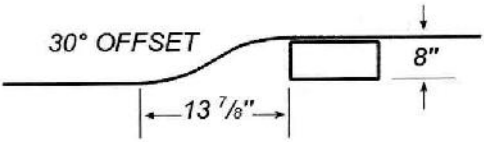

To preposition offsets for other than 45° we will use ***Offset Location Multipliers***. These multipliers will be used **only** for locating the first bend mark of the offset, bend mark A, and **must not** be confused with ***Offset Multipliers*** that are used to find the spacing between bend Marks A and B.

For 45° offsets we found that the height of the obstruction (Opposite Side) was equal to the adjacent side, or we could say the ratio of the

Opposite to the Adjacent was 1:1. For any other degree of offset angle the ratio ***will be different***.

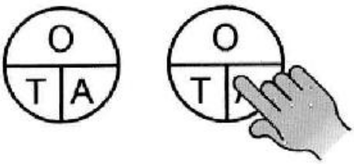
**EXAMPLE:** Offsets bent using 30° bends will have a ratio of 1:1.73 between the Opposite (height of obstruction) and Adjacent side. The added length of the Adjacent side can be seen in Figure 7-9.

**Figure 7-9**




We can prove the ratio using the formula shown in Figure 7-10.

**Figure 7-10**




Look up the Tangent of 30° using the partial Trig Table in Figure 7-11.

**Figure 7-11**
**Partial Trig Table**

| ANGLE | SINE | COSINE | TANGENT |
|---|---|---|---|
| 30° | .5000 | .8660 | .5774 |

By dividing the Opposite side by the Tangent of 30° we can determine the length of the Adjacent side.

Adjacent Side = O ÷ T **Adjacent Side = 8 ÷ .5774**

Adjacent Side = 13.86 or ≈ **13⅞"**

To find the ratio of the Opposite to the adjacent side for 30° offsets we divide the Adjacent side by the Opposite side.

$$\text{Ratio} = \frac{\text{Adjacent Side}}{\text{Opposite Side}} \qquad \textbf{Ratio} = \frac{\mathbf{13.86}}{\mathbf{8}} \qquad \textbf{Ratio is} \approx \mathbf{1.73}$$

This tells us, that for an offset bent with 30° bends, the Adjacent side will always be 1.73 times longer than the height of the obstruction

(Opposite Side). The ratio of 1:1.73 will be true no matter what size pipe is used and no matter what the height of the obstruction is. If the ratio is always true, the height of the obstruction can be multiplied by 1.73 to find the length of the Adjacent side for predetermining offset location using Method #1. Stated another way, the 1.73 becomes an ***Offset Location Multiplier*** for 30° offsets.

The ***Offset Constant***, as shown in Table 7-5, to compensate for bending on a radius and to assure straight pipe where the pipe crosses over the obstruction change as the angle of offset bends change. Table 7-12 lists the constants for 45°, 30°, 22½°, and 10E offsets using ½", ¾", and 1" EMT.

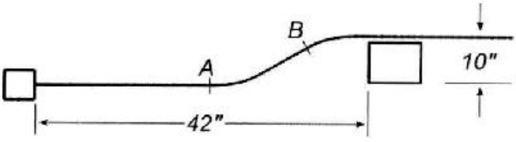
**TABLE 7-12**
**EMT Offset Constants**

| Offset Angle | ½" EMT | ¾" EMT | 1" EMT |
|---|---|---|---|
| 45° | 5" | 6¼" | 7½" |
| 30° | 4½" | 5½" | 6" |
| 22½° | 3½" | 4¼" | 4¾" |
| 10° | 3" | 3½" | 4" |

**NOTE:** For other offset angles use the procedure discussed earlier and, as shown in Figure 7-3.

**EXAMPLE:** Locate bend marks A and B to pre-position a 10" offset with ½" EMT using 30° bends, as shown in Figure 7-13.

**Figure 7-13**



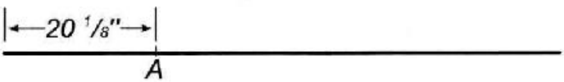

1. Multiply the height of the obstruction (10") times the ***Offset Location Multiplier*** for 30° offsets (1.73).
   10 × 1.73 = 17.3 Or ≈ **17⅜"**

2. Add the ***Offset Constant*** for 30° bends to compensate for bending on a radius as found in Table 7-12 (4½") to the Adjacent side (17⅜") to find the amount that is subtracted from the box to the obstruction measurement of 42" to locate Bend Mark A.

4 ½" + 17⅜" = 21⅞"
42" - 21⅞" = **20⅛"**

Measure 20⅛" from the end of the conduit and mark bend mark A, as shown in Figure 7-14.

**Figure 7-14**




2. The distance between bend mark A and B is found by multiplying the height of the obstruction (10") by the ***Offset Multiplier*** for 30°, which is 2.0. 10" × 2.0 = **20"**

**Table 7-14a**
**Offset Multiplier Table**

| OFFSET ANGLE | OFFSET MULTIPLIER |
|---|---|
| 10° | 5.759 |
| 22½° | 2.613 |
| 30° | 2.000 |
| 45° | 1.414 |
| 60° | 1.155 |

Measure 20" from bend mark A and mark bend mark B, as shown in Figure 7-15.

**Figure 7-15**

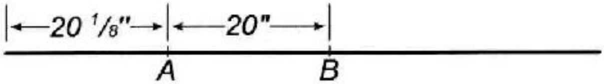



Table 7-16 gives the ***Offset Location Multiplier*** for predetermining offset location using Method #1 for 45°, 30°, 22½°, and 10° offsets.

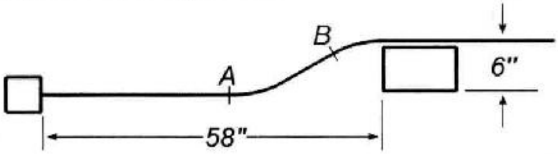
**TABLE 7-16**
**Offset Location Multipliers**

| OFFSET ANGLE | OFFSET LOCATION MULTIPLIER |
|---|---|
| 45° | 1.00 |
| 30° | 1.73 |
| 22½° | 2.42 |
| 10° | 5.67 |

**NOTE:** The ***Offset Location Multiplier*** for other offset angles can be found by looking up the ***Cotangent*** of the angle in the Trig Table at the end of the book.

**EXAMPLE:** Locate bend marks A and B for a 6" offset using 22½° bends and ¾" EMT, as shown in Figure 7-17.

**Figure 7-17**




1. Height of obstruction multiplied by the Offset Location Multiplier for 22½°offsets using ¾" pipe as found in Table 7-16.
   6" × 2.42 = 14.52 or ≈ **14½"**

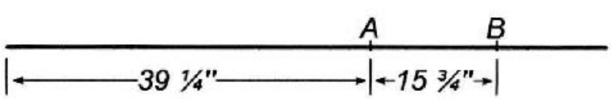
2. Add the ***Offset Constant*** for 22½° offsets for ¾" EMT, as shown in Table 7-12. 14½" + 4 ¼" = **18 ¾"**

3. Subtract the 18 ¾" from the distance from the box to the obstruction to locate Bend Mark A, as shown in Figure 7-18.

   58" - 18¾" = 39¼" Measure 39¼" from end of pipe and mark A

4. Multiply the height of the obstruction (6") by the Offset Multiplier for 22½° offsets as found in Table 6-11 (2.613) to find the spacing between marks A and B. **6 × 2.613 = 15.678.** As this measurement will determine the height of the finished offset, we will round .678 up to the next ⅛" to **15¾",** as shown in Figure 7-17.

**Figure 7-18**



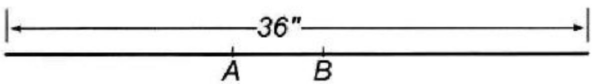
## Predetermining Offset Location Method #2

This method for predetermining offset location requires the use of ***Shrink*** values. Shrink is the amount the overall length of a pipe will shorten, or Shrink, when the offset is bent.

To determine Shrink for a given offset angle, proceed as follows:

1. Measure the overall length of a scrap piece of pipe. The scrap piece of pipe in Figure 7-19 has an overall length of 36".

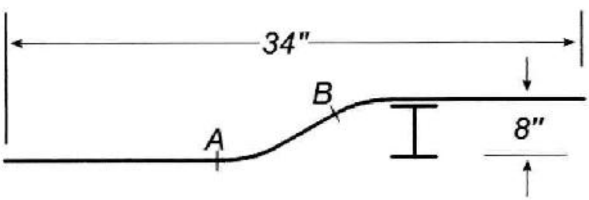
**Figure 7-19**




2. Calculate spacing between bend marks A and B for an 8" offset using 30° bends. 8" × 2 = **16"**

3. Bend the offset and then measure the distance from one end of the conduit to the other, as shown in Figure 7-20.

**Figure 7-20**




4. Subtract the new length of 34" from the original overall length of 36" to find a total Shrink of 2". 36" - 34" = **2" of Shrink**

5. Divide the total Shrink of 2" by the height of the obstruction (8") to find the Shrink per inch of offset, or Shrink per inch of rise. 2" ÷ 8" = **.25 or ¼" of Shrink per inch of rise.**

**EXAMPLE:** Find the total shrink for a 14" offset using 30° bends.
14" × ¼" = **14/4 or 3½" of Total Shrink**

Once the shrink value has been found for a given offset angle, the value will apply to ***any size*** conduit (EMT or Rigid).

Table 7-21 shows shrink values for the most common offset angles.

**TABLE 7-21**

**Offset Shrink Values**

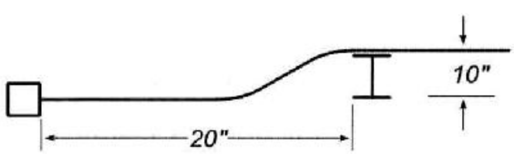
| Offset | Shrink per Inch of |
|---|---|
| 10° | 1/16" |
| 22 ½° | 3/16" |
| 30° | 1/4" |
| 45° | 3/8" |
| 60° | 1/2" |

**NOTE:** To find the Shrink values for other angles of bend, locate the ***Cotangent*** for the offset angle in the Trig Table and subtract the value from the ***Cosecant*** of the same angle. Convert the decimal answer to fractions of an inch to obtain Shrink per inch of rise. These are purely mathematical values and while they will be very close, for the most accurate Shrink values, always bend a scrap piece of pipe to determine Shrink per inch of rise for the bender you are using.

Figure 7-22 shows an offset consisting of the 30° bends and a 10" obstruction, or 10" of rise. By using the ***Shrink*** value for 30° (¼"), you need only multiply this value by the height of 10" to get ***Total Shrink***.

10" × ¼" = **10/4 or 2½" of Total Shrink**

**Figure 7-22**




If the pipe is 60" long it will shorten, or ***Shrink***, 2½" to 57½"overall, after the two 30° bends are made. Likewise, a mark placed on the conduit will end up 2½" closer to the box once the pipe is bent.

By knowing how much the mark will move allows us to mark the conduit and predetermine the offset location.

By measuring the distance from the box to the front of the obstruction as shown in Figure 7-23, which is 40", and adding to this measurement the Shrink value for a 10" offset using 30° bends of 2½", we get a measurement of 42½". We can place a mark on the pipe 42½" from the end of the conduit, and this mark will end up at the front edge of the obstruction after the offset has been bent, as shown in Figures 7-23 and 7-24.

**Figure 7-23**

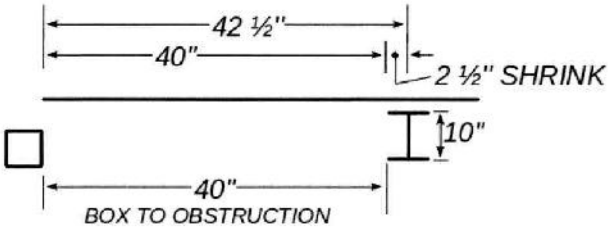



**Figure 7-24**

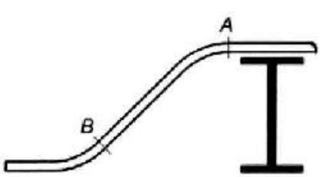

After the offset is bent, the pipe Shrink will move the mark 2½" toward the box and the mark ends up at the edge of the obstruction.

By using this mark (Distance + Shrink) as bend mark A we can pre-position the bend marks so the finished offset will fit perfectly from the box to the obstruction.

The actual bending will require that we ***turn our back*** on the end of the conduit we measured from. This will put the bend itself to the left of bend mark A and leave straight pipe to cross over the obstruction, as shown in Figure 7-25. Bend at bend mark A **first** and then bend at mark **B**.

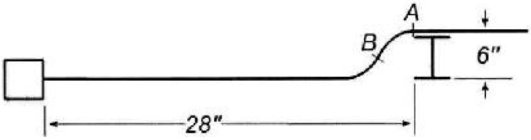
The bend marks are reversed on the pipe as a reminder that you must turn your back to the end you measured from, or, think of turning your back on bend mark B.

**Figure 7-25**



**EXAMPLE:** A 6" "I" beam is located 28" from a box. Using 30° bends, layout bend marks A and B, as shown in Figure 7-26.

**Figure 7-26**




Total shrink value is found by multiplying height of the offset (6") times the 30° Shrink value (¼" per inch of rise). Total Shrink equals
6" × ¼" = 6/4 or **1½" of Shrink**

Add the total Shrink of 1½" to the 28" distance from the box to the obstruction to locate Bend Mark A. 28" + 1½" = **29½"**

Measure 29½" from the end of the conduit and mark Bend Mark A as shown in Figure 7-27. Spacing between Bend Mark A and B is found by multiplying the 30° Offset Multiplier 2.0 times the 6" height of the obstruction.

2 × 6" = **12" Spacing between A and B,** as shown in Figure 7-27.

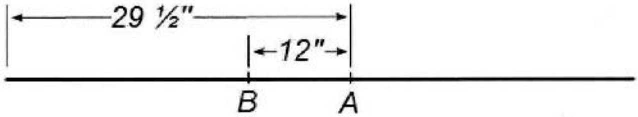
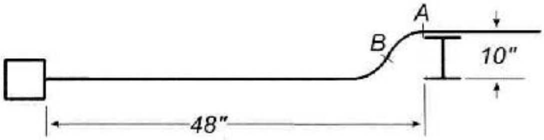



**Figure 7-27**

**EXAMPLE:** A conduit is to be bent as indicated in Figure 7-28, using 45° bends for the offset, layout Bend Marks A and B.

**Figure 7-28**



1. Determine total Shrink by multiplying the height of the obstruction (10") times the shrink value for 45° offsets (⅜" per inch of rise as shown in Table 7-21).

   10" × ⅜" = **30/8 or 3¾" of total Shrink**

2. Add the total Shrink to the distance from the box to the obstruction. 3¾" + 48" = **51¾"**

3. Measure 51¾" from the end of the conduit and mark bend mark A, as shown in Figure 7-29.

4. Multiply the height of the offset (10") times the 45° ***Offset Multiplier*** (1.414) to determine the spacing between bend marks A and B. 10" × 1.414 = **14.14"**. As this is the measurement that will determine the height of the obstruction, 14.14" will be rounded up to the next ⅛" for a measurement of 14 ¼".

5. Measure 14¼" from bend mark A and mark bend mark B, as shown in Figure 7-29. Remember to turn your back on the end of the conduit that the measurements were taken from when bending at bend mark A and B.

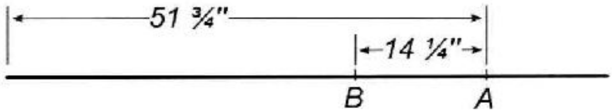
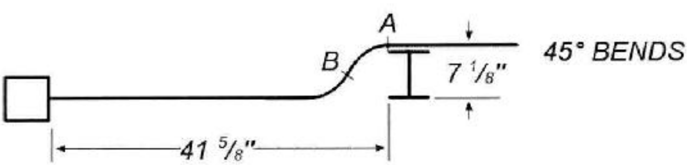


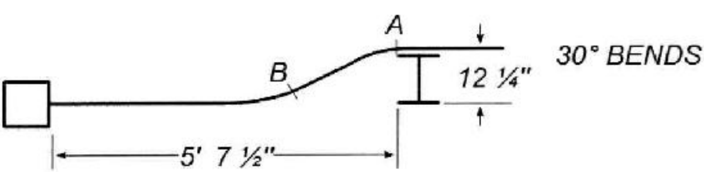

**Figure 7-29**

**PROBLEMS:** Layout pipe to bend as indicated using Method #2.

1.




2.



# PARALLEL OFFSETS 8

Figure 8-1 shows three pipes, each with a 10" offset. All three pipes were bent using the ***same layout***, and the offset were bent using 45° bends. When the pipes are mounted and spaced at 2" intervals, the spacing looks great, but the ends of the conduits end up staggered.

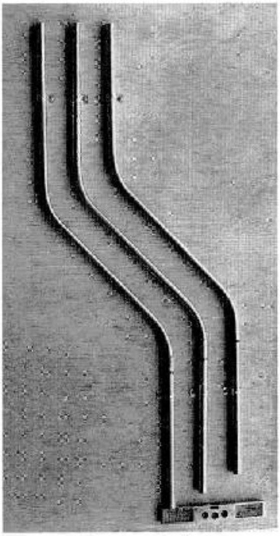


**Figure 8-1**

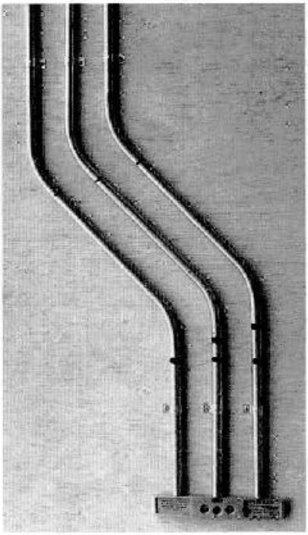


**Figure 8-2**

Figure 8-2 shows three other pipes, again with 10" offsets and 2" spacing, but the layout for the offsets on each pipe have been adjusted so the ends of pipes are now even.

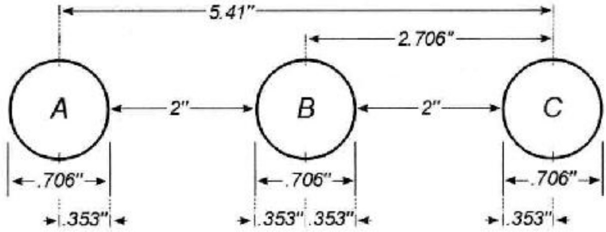
**NOTE:** In Figure 8-2 you can see a mark was placed on each pipe 12" from the end of the pipe. This mark is used to illustrate the adjustment that must be made to pipes 2 and 3 if the ends of the pipes are to be even, while maintaining 2" spacing.

The amount of adjustment needed to make the pipes even at the bottom is found by using the following ***Offset Adjustment*** formula.

Adjustment = Center to Center spacing × Tangent of ½ the offset angle

**EXAMPLE:** The pipes will be labeled A, B, and C from ***left*** to ***right***, as shown in Figure 8-3.

**Figure 8-3**




First, bend a 10" offset in Pipe A using 45° bends starting at bend mark A, which is 12" from the end of the pipe. Using 45° bends, the spacing between bend mark A and B 10" × 1.414 = 14.14 or ≈ 14¼". as shown in Figure 8-4.

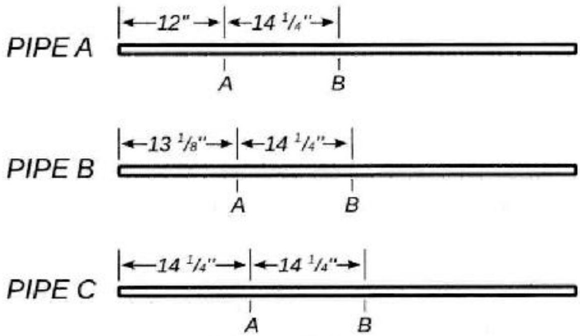



**Figure 8-4**

Using 2" spacing, calculate the ***Center to Center*** measurement between pipes A and B, as shown in Figure 8-3. The outside diameter of ½" EMT is .706", as shown in Figure 8-3, so the center to center measurement with 2" spacing will be 2.706" (.706" + 2.0" = 2.706").

1. The ***Offset Adjustment*** formula says to multiply the center to center measurement times the Tangent of ½ the offset angle. The offset is being bent using 45° bends, one half of the offset angle of 45° would be 22½°. The Tangent for 22½° is ≈ .4143. Multiplying 2.706" times .4143 equals 1.121" or ≈ 1⅛".

2. The value 1⅛" is the value that must be added to bend mark A of Pipe B, for the pipes A and B to be even. The distance from the end of the pipe to bend mark A on Pipe A was 12", so 12" + 1⅛" = 13⅛". This is the measurement from the end of the pipe to bend mark A of **Pipe B**, as shown in Figure 8-4.

3. To find the adjustment needed for Pipe C, we use the same formula as before, but the spacing used will be from Pipe A (the first pipe) to Pipe C. Referring to Figure 8-3, we see that the center to center spacing between Pipe A and Pipe C is 5.41". This distance (5.41") times the Tangent of 22½° (.4143) equals 2.241" or ≈ 2¼".

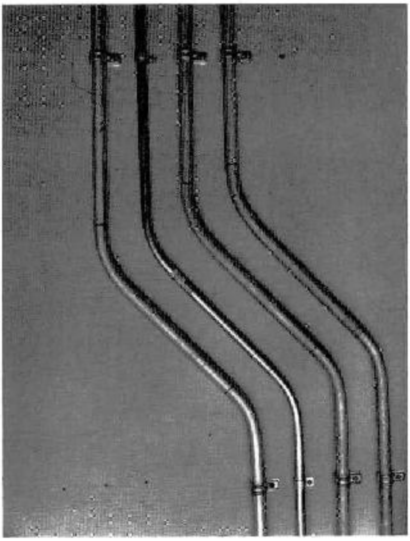
4. The value 2¼" is added to the 12" used for bend mark A of Pipe C to give us a measurement of 14¼" for bend mark A of **Pipe C**, as shown in Figure 8-4.

**NOTE:** The center to center spacing between pipes B and C could also have been used. Referring to Figure 8-3, we see the center-to-center spacing between pipe B and C would be .353"+ 2" + .353", which is equal to 2.706". This measurement times ½ the Tangent of 22½° would be 1⅛" (2.706" × .4143 is ≈ 1⅛"). The 1⅛" is the adjustment that would be added to the 13⅛" (1⅛" + 13⅛" = 14¼"). Measure 14¼" from the end of **Pipe C** to find bend mark A.

**CAUTION:** Making the adjustment as outlined to keep the ends of the pipe even will only work when the same size conduit is bent using the ***same*** bender ***or***, when ***different size pipes*** are bent using the ***same*** bender. ½" EMT can be bent on a ¾" EMT bender as an example. Likewise, ½" Rigid pipe can be bent on a ¾" Rigid bender.

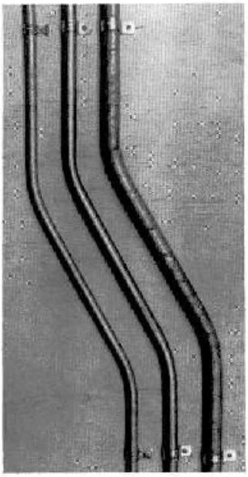
A ¾" EMT bender can be used to bend a mix of ½" and ¾" EMT to maintain the radius and spacing between the pipes, as shown in Figure 8-5.

**Figure 8-5**



The author has had little success trying to bend ½", ¾" and 1" EMT with a 1" EMT bender. However, Rigid pipe sizes ½", ¾", and 1" can be ***successfully*** bent using the 1" shoe on a ***"Chicago"*** style mechanical bender, as shown in Figure 8-6.

**Figure 8-6**



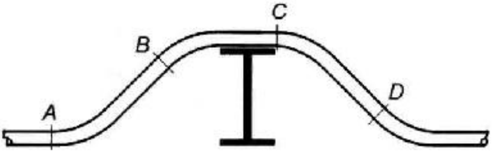
1¼", 1½", and 2" Rigid pipes can be bent on a hydraulic bender using the 2" shoe and pivot supports.

Use the Rigid Conduit Spacing Chart at the end of the book to determine center-to-center bend measurements for different size conduits.

# FOUR-BEND SADDLES 9

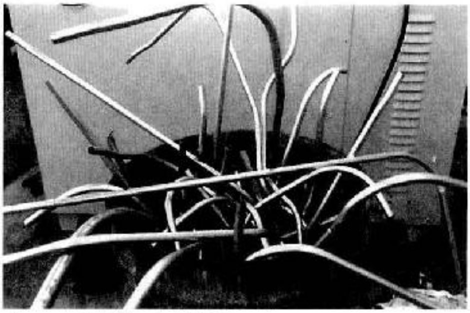
A four-bend saddle is used to change elevation to clear an obstruction, just like an offset, but then to return to the original elevation, as shown in Figure 9-1. A saddle as you can see is really just two offsets bent close together.

**Figure 9-1**




As with offset bending, extreme care must be taken to properly align the pipe in the bender when bending a saddle. With a saddle requiring four bends, you double your chance of getting a ***dog-leg***, or a ***WOW***, which will require you to make adjustments to the pipe for it to be useable. If the misalignment is so bad it cannot be corrected the pipe will end up in the ***Oh-Oh*** pile as shown in Figure 9-2. The old saying is ***"if you can screw up an offset, you can really screw up a four-bend saddle"***.

**Figure 9-2**



To bend a saddle, as shown in Figure 9-1:

1. Measure the ***height*** and ***width*** of the obstruction.

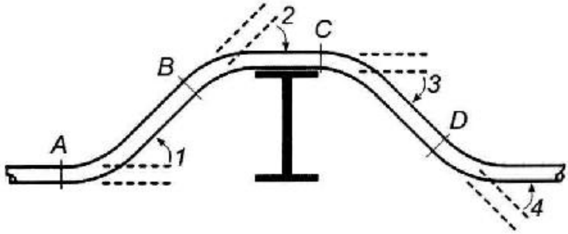
2. Determine the spacing between bend marks A and B for the first offset (height of obstruction × Offset Multiplier). As all four bends of a saddle are bent at the same degree, the spacing from C to D will be the same as A to B.

3. Bend the first offset, bends A and B

4. After the first two bends have been made, starting at a point where the conduit is straight after bend B, measure over the width of the obstruction and mark bend C. The spacing between bend marks C and D will be the same spacing as between bend marks A and B.

5. Figure 9-3 shows the bending sequence marked 1 through 4.

**Figure 9-3**

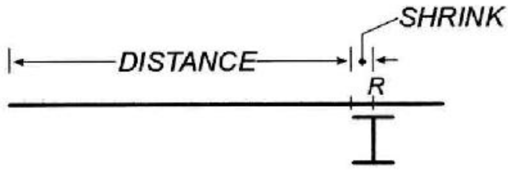



## Predetermining Saddle Location

Many electricians will bend a saddle and then cut the pipe at one end or the other to make it fit, rather than learning how to predetermine the saddle location. This may be O.K. if you don't mind wasting material, or if you only bend EMT. When you're working with Rigid pipe, however, the time it takes to cut and thread the pipe by hand after the bends have been made, makes no sense whatever. A better way is to predetermine the saddle location, much like we did with offset in Chapter 7. The procedure for predetermining saddle location requires no new knowledge, but will require marking the conduit with a ***Reference mark***, or ***R***.

The Reference mark, R will indicate the location of the edge of the obstruction after the first two bends (first offset) of the saddle have been made. R then is the distance from the box to the obstruction—plus ***Shrink*** for one offset, as shown in Figure 9-4.

**Figure 9-4**

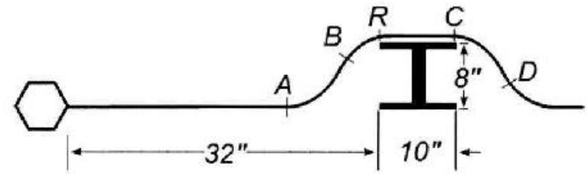



R will move to the left and be at the edge of the obstruction after the first offset of the saddle is bent. With R locating the edge of the obstruction, it can be used as a valid reference point for laying out the second offset (bend C and D) of the saddle. Predetermining offset location using Method #1 or #2 from Chapter 7 can now be used to locate the ***first*** offset of the saddle.

## Method #1 for Predetermining Saddles

**Example:** A beam 8" high and 10" wide is located 32" from the box, as shown in Figure 9-5. The saddle will be bent using ½" EMT and 45° bends.

**Figure 9-5**




To locate the bend marks for the saddle:

1. Find the location for bend mark A by adding the height of the obstruction (8") to the 45° ***Offset Constant*** for ½" EMT (5") and subtract this value (13") from the distance from the obstruction to the box (32") for a value of 19". Measure 19" from the end of the conduit and mark bend mark A, as shown in Figure 9-6.

**NOTE:** Make all marks, A, B, R, C, and D go completely around the conduit so they will be visible when the conduit is rotated.

2. Determine the spacing between bend marks A and B, which will also be the spacing between bend marks C and D. Multiply the height of the obstruction (8") time the 45° ***Offset Multiplier*** (1.414) for spacing of 11.312", or ≈11⅜" after we ***round up*** to the next closest ⅛", as shown in Figure 9-6.

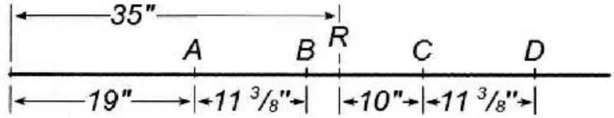



**Figure 9-6**

3. To locate R, we need to know the shrink for an 8" offset. The shrink for a 45° offset is ⅜" per inch of rise. Multiply

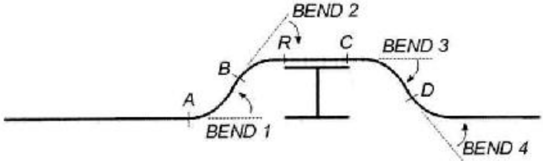
8" times ⅜" = 24/8, or 3" of shrink. Add the shrink (3") to the distance from the box to the obstruction (32") for a total of 35". Measure 35" from the end of the pipe and mark R, as shown in Figure 9-6

4. As R locates the edge of the obstruction, all that is needed to find bend mark C is to measure over from R, the width of the obstruction (10") and mark C, as shown in Figure 9-6. Remember that R will be at the edge of the obstruction after the first offset has been bent.

5. Measure 11⅜"from bend mark C and mark D, as shown in Figure 9-6. The spacing between C and D is the same as A and B.

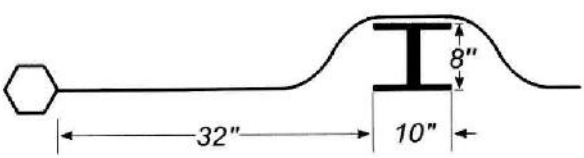
The conduit bending sequence will be A, B, C and D, as shown in Figure 9-7. All bends will be made facing the end of the pipe that the measurements were taken from.

**Figure 9-7**




## Method #2 for Predetermining Saddles

Method #2 will use shrink to locate Bend Mark A. Bend Mark A will be like R in Method #1. This method will require that the bends be done in a ***different sequence*** than Method #1. The pipe layout will be the same as in Figure 9-5. The height of the obstruction in 8", the obstruction is 10" wide and it is 32" from the box to the edge of the obstruction.




1. Find Shrink. Shrink = Height (8") × Shrink value for 45° (⅜"). 8" × ⅜" = 24/8, or 3" of shrink.

2. Locate bend mark A, which is also a reference to the front edge of the obstruction. Distance (32") plus shrink (3") or 32" + 3" = 35". Measure 35" from end of pipe to bend mark A, as shown in Figure 9-8.

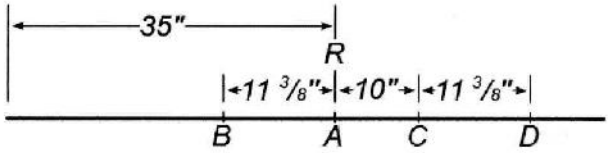



**Figure 9-8**

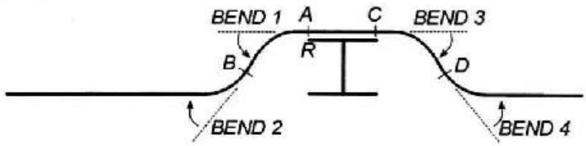
3. Determine spacing between bend mark A and B (same as C and D). Height (8") times the Offset Multiplier for 45° (1.414). 8" × 1.414 = 11.312", rounded to 11⅜". Measure 11⅜" from A and mark B, as shown in Figure 9-8.

4. Locate Bend Mark C. From Bend mark A, measure over the width of the obstruction (10") and mark C, as shown in Figure 9-8. Remember that A is the same as R, and is a reference to the front of the obstruction.

5. From bend mark C, measure 11⅜" to locate bend mark D, as shown in Figure 9-8. Spacing is the same as A to B.

The bending sequence required for bending a four-bend saddle using Method #2 is important if the saddle is going to fit properly. With your back to the end of the pipe that the measurements were taken from, place the arrow of the bender on bend mark *A* and bend a 45°, as shown in Figure 9-9.

**Figure 9-9**



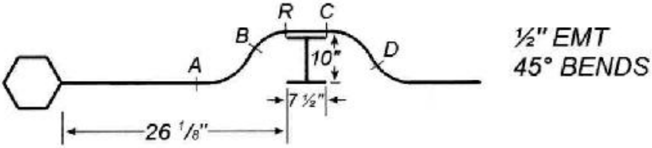

**NOTE:** Bend mark A **must be the first bend** made for Method #2 to work.

With your back still to the end of the pipe you measured from rotate the pipe 180°, place the arrow of the bender on bend mark ***B*** and bend a 45° bend. Remove the bender from the pipe. Now face the end of the pipe you measured from, and place the bender on the pipe. Place the arrow of the bender on bend mark ***C*** and bend 45°, roll the pipe 180° and bend another 45° bend at bend mark ***D***, as shown in Figure 9-9.

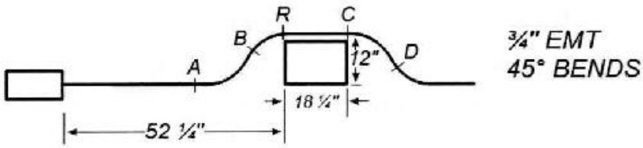
**PROBLEMS:**

Method #1

1.

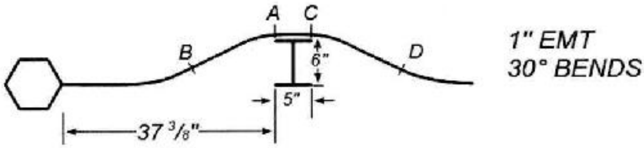



2.

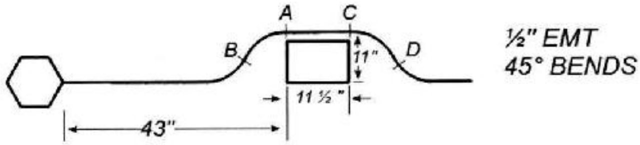



Method #2

1.



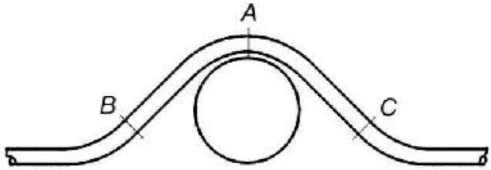

2.



# THREE-BEND SADDLES 10

As the name implies, this saddle requires only ***three*** bends. This type of saddle is used primarily to go over pipes, duct work, or other round obstructions, as shown in Figure 10-1.

**Figure 10-1**

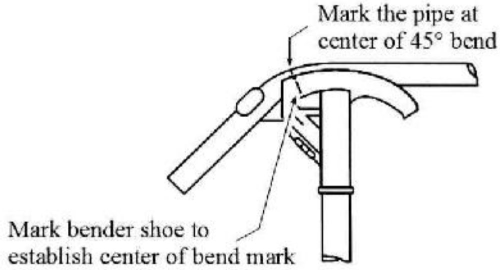



While a ***three-bend saddle*** can be bent using various angles of bends, the most common three-bend saddle is made using one 45° bend (A) and two 22½° bends (B and C). Notice in Figure 10-1 that bend mark **A**, the 45° bend, is centered on the obstruction, and that bend mark A also indicates the center of the 45° bend.

Most benders have a spot marked on the bending shoe that is used to indicate the ***center-of-bend***. If your bender does not have a dedicated mark, proceed as follows:

1. Mark a scrap piece of pipe, place the arrow on the mark and bend a 45° bend.
2. Take the pipe out of the bender and mark the center of the bend.
3. Put the pipe back in the bender and line the arrow up with the original bend mark. Make a mark on the bender shoe that corresponds to the mark at the center of the bend, as shown in Figure 10-2. This is the mark that will be used for bending the 45° bend of the three-bend saddle—**not** the arrow.

**FIGURE 10-2**




**TIP:** Once you have bent a few 45° bends and double checked the

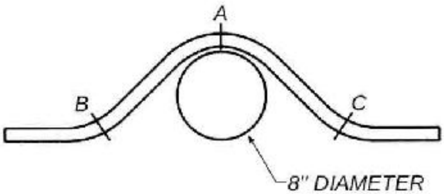
***center-of-bend*** mark, use a hacksaw and make a small cut on the bender shoe. This will give you a permanent reference, even if your original mark is rubbed off.

Bend marks B and C of the three-bend saddle are 22½° bends, and are located equal distance from bend mark A. Bends B and C will be bent using the ***arrow*** on the bender—***NOT*** the mark we just put on the bender to indicate ***center-of-bend***.

To determine the spacing from A to B, and A to C, we simply multiply the height of the obstruction times 2.5. The multiplier of 2.5 is used for all pipe sizes when bending 45° and 22½° bends.

**EXAMPLE:** Layout a three-bend saddle using ½" EMT to clear a pipe with an 8" outside diameter using a 45° and two 22½° as shown in Figure 10-3.

**Figure 10-3**




1. Determine the spacing from mark A to B and A to C.
   Spacing = 2.5 × Height (8")    2.5 × 8" = 20"
   Spacing from A to B, and A to C, will be 20"

2. Bend mark A is placed at the approximate center of the conduit. Mark B and C are marked 20" either side of bend mark A, as shown in Figure 10-4.

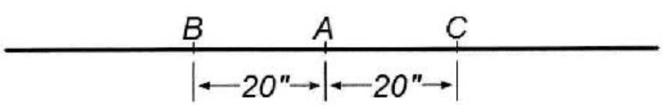
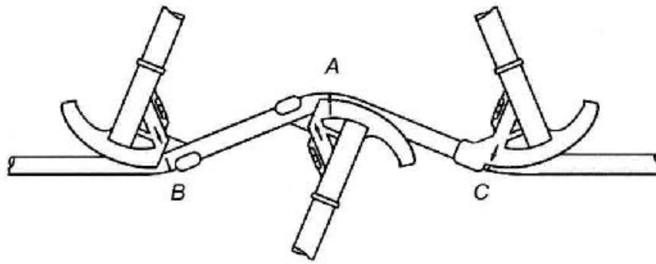



**Figure 10-4**

3. Bend the 45° bend at bend mark A first using the center of bend mark, as shown in Figure 10-5, ***NOT*** the arrow.

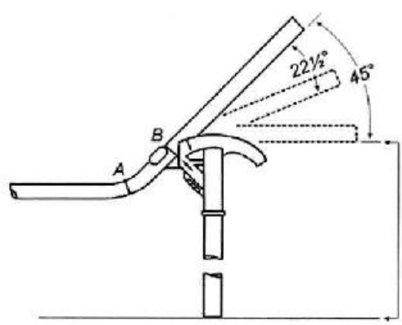
**Figure 10-5**




4. The bender is removed from the pipe and repositioned so that ***both*** bends B and C are made ***facing*** bend A, as shown in Figure 10-5. Bends B and C are bent to 22½° using the ***arrow*** on the bender.
5. Cut the end of the pipe as may be required for the offset to fit correctly at the obstruction.

**TIP:** If the EMT bender you are using is the type that the bender handle is perpendicular (vertical) to the work surface when a 45° bend has been achieved, then for the two 22½° bends, invert the bender, placing the handle vertical with to the floor (work surface), as shown in Figure 10-6.

**Figure 10-6**




If the pipe were now to be bent to 45°, the pipe would end up being horizontal to the work surface, as shown in Figure 10-6. It follows then, that if we bend half way we should have approximately a 22½° bend. Bend a few trial bends measuring your results with a protractor level. It won't take long before you can produce good results using this method.

For the three-bend saddle to look right when it crosses over (traverses) a round obstruction, the radius of the 45° bend must be large enough to fit over the obstruction, without touching the obstruction. The maximum diameter of a pipe, or round obstruction, that can be crossed will be limited to the radius of the bender shoe for any given pipe size. The larger the conduit, the larger the radius of the bending shoe, therefore, the larger the diameter of the obstruction can be. Table 10-7 gives the ***approximate*** maximum diameter of the obstruction for ½", ¾", and 1" EMT being bent with a hand bender. The maximum obstruction diameter for larger EMT pipe sizes bent using electric or mechanical benders can be determined by bending scrap pipe.

**TABLE 10-7**

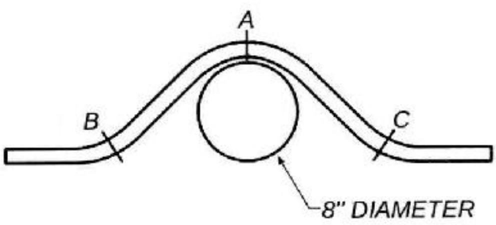
| EMT PIPE SIZE | MAXIMUM OBSTRUCTION DIAMETER |
|---|---|
| ½" | 8½" |
| ¾" | 10 ½" |
| 1" | 12½" |

If it is more desirable to bend all three bends facing the same direction, it can be done by using a multiplier of 3 (instead of 2.5) and bending **all the bends** A, B, and C using the mark on the bender that represents the center of the bend.

**NOTE:** This method can be used for hand benders and is the recommended method for "Chicago" style benders.

**EXAMPLE:** Layout a ***three-bend saddle*** to clear an 8" pipe, as shown in Figure 10-8.

**Figure 10-8**

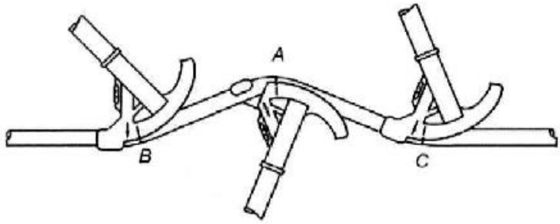



1. Determine the spacing from bend A to B and A to C.
   Spacing = 3 × Height (8")   Spacing = 24"

2. Bend mark A is placed at the approximate center of the conduit.

3. Locate marks B and C at 24" either side of bend mark A.
4. Bend all bend using the ***center-of-bend*** indicating mark, ***NOT*** the arrow. Bend all three-bends facing the same end of the pipe, as shown in Figure 10-9

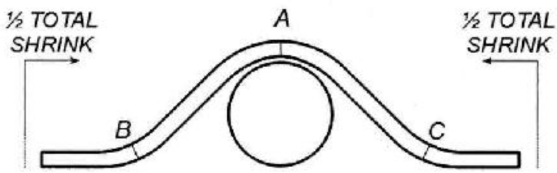
**Figure 10-9**




## Predetermining Three-Bend Saddle Location Using Shrink

To save cutting pipe to make the three-bend saddle fit, the center of the saddle (center of obstruction) can be predetermined by adding ***shrink*** to the distance required. The three-bend saddle requires one 45° bend and two 22½° bends. As the two 22½° bends total 45°, the three-bends 22½°, 45° and 22½° are the equivalent of two 45° offset bends, so the 45° offset shrink of ⅜" per inch of rise can be used (see Table 7-21). The total shrink for an 8" saddle will be: 8" × ⅜" = 24/8 or 3". The way the bends are made, both ends of the conduit will shrink in relation to bend mark A, a total of 3". Each end of the pipe then will shrink ½ of 3", or 1½", as shown in Figure 10-10.

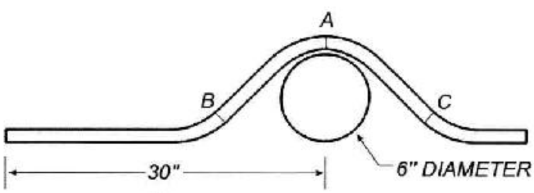
**Figure 10-10**




As we are only concerned with locating the center of the bend from one end of the conduit, ½ of the ***total shrink*** will be used for pre-positioning the saddle location.

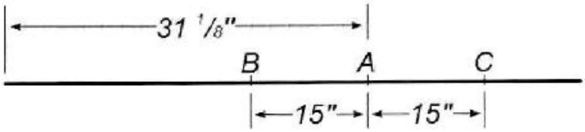
**EXAMPLE:** Layout the bend marks for a three-bend saddle to clear a 6" pipe. The box is located 30" from the center of the pipe, as shown in Figure 10-11. A multiplier of 2.5 and 3 will be explained.

**Figure 10-11**



1. Find the total shrink of the pipe.
   6" × 3/8" = 18/8 or 2¼" Total Shrink
2. Locate bend mark A.
   Distance from box to center of pipe (30") plus ½ shrink. One half of 2¼" is 1⅛". 30" + 1⅛" = 31⅛". Measure 31⅛" from end of pipe and mark bend mark A as shown in Figure 10-12.
3. Determine spacing from A to B and A to C. Using 2.5 as a multiplier: 2.5 × 6" = 15" Spacing = 15"
4. Locate bend marks B and C 15" either side of bend mark A, as shown in Figure 10-12.

**Figure 10-12**




5. Bend a 45° bend at mark A using the center of bend mark on the bender. Bend 22½° bends at bend marks B and C using the arrow as a reference as, shown in Figure 10-5, and facing bend mark A.

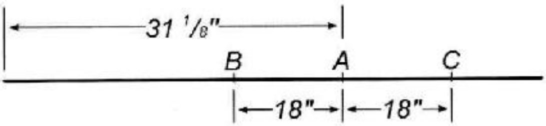
If it is more desirable to bend all three-bends facing the same direction, it can be done using a multiplier of 3 and by bending ***all*** bends (A, B, and C) using the mark on the bender that represents the ***center-of-bend***.

**NOTE:** This method can be used for hand benders and is the recommend method to use for "***Chicago***" type benders and hydraulic benders.

To find the spacing using a multiplier of 3 for the previous Example:

1. Spacing = 3 × Height (6") Spacing = 18"
2. Locate marks B and C 18" either side of bend mark A, as shown in Figure 10-12

**Figure 10-12**

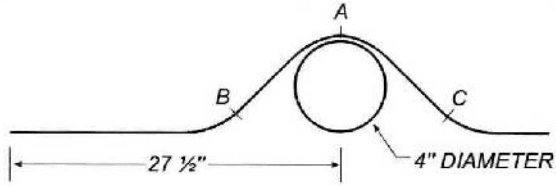


3. Using the ***center-of-bend mark*** on the bender, bend at bend mark B (22½°), then bend mark A (45°), and then at bend mark C (22½°). All three-bends are made facing the same direction (facing the end the measurements were taken from), as shown in Figure 10-9.

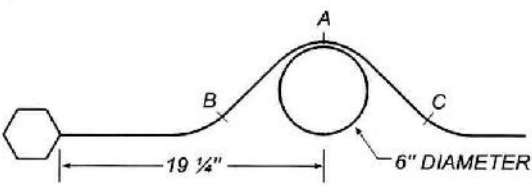
**PROBLEMS:**

Preposition the saddles shown in 1 and 2, using a multiplier of 2.5, to locate bend marks A, B and C.

1.

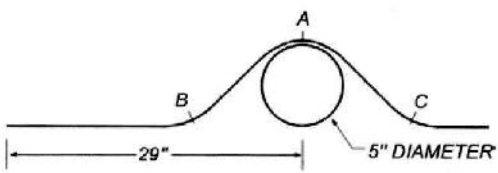



2.

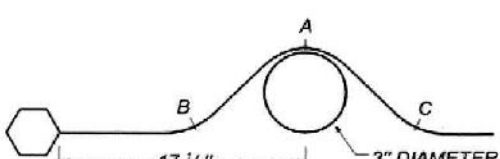



Preposition the saddles shown in 3 and 4, using a multiplier of 3, to locate bend marks A, B and C.

3.




4.



# BENDING AROUND A CORNER WITH AN OBSTRUCITION 11

Although this is not a common bending job, it is one that can become very frustrating if the proper method is not known.

The examples that follow are the most common types of obstructions that are encountered. In each case, to go around the corner and the obstruction, the pipe is bent using two 45° bends. For each type of obstruction illustrated, a formula is given to determine the spacing between Bend marks A and B.

## Round Obstruction

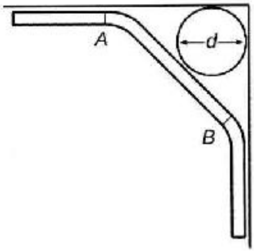
Figure 11-1 shows a ***Round Obstruction*** in a corner and gives the formula: Spacing = d × 2.4

***d*** is the diameter of the obstruction.

***2.4*** is a constant that is used regardless of pipe size when bending 45° bends.

***Spacing*** is the spacing between the two 45° bends.

**Figure 11-1**

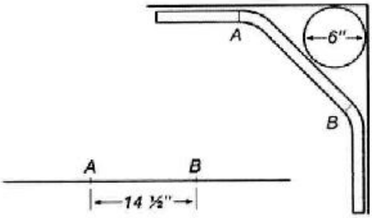



If the pipe in Figure 11-1 is 6" in diameter, the spacing between the bend marks is found as follows:

Substitute values into the formula and solve:

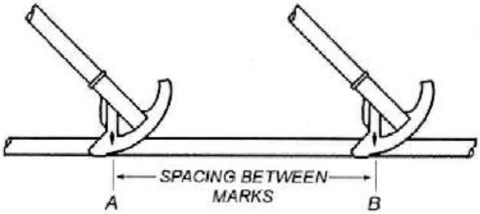
Spacing = d × 2.4
Spacing = 6 × 2.4
Spacing = 14.4 or ≈ 14 ½" (rounded up to the next ⅛", as shown in Figure 11-2.

**Figure 11-2**



The arrow of the bender is placed on the bend marks as indicated in Figure 11-3. A 45° bend is made at Bend mark A and Bend mark B with the bender facing the same direction.

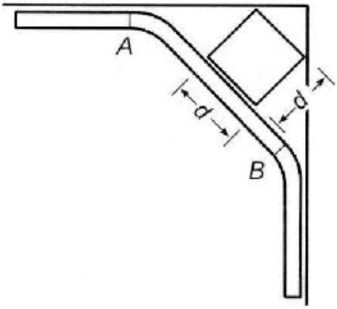
Figure 11-3




## Square Obstruction

The next example is a ***square obstruction***, as shown in Figure 11-4. The formula for this type of obstruction is: Spacing = d × 3 when bending 45° bends.

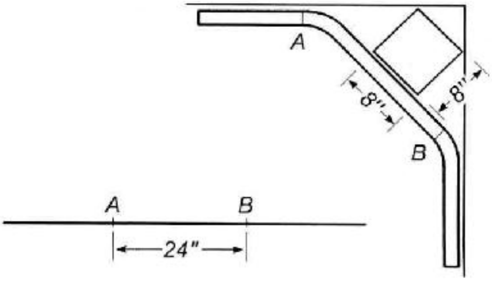
Figure 11-4




If the dimension of the square obstruction was 8" × 8" the spacing between Bend marks A and B can be found as follows:
Substitute value in the formula and solve.

Spacing = d × 3
Spacing = 8 × 3
Spacing = 24", as shown in Figure 11-5

Figure 11-5

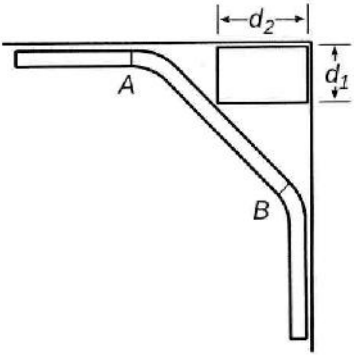


## Rectangular Obstruction

In the next example the obstruction in the corner is ***rectangular***, as shown in Figure 11-6. The formula to find the spacing between Bend mark A and B when bending 45° bends is:

$$\text{Spacing} = (d_1 + d_2) \times 1.414$$

**Figure 11-6**

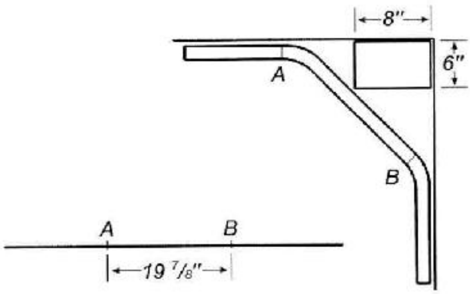



The rectangle in the corner measures 6" × 8". To determine the spacing between A and B, substitute values into the formula and solve:

$$\text{Spacing} = (d_1 + d_2) \times 1.414$$
$$\text{Spacing} = (6" + 8") \times 1.414$$
$$\text{Spacing} = 14" \times 1.414$$

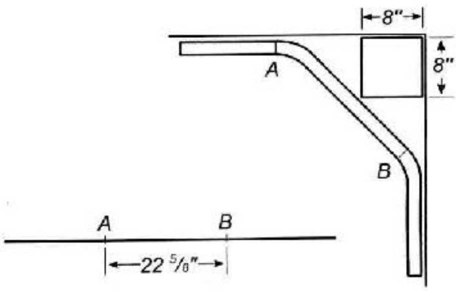
Spacing = 19.796 or ≈ 19⅞" as shown in Figure 11-7.

**Figure 11-7**




If the obstruction is square as shown in Figure 11-8 the rectangular obstruction formula can be used.

**Figure 11-8**



The square shown in the corner measures 8" × 8". To determine the spacing between A and B, substitute values into the formula and solve:

Spacing = $(d_1 + d_2) \times 1.414$
Spacing = (8" + 8") × 1.414
Spacing = 16" × 1.414
Spacing = 22.624 or ≈ 22⅝" as shown in Figure 11-8.

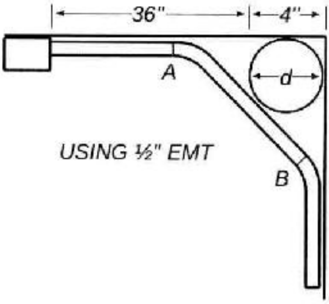
**NOTE:** All of the formulas discussed and the layouts may be used with "Chicago" style benders.

## Predetermining Bend Marks

### Round Obstructions

To find Bend mark A for the round obstruction shown in Figure 11-9, the formula is: ***Bend mark A*** = Distance − (d × .68 + ½ the Offset Constant for 45°)

**Figure 11-9**




***Distance*** is the distance from the box or conduit fitting to the obstruction. In Figure 11-6 the distance is shown as 36".

***d*** is the diameter of the obstruction and is 4" as shown in Figure 11-8
***.68*** is a constant use for all pipe sizes.

***½ the Offset Constant*** is one half the value found in Table 7-12 if the pipe is ½", ¾", or 1" EMT. If you are using rigid conduit or EMT larger than 1" use half the value you have determined to be the Offset Constant for the type and size of pipe you are using. Figure 11-8 indicates that the pipe size is ½" EMT, the Offset Constant for ½" EMT would be 5". One half of 5" is 2½".

**Substitute values and solve:**

Bend mark A = 36" − (4" × .68 + 2½")

Bend mark A = 36" − (5.22)

Bend mark A = 30.78 or ≈ **30⅞"** if rounded to the next ⅛", as shown in Figure 11-10

Spacing from A to Bend mark B is found by using the formula:

Spacing = d × 2.4

Spacing = 4" × 2.4 = 9.6 or ≈ **9⅝"** spacing between A and B, as shown in Figure 11-10

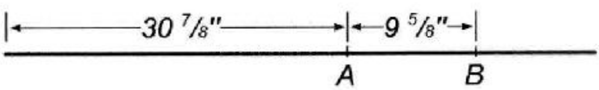



**Figure 11-10**

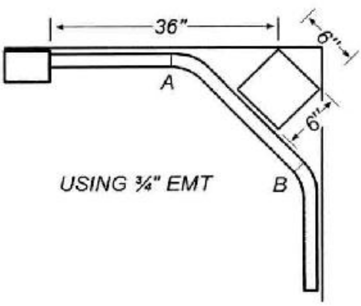
## Predetermining Bend Marks

### Square Obstruction

To find Bend mark A for the square obstruction shown in Figure 11-11 the formula is:

Bend mark A = Distance − (d × 1.4 + ½ the Offset Constant for 45°)

**Figure 11-11**




This pipe job is using **¾" EMT** with an Offset Constant of 6¼". One half of the Offset Constant would be 3⅛".

**Substitute values and solve:**

Bend mark A = 36" − (6" × 1.4 + 3⅛")

Bend mark A = 36" − 11.525

Bend mark A = 24.475 or ≈ **24½"** as shown in Figure 11-12

Spacing from A to Bend mark B is found by using the formula:

Spacing = d × 3

Spacing = 6" × 3 = 18"

The spacing between A and B is 18". Figure 11-12

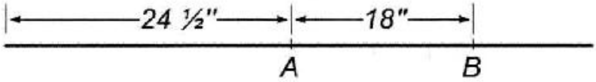



**Figure 11-12**

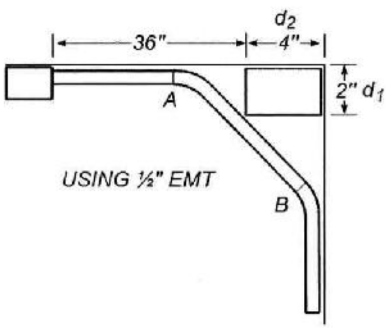
## Predetermining Bend Marks

### Rectangular Obstruction

To find Bend mark A for the rectangular obstruction shown in Figure 11-13, the formula is:

Bend mark A = Distance − ($d_1$ + ½ the Offset Constant for 45°)

**Figure 11-13**




This pipe job is using ½" EMT, so the Offset Constant is 5", ½ the Offset Constant would be 2½".

**Substitute values and solve:**

Bend mark A = 36" − (2" + 2½")

Bend mark A = 36" − (4½")

Bend mark A = 31½" as shown in Figure 11-13

Spacing from Bend mark A to Bend mark B is found by using the formula:

Spacing = ($d_1$ + $d_2$) × 1.414

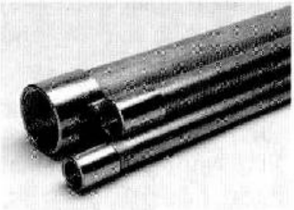
Spacing = (2" + 4") × 1.414

Spacing = 6" × 1.414

Spacing = 8.484 or ≈ **8½"** as shown in Figure 11-14.

**Figure 11-14**

# RIGID METAL CONDUIT (RMC) 12



Rigid Metal Conduit (RMC) includes pipe made of ***ferrous*** (steel) and ***non-ferrous*** (aluminum, copper, bronze, etc.) materials.

Article 344 of the National Electrical Code® covers the use and installation of Rigid Metal Conduit (RMC). This Article defines Rigid Metal Conduit as: "A threadable raceway of circular cross section designed for the physical protection and routing of conductors and cables and for use as an equipment grounding conductor when installed with its integral or associated couplings and/or appropriate fittings."

Standard Rigid Metal Conduit sizes are ½", ¾", 1", 1¼", 1½", 2", 2½", 3", 3½", 4", 4½", 5", and 6". These sizes are called ***trade sizes***. Trade sizes give the dimension for the minimum inside diameter of the pipe, rather than the overall, or outside dimension of the pipe, a full listing of pipe diameter inside and outside are listed at the back of the book. The metric designator for these sizes range from 16 mm to 155mm.

Rigid metal conduit is manufactured in standard lengths and is threaded on each end. The standard thread, called the National Pipe Thread (NPT) is a U.S. standard for tapered threads used on threaded pipes. The taper rate for all NPT threads is $\frac{1}{16}$. or ¾ inch per foot measured by the change of diameter of the pipe thread over distance.

The threaded couplings that are used to connect, or join, two pieces of rigid metal conduit together have no taper, or have straight threads (NPS). By not having a taper, more threads can be engaged, making for a better electrical connection which enables the conduit to be used as an equipment grounding conductor.

Color-coded end caps, or thread protectors, are used on the end of the threaded pipe to protect the threads from damage and to keep the threads clean. Pipe sizes that are in inch sizes: 1, 2, 3, 4, 5, and 6" are protected with caps that are color coded ***Blue***. Trades sizes ½, 1½, 2½, and 3½" are protected using ***Black*** caps, while sizes ¾" and 1¼" have ***Red*** colored thread protectors.

The standard length of rigid metal conduit is be 10', which includes a required coupling on one end of the conduit. It is worth repeating that the actual length of the conduit itself will be less than 10' in length, and only when the length of the coupling is added will the length be 10'.

As with EMT, the bending qualities of ***Rigid*** will be affected by the ductility, uniformity and surface treatment of the conduit and these qualities will vary with each manufacturer.

The minimum bend radius for any field bend is found in Table 2, Chapter 9 of the NEC® as shown in Table 12-1.

**Table 12-1**

| Table 2 (Chapter 9) Radius of Conduit and Tubing | | |
|---|---|---|
| Conduit Size<br>Trade Size | One Shot and Full Shoe Benders<br>Bending Radius<br>(in Inches) | Other Bends<br>Bending Radius<br>(in inches) |
| ½ | 4 | 4 |
| ¾ | 4½ | 5 |
| 1 | 5¾ | 6 |
| 1¼ | 7¼ | 8 |
| 1½ | 8¼ | 10 |
| 2 | 9½ | 12 |
| 2½ | 10½ | 15 |
| 3 | 13 | 18 |
| 3½ | 15 | 21 |
| 4 | 16 | 24 |
| 5 | 24 | 30 |
| 6 | 30 | 36 |

A field bend, is any bend made by an electrician as needed for installation of the conduit. The NEC® limits the number of bends that may be made between pull or junction boxes to not more than the equivalent of four quarter bends, or ***360 degrees of total bend***. Box offsets, if used, must be counted toward the 360 degree limit.

## TYPES OF RIGID METAL CONDUIT BENDERS

Rigid pipe may be bent using several different types of benders; Hickey Benders, Mechanical Benders, Electrical Benders, and Hydraulic Benders.

### Manually Bending Rigid Pipe Using a Hickey Bender

For hand bending, a ***Hickey*** style bender is used. Figure 12-2 shows a hickey bender that is used when precision bending is not required. The hickey is normally only used when the conduit is to be embedded in concrete or buried for underground work. Effective bending with a hickey is limited to pipe sizes ½", ¾", and 1". Conduit larger than 1" would require more strength than most electricians possess.

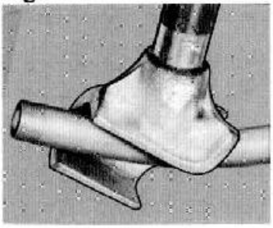


**Figure 12-2**
Courtesy Greenlee Tool Company

As with hand EMT benders, constant pressure must be applied with the foot to prevent irregular bends. As there is no foot piece on a hickey, the pressure must be applied to the pipe, just behind the bender, as shown in Figure 12-3 and 12-4.

**Figure 12-3**

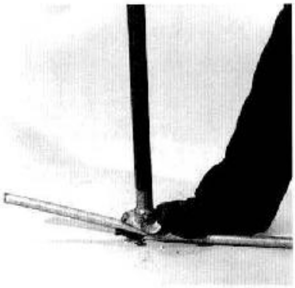


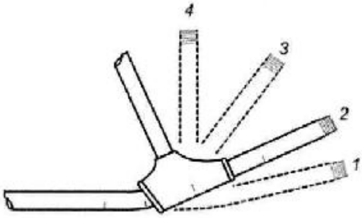
**Figure 12-4**

Accurate bending with a hickey is difficult without many hours of experience, but acceptable bends can be made by the beginner.

The correct method for bending a 90° stub with a hickey is to make several smaller degree bends. Place the hickey bender on the pipe where the 90° bend is to start. Pull a small degree bend, slide the bender down on the pipe and bend again. Continue to bend small bends (called bites) while moving the bender after each bend until the full 90° bend has been achieved.

After the third or fourth bend has been made, check the stub length, as shown in Figure 12-5.

**Figure 12-5**




If the stub length is going to come up short, move the bender further down the pipe than you did for the first three or four bends (take a bigger bite) and bend more degrees to make the stub come out to the right height. If the stub is coming up long, reverse the hickey head on the pipe and push some of the bend out. Return the hickey head to the normal position and take shorter "bites", with more bend per bite, to finish the bend. While it is possible to bend a 90° bend with one pull on the bender handle, the resultant bend would have a radius that is usually too small (too tight) and would make wire pulling difficult, if not impossible (see Table 12-1).

Rough take-up values for bending 90° stubs are shown in Table 12-6.

| Pipe Size | Take-up |
|---|---|
| ½" | 5" |
| ¾" | 7" |
| 1" | 9" |

**Table 12-6**

Take-up will vary with hickey type and the material that the conduit is made of. Use these take-up figures and layout the pipe as described for 90° stubs in Chapter 3 for a starting point.

**Mechanical Benders**

"Chicago" style mechanical benders like the one shown in Figure 12-7 can be used to bend rigid metal conduit (steel and aluminum) up to 2" trade size. This style bender can also be use for bending EMT up to 2". This style of bender can produce very accurate bends with little physical exertion on the part of the electrician. Bending techniques for Chicago style benders are covered in Chapter 13.

**Figure 12-7**

Mechanical Sidewinder® Bender
Courtesy Gardner Bender

**Electrical Benders**

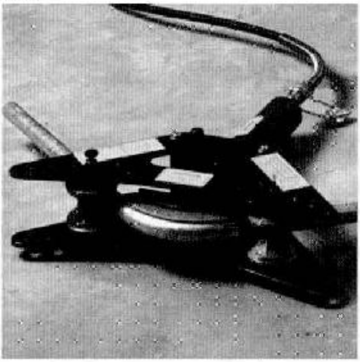
Figure 12-8 shows one style of electrical bender that is capable of bending rigid conduit, EMT and IMC in sizes ½" through 2". No need to change shoes, as the shoes are all included in one casting. Though the shoe design is convenient, what makes the Cyclone® bender unique is the solid state circuitry that allows you to "dial in" the desired angle of bend from 1° to 105°. The Cyclone® even compensates for "spring back" and requires no physical effort to bend the conduit.

**Figure 12-8**
Courtesy Gardner Bender

**Hydraulic Benders**

Figure 12-9 shows a Greenlee GL-880 hydraulic bender that can bend up to 2" rigid conduit.

**Figure 12-9**



Greenlee® GL-880 Hydraulic Bender
Courtesy Greenlee®

Hydraulic benders are available that will bend up to 6" rigid metal conduit. Hydraulic bending techniques are covered in Chapter 14.

# BENDING WITH A MECHANICAL STYLE BENDER 13

The mechanical ratchet style bender, as shown in Figure 13-1 is a great bender for various sizes of EMT, Rigid, IMC, and Aluminum conduit. This style of bender is frequently referred to as a "Chicago" bender. One of the first manufacturers of this style bender was the Lindseen Company from NC. They called their bender a "Chicago Bender" and the name became synonymous for any mechanical bender of this style.

**Figure 13-1**
Courtesy Enerpac

While one person can successfully bend conduit using this style of bender, it is easier if two electricians work together. While one is watching for alignment and leveling, the other operates the ratchet handle for bending.

With careful layout and by following the proper procedures, bending conduit with this type of bender becomes an art form. While not all electricians are capable, nor aspire to this degree of proficiency, for those that do, this is the style bender that makes it possible.

The ratchet mechanism that engages the notches on the bending shoe that causes the shoe to rotate is called the ***pawl*** as shown in Figure 13-2. There will be a release mechanism on the bender frame that will disengage the pawl from the shoe, so the shoe can be rotated to remove the conduit after the bend has been made, or to move the pipe forward.

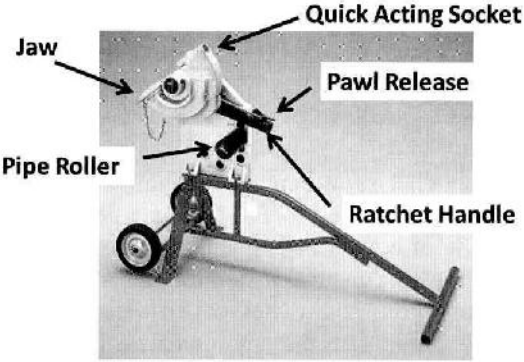



**Figure 13-2**
Gardner Sidewinder® Bender
(Courtesy Gardner Bender)

The jaw, or front of the bending shoe will be used as a reference for bending, the ***same*** as the arrow on a hand EMT bender.

All benders of this type will have a degree scale, or degree indicator that is part of the bender to indicate the degree of bend that has been made. The accuracy of these degree indicators are questionable, especially on older or well used benders. The scale can be used effectively, however, if some scrap pieces of pipe are bent using a level and then making notations or corrective marks (in pencil) on the scale to indicate when a 45° and 90° bend have been achieved. The take-up as measured from the front of bending shoe can also be found while checking the accuracy of the bending indicator scale. Write the take-up on the shoe in pencil. ***DO NOT*** rely on someone else's notations about scale accuracy or take-up. You are responsible for the conduit you bend, so establish your own figures.

For accuracy of bends and ease of bending, level the bender frame. If the work surface is rough and uneven, use a piece of plywood to give yourself a good solid, level work surface. By having the bender frame level, precision offsets, 90° stubs and multiple bend pipe jobs are greatly simplified and will produce results that you can take pride in.

The same procedures outlined in previous Chapters for bending 90° stubs, kicks, offsets, and saddles with EMT will apply to bending rigid metal conduit. The only difference will be that the front of the bending shoe will be used as a ***reference***, instead of using the arrow as we did on the hand bender.

When bending rigid conduit, the accuracy of your bends has added importance as the conduit must be cut, reamed and threaded. Pipe that fits right the first time, without additional cutting and threading to make it fit, more than pays for the little extra time that was spent on calculating the location of the bend marks.

As discussed earlier, the success of bending using formulas is dependent on the precision of the bend angles. As the degree scale on the bender may be questionable, magnetic angle finders, as shown in Figures 13-3 and 13-4, are an indispensable tool for the serious conduit bender.

**Figure 13-3**
Johnson Magnetic
Angle Locator


**Figure 13-4**
SmartTool Electronic
Angle Finder

If a magnetic angle finder is not available, an alternate method for bending angles less than 90° is the ***"amount of travel method"***.

**Amount of Travel Method**

The basis for this method is the fact that for any given pipe size, the ***same amount*** of pipe will be drawn (travel) into the bender and formed around the radius of the bending shoe ***every time*** a bend is made. The relationship between the amount of conduit ***travel*** and the degree of bend can be used to bend various degrees of bend.

**Example:** If 10" of conduit travels into the bender for a 90° bend, only 5" should travel into the bender for a 45° bend.

**To apply the method:**

1. Carefully level the bender frame.
2. Insert a straight length of conduit into the bender. Attach the front jaw to the bending shoe, release the pawl, lift the handle and engage the ratchet. Lower the handle, letting the weight of the handle hold the conduit in place.
3. Using the back of the conduit support, bending shoe back plate assembly, or other convenient non moving part as a reference, place a mark on the conduit as shown in Figure 13-5.

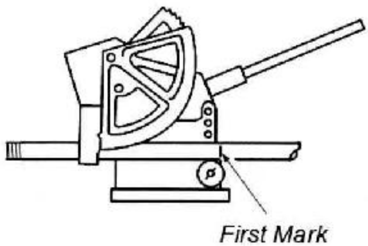



**Figure 13-5**

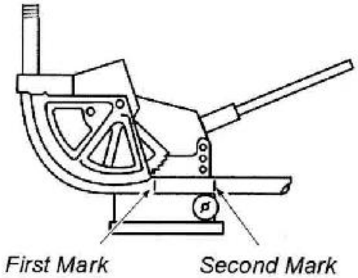



**Figure 13-6**

4. Bend a full 90° bend, checking carefully with a level for accuracy and adjusting for "spring-back" (the amount the bent pipe tends to straighten when pressure on the ratcheting mechanism is released).
5. Using the same spot on the bender as you used to put the first mark on the conduit, make a second mark as shown in Figure 13-6.
6. Remove the pipe from the bender and measure the distance between your first mark and your second mark. This measurement is the ***amount of travel*** for a 90° bend for ***this size*** of conduit using this bender.

To find the amount of travel for any given angle of less than ninety degrees—divide the amount of travel by 90, and than multiply the answer by the number of degree you want to bend.

**EXAMPLE:** If the total amount of travel for 90° was 8¾"; find the amount of travel for (a) 22½°, (b) 10° and (c) 17°.

(a) First divide the amount of travel by 90 to get the travel per 1°.
8¾" or 8.75 ÷ 90 = **.09722** Next multiply 22½° by .09722 to get the amount of travel for a 22½° bend.
22½ × .09772 = 2.18745 or ≈ **2 3/16"**

***As accuracy with the measurement is essential your measurements should be rounded to the nearest 1/16 of an inch.***

(b) As we already know the amount of travel for 1°, we only need to multiply that amount by 10 to find the travel for 10°. 10 times .09722 = .9722 or ≈ 31/32", or for all practical purposes 1".

(c) To find the total travel for a 17° bend.
Total travel = Angle × travel per degree
Total travel = 17 × .09722 = 1.652 or ≈ 1⅝"

Once the travel has been determined, angle bends of less than 90° are achieved by accurately marking and monitoring conduit travel into the bender. This method works even when the bender is **not level** or **on a level surface**.

**PROBLEMS:**

1. If ninety degrees of travel is 10⅝", what would be the travel for:
   (A) 15° (B) 30° Rounded to the nearest ⅛"
2. If ninety degrees of travel is 8⅞", what would be the travel for:
   (A) 60° (B) 45° Rounded to the nearest ⅛"

**Finding Total Pipe Length Required**

All of the pipe layout techniques described in the EMT section of this text may be used for bending rigid conduit using a "Chicago" style bender. The same is also true for any other kind of bender be it electrical or hydraulic.

In most bending jobs, the conduit will have more than one bend and the pipe cannot be placed in a power threading, like the Rigid Model 300 shown in Figure 13-7, so the final cutting and threading will need to be done by hand. Not a popular job for most electricians.

**Figure 13-7**

**Rigid Power Drive Threading Machine**
(Courtesy Rigid Tool Company)

The need to cut, ream and thread by hand can be eliminated if the total pipe length required for a given job can be determined first. A straight length of pipe can then be measured, cut, reamed, and threaded using the power threading machine. Power threading machines are sometimes called "Mules," in part due to the power that these types of machines can produce.

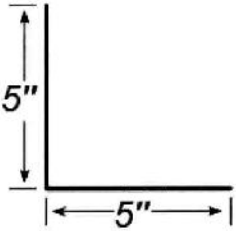
Another situation where it is more convenient to cut, ream, and thread before bending the conduit, is when the pipe pile and threading equipment are located some distance from the bender.

To determine ahead of time how long a piece of pipe needs to be to go from ***point A*** to ***point B*** after a series of bends have been made, will require that we know the ***gain*** for each bend.

Gain is the amount of pipe that is **gained** by bending on a radius, rather than at a right angle as shown in Figure 13-8.

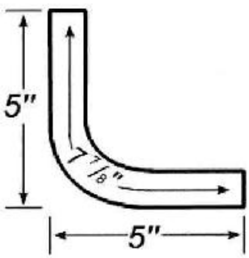
In Figure 13-8 the measurement for each length is 5". If pipe could be bend at a right angle as shown the bend would require 10" of total pipe length (5" + 5" = 10")

**Figure 13-8**




Of course pipe cannot be bent at a right angle if we want to pull wire through the pipe after it is bent. Pipe then must be bent on a ***radius*** as shown in Figure 13-9

**Figure 13-9**




If a measurement is taken from the back of the bend to the end of the pipe as shown in Figure 13-8, the measurement shown for the ***stub*** is 5". The same measurement would be found if the pipe is measured from the back of the bend to the ***leg*** end of the pipe.

By bending on a radius, less pipe is actually required to make the bend and still have a stub length of 5" and a leg length of 5". In Figure 13-9, the total pipe required is given as 7⅞". The difference between the 7⅞" and the 10" that would be required if we bent our 90° at a right angle is called ***GAIN***.

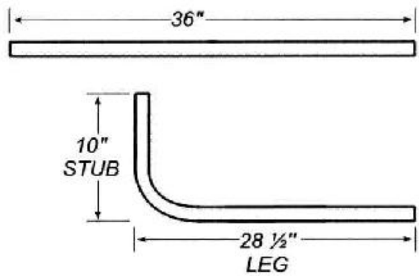
Gain is the amount of pipe that is gained by bending on a radius rather than at a right angle. In this example the gain would be: 2⅛" (10" – 7⅞" = 2 ⅛").

The gain for a 90° bend will vary with each size of pipe as well as with the type of bender that is being used.

To find gain for a given size of pipe and a given bender, proceed as follows:

1. Select and measure a straight length of scrap pipe. For this example let's say that the scrap piece of pipe is 36" long.
2. Using the take-up for the pipe size and bender type, place the pipe in the bender and bend a 10" 90° stub. Check the bend with a level to make sure that the bend is a full 90°. Accuracy at this point is **very** important.
3. Remove the bent pipe from the bender and using a straight edge measure the Stub and Leg lengths as shown in Figure 13-10.

**Figure 13-10**




4. As shown in Figure 13-10 the Stub length is 10" and the Leg length is 28½". Add the measurement of the Stub (10") and Leg (28½") lengths together (10" + 28½" = 38½") and subtract the original pipe length of 36".

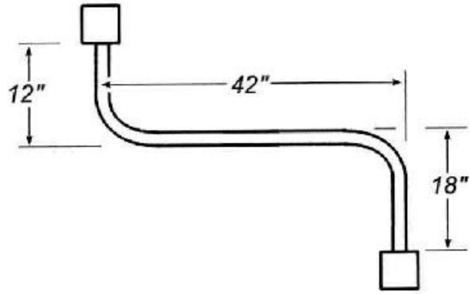
   The difference: 38½ − 36 = 2½" of gain. So the ***Gain*** for a 90° bend for this ***size*** of conduit and this ***bender*** will be 2½". This gain will be unique for this pipe size and bender. A different pipe size will have a different gain for 90°. The only way to find gain is to bend scrap pipe as outlined. The author knows of no way to find gain mathematically that will be as accurate as the gain found by bending a piece of scrap pipe.

Consider two examples of typical bending jobs to find the total pipe length that would be required.

**EXAMPLE 1:**

The pipe used will be ½" Rigid with a gain of 2½" with the dimensions as shown in Figure 13-11.

**Figure 13-11**




**NOTE:** All dimensions are measured to the back of the pipe to the end of the pipe, or from the back of the pipe to the back of the pipe, which is outside to outside.

Add all dimensions:

12" + 42" + 18" = 72" Total of dimensions

There are two 90° bends—so there will be two ***gains*** to consider.

Gain is given at 2½" for each 90° bend.

Total gain = 2½" × 2     Total Gain = 5"

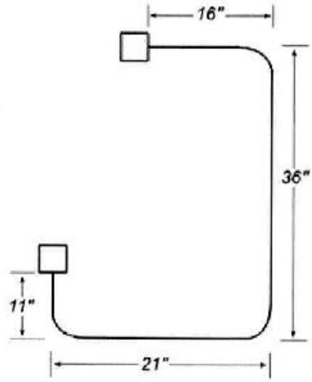
Subtract the total gain (5") from the total dimension (72") for a total pipe length requirement of 67". A straight piece of ½" Rigid conduit could now be cut to 67", reamed and threaded knowing that the pipe is the right length for the required conduit job. The bending marks can now be placed on the conduit and the bends can be made.

**NOTE:** For simplicity, all examples and problems from this point on will be drawn in one line form, box offsets and thread lengths will not be included. All measurements are to the back of the bend, or outside edge of the pipe.

**EXAMPLE 2:**

This pipe job calls for ¾" Rigid conduit that has a gain of 3¾" and measurements as shown in Figure 13-12.

**Figure 13-12**




Add all dimensions:
16" + 36" + 21" + 11" = 84" Total Dimensions

There are three (3) 90° bends—so there will be three (3) gains.
Gain is 3¾" × 3 = 11¼" ***total*** gain

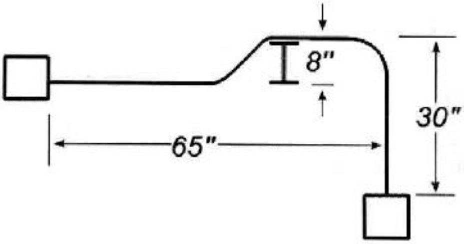
Subtract total gain (11¼") from the total dimension (84") to get an actual pipe length requirement of **72¾"**.

Now let's add an offset to our bending job and find the total length that will be required.

For 90° bends we ***subtract*** gain—for offsets we must ***add*** shrink. ***Shrink was covered in Chapter 7 of this book.***

**EXAMPLE 3:**
This conduit bending job shown in Figure 13-13 will use ½" Rigid conduit with a ***gain*** of 2½" and 45° offsets with ***shrink*** of ⅜" per inch of rise.

**Figure 13-13**




Add the dimensions:
65" + 30" = 95" Total dimension

Find total shrink:

The offset is 8" so the shrink will be ⅜" for each inch of rise.
8 × ⅜ = 24/8 or **3"** ***total*** shrink

Add total shrink to the total dimensions:

3" + 95" = 98" ***adjusted*** total dimension

Find total gain:

There is only one 90° bend, so the gain would be 2½".

Subtract the gain from the adjusted total dimension:

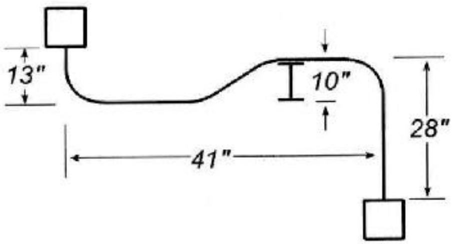
98" – 2½" = **95½"** ***total*** pipe length required

**NOTE:** Remember that if you are not using Myers Hubs, you must also add an amount for the threads to enter the boxes. For a double lock nut and bushing it is normal to add ¾" to each end of the pipe for threads.

**EXAMPLE 4:**

Figure 13-14 is a job using ¾" rigid pipe. The offset will be made using 30° bends, the gain for the ¾" pipe will be 3¾", shrink for the 30° offset will be ¼" per inch of rise.

**Figure 13-14**




Add all dimensions:

13" + 41" + 28" = 82" Total dimension

Find total shrink:

30° 10" offset = 10" × ¼" = 2½" Total shrink

Add total shrink to total dimension:

2½" + 82" = 84½" ***Adjusted*** total dimension

Find total gain:

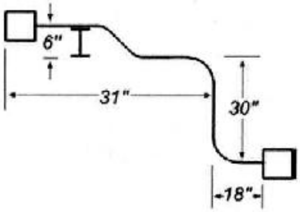
Two 90° bends = 2 × 3¾" = 7½" Total gain

Subtract total gain from the ***adjusted*** total dimension:

84½" − 7½" = 77". 77" of pipe, plus threads, will be needed for this bending project.

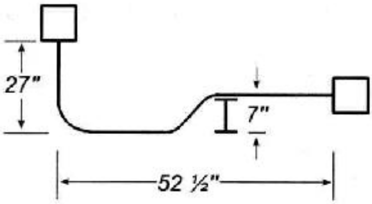
**PROBLEMS:**

1. Gain 2½" Shrink ⅜" per inch of rise



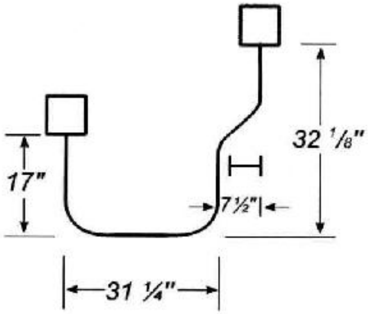

Total Pipe Length________

2. Gain 3¾" Shrink ¼" per inch of rise



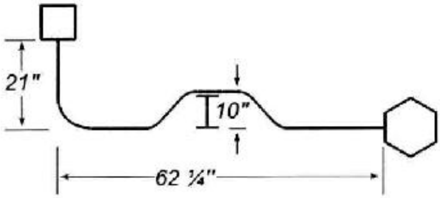

Total Pipe Length_______

3. Gain 5⅜" Shrink ½" per inch of rise




Total Pipe Length_______

4. Gain 4¼" Shrink ⅜" per inch of rise




Total Pipe Length______

## Push-Through Bending

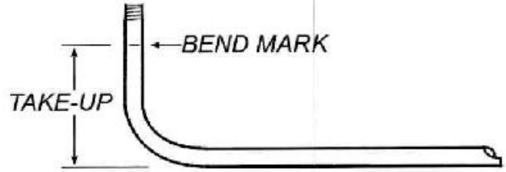
The "Chicago" type bender allows us to advance the art of pipe bending. All bends in a given piece of conduit can be made in succession without removing the pipe from the bender. After a bend is made, the pawl is released, the jaw is removed and the pipe is advanced forward to the next bend mark. The jaw is replaced, the pawl is engaged, and the next bend is made. This technique is called "Push-Through Bending".

To use this technique, all bend marks for a given length of pipe are placed on the conduit first. This requires additional calculations, but will actually save time once you become familiar with the procedures used. An added benefit is the feeling of accomplishment and pride you will feel when the pipe fits right the first time—every time.

Let's review two terms from previous discussions: ***Take-up*** and ***Gain***.

***Take-up*** is the distance from the back of the bend to the bending mark and is used to position the bender for accurate 90° bends as shown in Figure 13-15.

**Figure 13-15**




***Gain*** is the amount of conduit saved by bending on a radius rather than at right angles as shown in Figure 13-16.

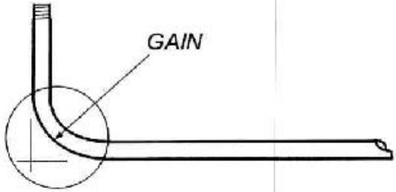


**Figure 13-16**

Now let's assume we are bending ½" rigid pipe. The take-up of the bender is 5" and the gain is 2". We need to bend a piece of pipe with a stub of 12" and a leg of 20".

Total pipe length required would be:
Total pipe length = 12" + 20" (stub plus leg) minus 2" (gain).
12" + 20" = 32"  32" − 2" = 30"
Total pipe length = **30"** as shown in Figure 13-17.

To layout the pipe for a 12" stub length, we would subtract 5" for take-up and place a bend mark on the conduit 7" from the end of the pipe as shown in Figure 13-17.

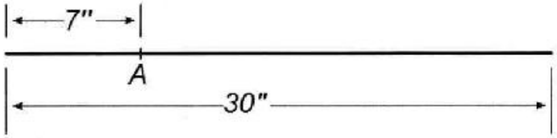
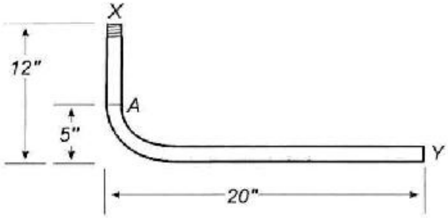



**Figure 13-17**

Bend the 90° stub as shown in Figure 13-18.

**Figure 13-18**



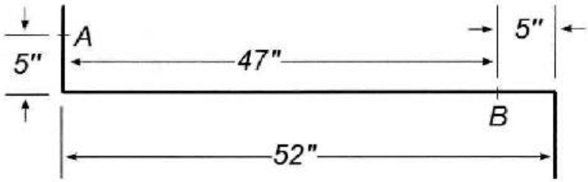

## Locating Bend Mark From Opposite End of The Pipe

To find the distance from bend mark A to the end of the leg (Y), as shown in Figure 13-18, we add 5" take-up plus 20" for the leg length and then subtract 2" for gain, making the distance 23". Another way to get the measurement from **bend mark A** to the end of the pipe, point Y, is as follows:

If bend mark A is 7" from end X and the pipe is 30" long, then bend mark A must be 30" − 7" = 23".

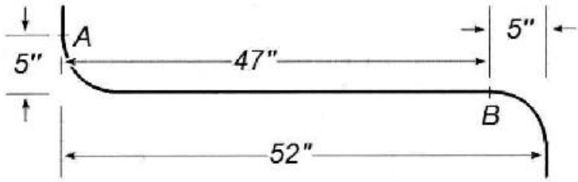
Figure 13-19 shows two right angle bends. Mark A is 5" before the first angle and mark B is 5" before the second angle. The distance from mark A to mark B then is 5" + 47" or 52".

**Figure 13-19**




In Figure 13-20 the bends are not at right angles, but are bent on a radius. The distance from bend mark A to bend mark B would be:
5" + 47" = 52" minus 2" for one gain—for a distance of 50".

**Figure 13-20**

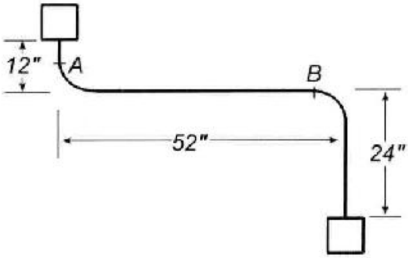



For double 90° bends, the back-to-back distance minus one gain will be the spacing, or distance, between bend marks A and B.
The back-to-back measurement is 52", 52" − 2" = 50"

Now that we understand how to use take-up and gain, we can locate other bend marks on the pipe from a preceding bend mark.

**EXAMPLE:**
In this example we will be using ½" rigid conduit. Our bender has a take-up of 5" and we have bent scrap pipe and know the gain for each 90° bend will be 2". Using this information let's layout bend marks A and B for the pipe job as indicated in Figure 13-21.

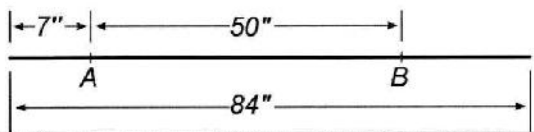
**Figure 13-21**



To find total pipe length required add 12" + 52" + 24" = 88". From this total we must now subtract two gains (one for each 90° bend) for a total of 4". 88" – 4" = 84" will be the total pipe length required for this job.

The distance from the end of the conduit to bend mark A will be 12" (stub length) minus 5" (take-up) or 7" as shown in Figure 13-22.

**Figure 13-22**




| Constants | EMT Pipe Size | | | Rigid Pipe Size | | |
|---|---|---|---|---|---|---|
| **Angle** | ½" | ¾" | 1" | ½" | ¾" | 1" |
| 45° | 5" | 6¼" | 7½" | 5" | 6" | 8" |
| 30° | 4½" | 5½" | 6" | 4½" | 5½" | 6½" |
| 22½° | 3½" | 4¼" | 4¾" | 4" | 5" | 6" |
| 10° | 3" | 3½" | 4" | 3" | 3½" | 4½" |

**Table 13-23 Offset Constants for "Chicago" Style Benders**

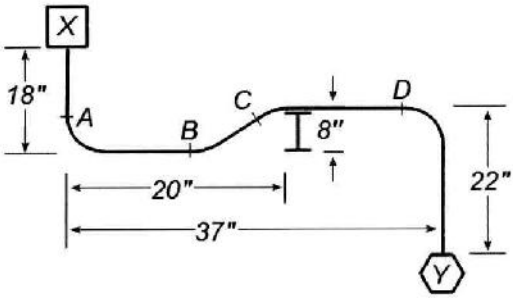
The back-to-back measurement between the two 90° bends in Figure 13-21 is 52". The spacing between bend mark A and B then is found by subtracting one gain of 2" from the back-to-back measurement of 52". 52" – 2" = 50" distance form bend mark A to bend mark B as shown in Figure 13-22.

This same technique could be used for three or four 90° bends if required. The next Example will have an offset and will use Pre-positioning Offset Method #1 for bend mark layout. Method #1 is the only method that will work for push-through bending.

**NOTE:** For bending conduit on a "Chicago" style bender, the ***Offset Constants*** shown in Table 13-23 are used.

Using the same bender from the previous Example that had a take-up of 5" and a gain of 2" when bending ½" rigid pipe, layout the pipe as required in Figure 13-24. The offset will be bent at 45°.

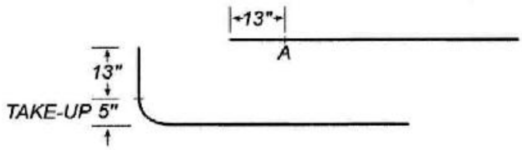
**Figure 13-24**




Total length:
18" + 37" + 22" (total dimensions) + 3" (shrink for 8" offset) – 4" (for gain for two 90° bends) = 76" Total pipe length required is 76.

To locate Bend mark A from the end of the pipe, subtract 5" (take-up) from the 18" stub length, that give us a measurement from the end of the pipe to Bend mark A of 13", as shown in Figure 13-25.

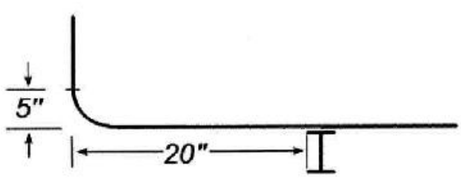
**Figure 13-25**




The distance from Bend mark A to Bend mark B, using Method #1 for pre-positioning offsets is found as follows:

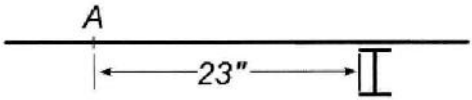
From Bend mark A to the back of the bend is 5" (take-up). From the back of the pipe to the edge of the obstruction is 20", as shown in Figure 13-26. If it were not for the gain of the 90° bend, we could simply add 5" plus 20" for a total of 25" to find the distance from Bend mark A to the edge of the obstruction.

**Figure 13-26**



Because of the gain, we must subtract 2" from the 25" to give us an accurate measurement from Bend mark A to the edge of the obstruction of 23" as shown in Figure 13-27.

**Figure 13-27**




To pre-position the 45° offset using Method #1 we take the height of the obstruction and add the offset constant for the size pipe we are using. In this case the offset height is 8" and the offset constant for ½" rigid conduit using a "Chicago" style bender is 5" (Table 13-23).

| | | |
|---|---|---|
| Height of obstruction (H) | | 8" |
| Offset Constant for ½" EMT | | +5" |
| | Total | 13" |

| | |
|---|---|
| Distance from Bend Mark A to the Obstruction | 23" |
| Subtract H + Offset Constant | −13" |
| | 10" |

Measure 10" from Bend mark A and mark Bend mark B, as shown in Figure 13-28.

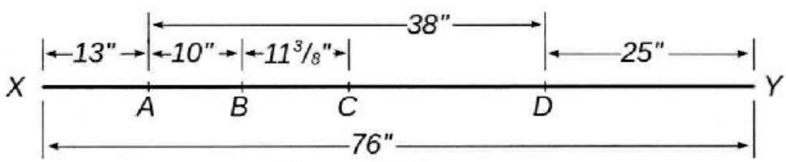



**Figure 13-28**

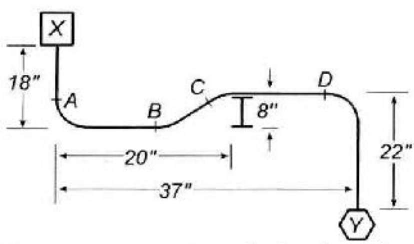
The measurement from Bend mark B, the start of the offset, to Bend mark C would be found by multiplying the height of the obstruction by the offset multiplier for a 45° offset.

Offset height 8" × 1.414 = 11.312". Round up to 11⅜" for the spacing between Bend mark B and Bend mark C, as shown in Figure 13-28.

To locate Bend mark D, it will be easiest if we use mark A as a reference. The back-to-back measurement from the back of the first 90° bend to the back of the second 90° bend is shown in Figure 13-24 as 37". Between Bend mark A and D there is one 90° bend and an offset. For the 90° bend we will subtract 2" for ***gain***, but then we must add shrink for the 8" offset. Shrink for the 8" 45° offset would be 8 × ⅜" = 24/8 or 3" of total ***shrink***.

37" Back-to-back distance
+ 3" Shrink
40"
− 2" Gain
38" Distance from Bend mark **A** to Bend mark **D** as shown in Figure 13-28.

We can, and should, always double check our measurements before bending the pipe. The best way is to work backwards, or from the opposite end that we originally measured from.



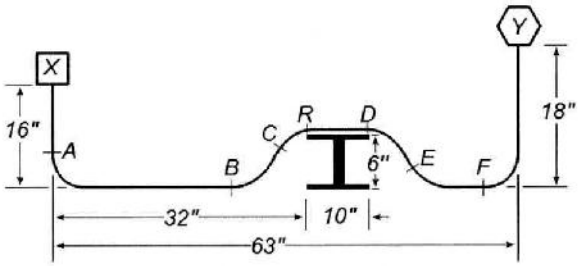

Starting from box Y, the measurement to the back of the 90° bend is 22" + 5" for take up and then minus 2" for gain, or 25" from the end of the pipe at Y to Bend mark D as shown in Figure 13-28. From D to A, as shown in Figure 13-28 is 38". Add 38" to 25" for a total of 63" from the end of the conduit at point Y to Bend mark A. From A to box X is 18" minus 5" of take-up, or 13". Add the 13" from X to Bend mark A to the 63" measurement for Bend mark A to the end of the conduit at Y for a total length of 76", which was the calculated total length.

By taking the time to make these extra calculations, any mistakes that might have been made will be found. We can now proceed to bend the pipe with the confidence that the end results will be a pipe that fits right the first time, without adjustments.

The next problem will have a four-bend saddle and two 90° bends. As with offsets, Method #1 must be used for push-through bending four-bend saddles. If necessary, review Chapter 9 for Pre-positioning four-bend saddles using Method #1.

Layout the pipe as indicated in Figure 13-29. The pipe will be ¾" rigid, the take-up is 6", the gain for each 90° bend is 2 ¾", and the saddle is bent using 45° bends.

**Figure 13-29**




First find the total length:
Measurement of the two stubs and the back-to-back measurements are (16" + 63" + 18") for a total of 97". To this value add the shrink for the four-bend saddle. Remember that there will be two shrinks, one for the first two bends and another for the second two bends to complete the saddle. Height of the obstruction is 6", double this to give us 12". Now multiply 12" × ⅜" to find total shrink. 12" × ⅜" = 36/8 or 4½" of shrink. Add the 4½" to the previous measurement of 97" for a total of 101½". From this total we must now subtract gain. There are two nineties so the gain will be 2 × 2¾", or 5½" of total gain. Total gain of 5½" is subtracted from the 101½", measurement for a total pipe length of 96", as shown in Figure 13-30.

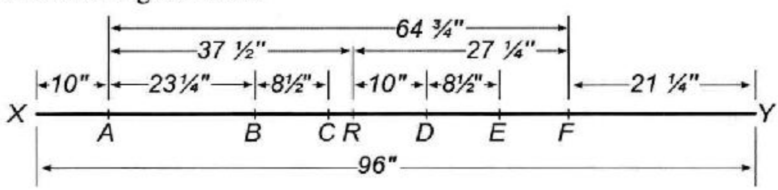



**Figure 13-30**

To locate Bend mark **A**, subtract the take-up of the bender, which was given at 6", from the desired stub length of 16".

16" − 6" = 10", the distance from the end of the pipe at box X to Bend mark A is 10", as shown in Figure 13-30.

The distance from **A** to **B**:

From A to the back of the bend is 6" (take-up) minus 2¾" for gain.

6 − 2¾ = 3¼"

The edge of the obstruction is 32" from the back of the bend. By adding the 3¼" to the 32" we have a measurement of 35¼" that represents the distance from Bend mark A to the edge of the obstruction.

From this measurement (35¼") we subtract the height of the saddle (6") plus the Offset constant for ¾" rigid pipe as found in Table 13-21, which is 6", for a total of 12".

35¼" − 12" = 23¼"

This is the distance from Bend mark A to Bend mark B, as shown in Figure 13-30a.

The distance for **B** to **C**:

The distance from B to C is found by multiplying the height of the obstruction (6") by the offset multiplier for 45° offsets (1.414).

6 × 1.414 = 8.484 or ≈ 8½"

The spacing from B to C then is 8½", as shown in Figure 13-30a

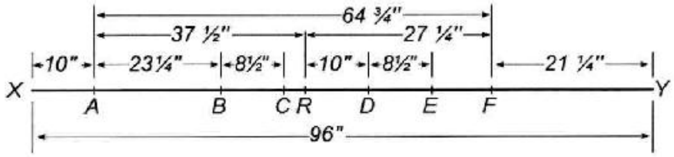



**Figure 13-30a**

The distance from **A** to **R**:

Previously we had located the edge of the obstruction from Bend mark A, which was 35¼". If we add the shrink for the first two bends of the saddle to 35¼" we have located the reference mark R. The shrink would be the height of the obstruction multiplied times ⅜". 6" × ⅜" = 18/8 or 2¼". The distance from A to R then is 35¼" + 2¼" = 37½", as shown in Figure 13-30a.

Distance from **R** to **D**:

The distance from R to D will be the width of the obstruction. The obstruction is 10" wide, so the distance from R to D is 10", as shown in Figure 13-30a.

Distance from **D** to **E**:

The distance from D to E will be the same measurement as B to C, 8½", as shown in Figure 13-30a.

Locate Bend mark **F**:

Bend mark F may be located from A or R.

From **R** to **F**:

The back-to-back measurement for the two nineties is 63". It is 32" from the back of bend A to the edge of the obstruction, so it must be 31" from the obstruction to the back of bend F, as shown in Figure 13-29. If we add 2¼" of shrink, for bends D and E, to 31" we get a measurement of 33¼". All we need to do now is subtract 6" for take-up from 33¼" to get a measurement of 27¼" from R to F, as shown in Figure 13-30a.

From **A** to **F**:

Back-to-back measurement from bend A to bend F is 63" (distance) + 4½" (total shrink) minus 2 ¾" (one gain) = 64¾" as shown in Figure 13-30a.

To make sure that we have not made any mistakes, we will double check our figures by locating bend mark F again, but starting from the **Y** end of the pipe.

From the **Y** end of the pipe we can locate bend mark F by adding the stub length of 18", plus 6" for take-up, and then deducting 2 ¾" for gain.

18" + 6" = 24"
24" minus one gain of 2 ¾" = 21 ¼"

From the Y end of the pipe to bend mark F will be 21¼" as shown in Figure 13-30a.

Adding this measurement (21¼") to the measurement we have already found for the distance from A to F (64¾") we would get a total of 86". Add the 10" from bend mark A to the X end of the pipe to the 86" and we get the total pipe length of 96" as shown in Figure 13-30b.

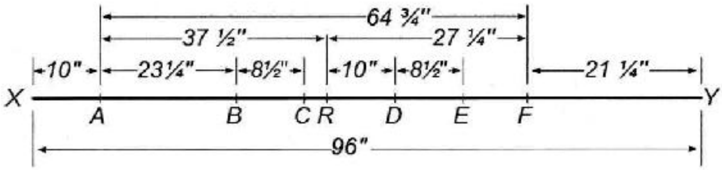


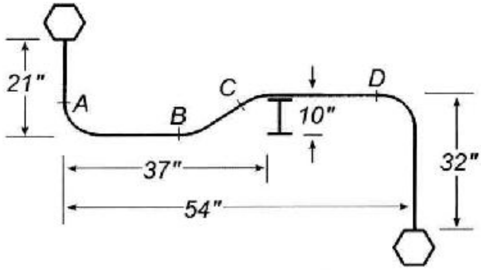

**Figure 13-30b**

Laying out a pipe with this many bends may seem very complicated at first, but with a little practice you will be able to do it rather easily. The key is a complete understanding of take-up, gain, shrink and offset constant values.

**PROBLEMS:**

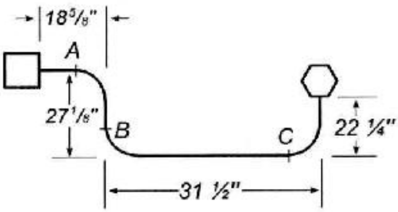
1. Find the total pipe length need and layout the bend marks as required for the pipe job shown in Figure 13-31. The pipe size is ½" rigid, the bender take-up is 5 ¼", the offset is 45°, and the gain for each 90° bend is 2 ⅜".

**Figure 13-31**



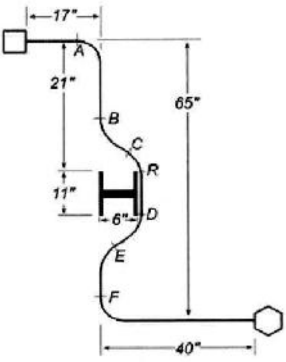
2. Find the total pipe length need and layout the bend marks as required for the pipe job shown in Figure 13-32. The pipe size is ¾" EMT, the bender take-up is 6", and the gain for each 90° bend is 3 ⅜".

**Figure 13-32**




3. Find the total pipe length needed and layout the bend marks as required for the pipe job shown in Figure 13-33. The pipe size is ¾" rigid, the bender take-up is 6 ½", the saddle is bent using 45° bends, and the gain for each 90° bend is 3 ¼".

**Figure 13-33**




## Predetermining Saddle Location Using a "Chicago" Style Bender

When using "Chicago" type bending equipment an adjustment ***must*** be made to assure that the saddle will be centered on the obstruction. The adjustment is necessary because the bend will not actually start at the bend mark, as was the case with a hand bender, but will be back of the bend mark. Place the bend mark at the start of the bending shoe and bend a 45° bend as shown in Figure 13-34. Take the pipe out of the bender and mark where the actual bend starts. The distance from the bend mark to where the actual bend starts is the amount that will be deducted from the width of the obstruction to assure that the completed saddle will be centered on the obstruction.

**Figure 13-34**

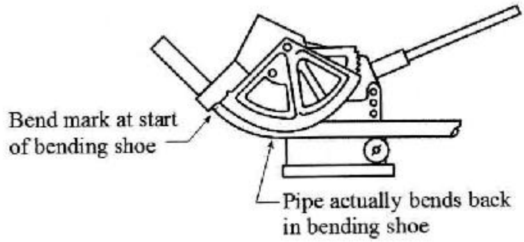



Figure 13-35 shows how the saddle would fit if no adjustment is made, while Figure 13-36 shows how the saddle will fit when the correct adjustment has been made.

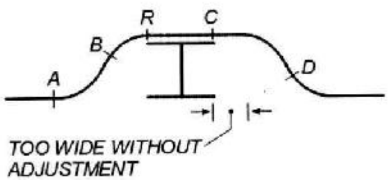



**Figure 13-35**

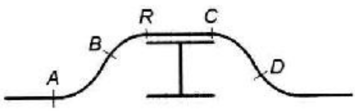



**Figure 13-36**

The amount of adjustment will vary with different types of benders. The only way to determine the correct adjustment for the bender you are using is to bend a scrap piece of pipe.

## Three Bend Saddles Using "Chicago" Style Benders

When using a "Chicago" style bender for bending three bend saddles the multiplier will be 3, not 2½ as was the case with bending EMT using a hand bender. When a multiplier of 3 is used, the bend marks for each of the three bends that make up the three bend saddle will be center of the bend marks, not the front of the shoe marks.

To find the center of bend mark for your "Chicago" style bender:

1. Bend a scrap piece of pipe to a 45° bend. Take the pipe out of the bender and determine where the center of the 45° bend is. Mark the pipe and put it back into the bender lining the

original bend mark with the front of the bending shoe. Now place a mark on the bender shoe that corresponds with the mark on the conduit. You now have a mark that represents the center of the bend for 45° as shown in Figure 13-37.

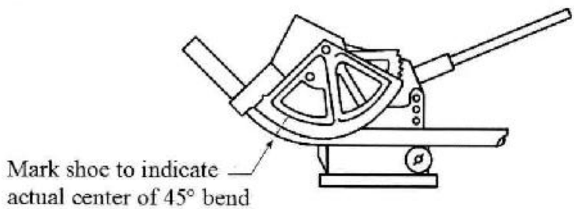



**Figure 13-37**

This mark on the bender shoe will be the mark that will be used to bend both the 22½° bends as well as the 45° bend that will make the three bend saddle.

**EXAMPLE:** Bend a three bend saddle to go over an 8" diameter pipe. The spacing between bend mark A and bend marks B and C is found by multiplying the diameter of the pipe (8") by the multiplier of 3. The spacing then between bend mark A and B and A and C will be 24" as shown in Figure 13-38.

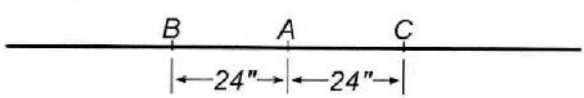


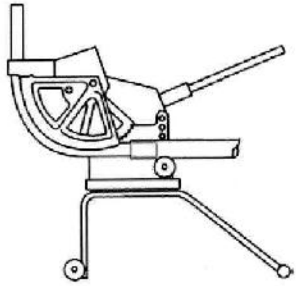

**Figure 13-38**

Place the conduit in the bender lining bend mark B on the mark on the bender shoe that ***indicates the center of a 45° bend***. Bend a 22½° bend, rotate pipe 180° and advance pipe to bend mark A. Bend a 45° bend, rotate the pipe again 180°, advance the pipe to bend mark C and bend a 22½° bend to complete the saddle.

## General "Chicago" Style Bender Tips:

1. To reduce the time it take to convert fractions to decimal equivalents or decimal values to fractions purchase a pocket calculator that will do fractions. To do fractions the calculator must have a $a^{b}/_{c}$ key. To enter the fraction 3/8 as an example you press the $a^{b}/_{c}$ key then the number 3 key then the $a^{b}/_{c}$ again followed by the number 8. The calculator will display the fraction 3/8. You can then multiply, divide, add or subtract.
2. When minimum length stubs are being bent, the shoe tends to creep and deform the ends of the conduit and threads. Screwing a coupling on the pipe stops the shoe from creeping forward and protects the pipe threads.
3. When bending offsets, the front of the bender can be temporarily elevated to grain necessary clearance for the bends.
4. Most bender shoes are made of cast aluminum and are easily pitted and gouged if foreign material gets between the shoe and the pipe. Keep the pipe clean and the shoe wiped down for longer shoe life.
5. When the remaining pipe length is not long enough to reach the roller or pipe support, a larger diameter pipe can be slid over the pipe being bent to complete the bend as shown in Figure 13-39, or if the pipe has threads, screw on a short piece of scrap pipe.

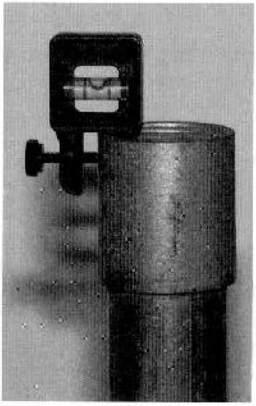
**Figure 13-39**



6. To prevent wows and dog-legs when bending offsets and saddles use a "WOW Watcher" or no-dog as shown in Figure 13-40. This device screws onto the end of the pipe to maintain correct alignment between each bend.

**Figure 13-40**

Order @
www.coxco.net



7. For matching bends in sizes ½", ¾", and 1", all bends can be made using the 1" bending shoe.

# HYDRAULIC BENDERS 14

For bending larger sizes of conduit the hydraulic bender is indispensable. Only by the addition of the hydraulic pump and cylinder to a bender frame is the necessary power available for bending rigid conduit up to 6" trade size.

The typical completely assembled hydraulic bender is shown in Figure 14-1 not only gives the electrician extended bending capability, but also requires additional responsibility. Hydraulic bending equipment represents a large initial investment of money and the bender must be properly cared for if it is to last and give the service necessary to justify the cost.

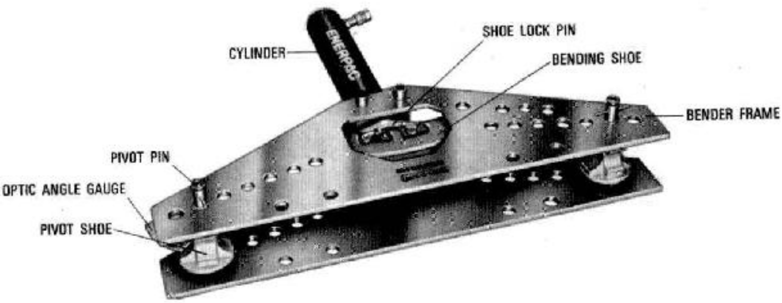



**Figure 14-1**
Hydraulic Bender
(Courtesy Enerpac)

The bender frame, pivot shoes and bending shoes will require little more than occasional wiping down with a rag to remove the dirt and oil film. The pump, cylinder and hydraulic hoses, however, will demand more attention. Hydraulic benders will come with quick-disconnect couplers on the pump, cylinder and hoses. Each coupler end whether male or female comes with a dust cover as shown in Figure 14-2. The male coupler is on the left and the female coupler is on the right.


**Figure 14-2**


These dust covers must be in place when the bender is disassembled to keep dirt and dust out of the couplers. Failure to keep the couplers clean will result in damage to the "O" rings (hydraulic pressure depends on the "O" rings seating and sealing properly).

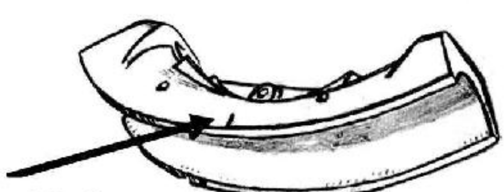
The pump, whether hand, or electrically operated, should have the fluid level checked periodically. Low fluid pressure will keep the pump from developing its rated hydraulic pressure. When the fluid level is low and fluid must be added, use ***only*** approved hydraulic oil. Ordinary oil will cause damage to the pump assembly. Figure 14-3 shows a hand hydraulic pump, while Figure 14-4 shows and electric hydraulic pump.


**Figure 14-3**
Hand Hydraulic Pump
(Courtesy Enerpac)

**Figure 14-4**
Electric Hydraulic Pump
(Courtesy Enerpac)

Hydraulic benders have two types of bending shoes, ***One-shot*** and ***segment***. The one-shot shoe has a full 90° radius. The conduit can be formed around the shoe to a full 90° bend without collapsing the walls of the pipe. One-shot benders require no new bending techniques. The Take-up is figured to the center of the bend and the bender shoe will have a mark at its center as shown in Figure 14-5.

**Figure 14-5**
One-Shot Shoe

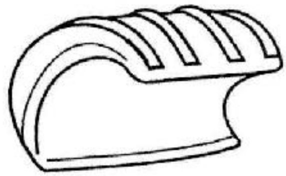


**Center of Shoe Mark**

If the take-up values are not listed on the bender frame or on the storage box, scrap pipe can be bent and take-up values can be determined. All the methods and layout techniques discussed for EMT and Rigid can be used with a hydraulic bender and one-shot shoes. Offsets will have to be adjusted (less angle of bend) so the spacing between the bend marks are far enough apart to allow the first bend to be rolled 180° and advanced enough to clear the pivot shoes. The pivot shoes are shown in Figure 14-1.

Segment shoes are shorter and have a very limited radius as can be seen in Figure 14-6.

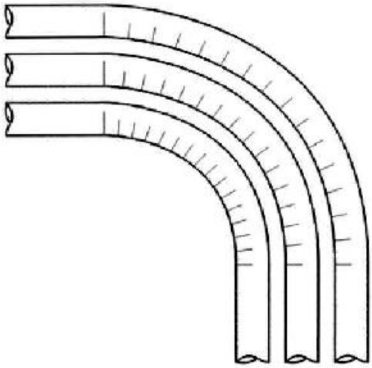
**Figure 14-6**
Segment Bending Shoe



90° bends cannot be made in one operation with a segment shoe as the conduit walls will collapse. Bends must be made in several steps (as few as 4, and as many as 30) to form a smooth radius. The segment shoe allows pipe to be bent to larger size radii.

Segment shoes are used for ***Concentric Bending.*** Concentric bending is when several conduits are bent with increasing or decreasing radii. Figure 14-7 shows three pipes that have different radius bends. To maintain correct spacing between the pipes, the radius of each pipe will be different. The inside pipe will have one radius and then the next pipe will require a larger radius and the third pipe will require an even larger radius to maintain proper spacing.

**Figure 14-7**
Concentric Bent Pipes



Concentric bending is covered later in the text.

Accurate bending of large conduit is possible, but requires practice, patience and ability. With few exceptions, all formulas and bending techniques discussed to this point will apply. ***One-shot*** shoes can be used for segment bending, but are not as convenient.

**Bending Tips for Rigid Aluminum Conduit**

Aluminum conduit is available in all trade sizes, ½" through 6". It is light weight, corrosion resistant and has low ground impedance. It is, however, difficult to bend consistently and accurately. Two pipes out of the same bundle can act differently when bent. Even if two pipes are bent using the same layout, they don't always come out **exactly** the same. Don't be discouraged, this is the nature of the metal, and it can't be helped.

Bending aluminum conduit with a one-shot hydraulic bending shoe will dig-in and score the pipe and where the pipe rides on the pivot shoes it is also prone to wrinkling and scoring. Applying petroleum jelly (Vaseline) to the shoes will allow the pipe to slide without the shoes digging in. The Vaseline will also make it easier to remove the conduit from the bender shoe when the bend is completed.

# LAYOUT FOR SEGMENT BENDING 15

Segment bending will require some new information and bending techniques.

Segment bends, as mentioned earlier, require more than one bend to complete a 90° stub. As many as 30 bends may be used and would require 30 bend marks.

The first step in segment bending is to determine the size of radius that is needed for a given pipe job. The larger the radius, the easier wire pulling will be. Space requirements and installation location will also be a factor that will govern the radius of a given pipe.

The National Electrical Code® gives the minimum bend radius for conduit and tubing in Table 2 of Chapter 9.

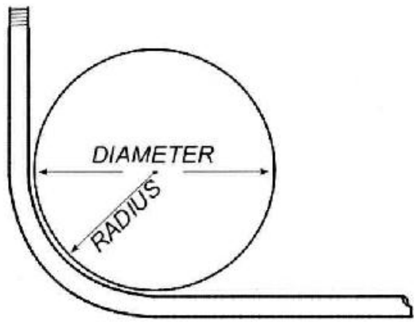
| Table 2 (Chapter 9) Radius of conduit and tubing | | |
|---|---|---|
| Conduit Size Trade Size | One Shot and Full Shoe Benders Bending Radius (in Inches) | Other Bends Bending Radius (in inches) |
| ½ | 4 | 4 |
| ¾ | 4½ | 5 |
| 1 | 5¼ | 6 |
| 1¼ | 7¼ | 8 |
| 1½ | 8¼ | 10 |
| 2 | 9½ | 12 |
| 2½ | 10½ | 15 |
| 3 | 13 | 18 |
| 3½ | 15 | 21 |
| 4 | 16 | 24 |
| 5 | 24 | 30 |
| 6 | 30 | 36 |

For factory 90° or field bends made with a one-piece shoe the first column of Table 2 is used. When bends are made with multiple bends the column ***"other bends"*** is used. In all cases the minimum radius of bend is measured to the centerline of the conduit or tubing.

If you don't have access to the Table a "rule-of-thumb" that is used to determine the radius for a given pipe size is 6 to 8 times the trade size of the conduit or tubing.

Notice in Figure 15-1 that the bent portion of the 90° bend makes up ¼ of the circumference of a circle. Also note that ½ the diameter is called the ***radius (R)***.

**Figure 15-1**




To find the circumference (C) of a circle use the formula:

$C = \pi \times \text{diameter}$

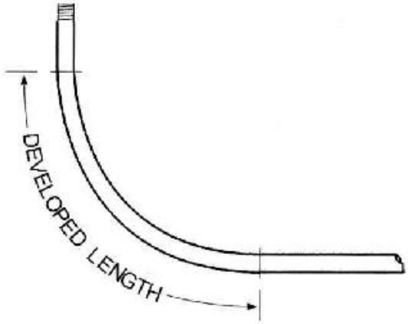
The Greek letter π which is the ratio of the circumference (C) of a circle to its diameter (d) has a value of 3.14.

The formula can be rewritten as: $C = 3.14 \times d$.

To find only ¼ of the circumference, which is the amount of bent pipe, we can modify the formula. As π (3.14) is the ratio of the circumference to diameter of the circle we can use half the value of 3.14 which is ***1.57*** and use the value of the ***radius*** instead of the diameter. The revised formula is: ***¼ C*** = 1.57 × Radius

The amount of pipe that is actually bent to make a 90° bend (¼ the circumference) is called the ***developed length***. Stated another way, developed length is the amount of straight pipe required to bend a given size of radius as shown in Figure 15-2.

Figure 15-2



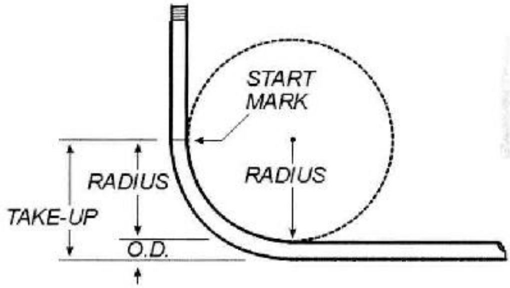

The developed length for a 90° bend is equal to ¼ of the circumference, the formula for finding developed length for 90° then is:

Developed Length = 1.57 × Radius

As indicated in Figure 15-3, the radius is measured on the inside of the bend. The radius plus the outside diameter of the pipe is just like "take-up" as described in earlier Chapters.

**NOTE:** A full list of outside diameters for all pipe sizes is found at the back of the book.

Figure 15-3

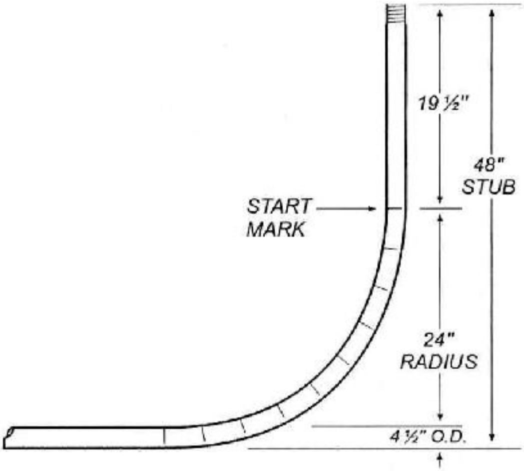



The amount of the radius + the outside diameter subtracted from the desired stub length will give us the start mark. The start mark is used for layout only and is ***not*** a bend mark.

**EXAMPLE:** To locate the start mark for laying out a 4" rigid conduit with a 48" stub that has a radius of 24" we add the outside diameter (O.D.) for 4" pipe which is 4½" to the 24" radius and subtract that value from 48", the desired stub length.

Start mark = 48 – (4½ + 24)
Start mark = 19½" as shown in Figure 15-4.

**Figure 15-4**




The start mark, as well as all other bending marks, should go at least half way around the pipe. If the marks are too small, they will be covered up by the bending shoe and create a problem when the bending is started.

As more than one bend must be made to complete the 90° stub, the next step then is to determine the number of bends to use. The number of bends is also referred to as ***"shots"***.

Figure 15-5 and 15-6 are exaggerated, but serve to illustrate a point. The more bends—the smoother and uniform the radius will be.

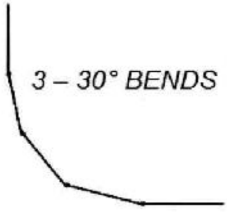



**Figure 15-5**

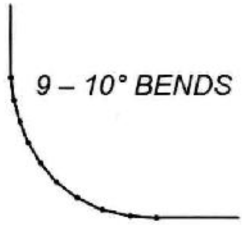



**Figure 15-6**

Examples of the number of bends and degree per bend for 90° segment bending are shown in Table 15-7.

**Table 15-7**

| Number of Bends | Degree per Bend |
|---|---|
| 15 | 6 |
| 18 | 5 |
| 20 | 4.5 |
| 30 | 3 |

Normally the degrees per bend should not be less than 3° (30 shots) nor more than 6° (15 shots) for a smooth and even radius bends. Any degree between 3° and 6° of course can be used. An angle finder or digital level will be necessary if accurate results are to be expected.

Remember the more bends—the smoother the 90° stub and the easier wire pulling will be.

Once you have decided on the number of bends to be used (shots), the number is divided into the developed length (the amount of straight pipe needed to bend a given radius) to give us the spacing between the bend marks as shown in Figure 15-8.

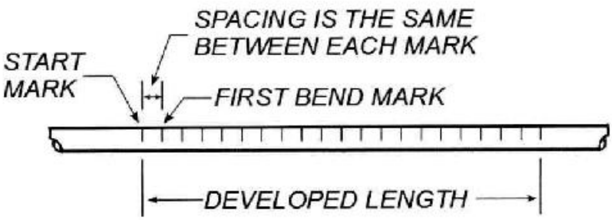



**Figure 15-8**

$$\text{Spacing between bend marks is} = \frac{Developed\ Length}{Number\ of\ Bends}$$

**EXAMPLE:** Determine spacing between bend marks for a 22" radius bent in 20 shots. 20 shots is the same as 20 bends.

Developed length = 1.57 × Radius
Developed Length = 1.57 × 22
Developed Length = 34.54 or ≈ 34½"

To find the spacing between the bend marks divide the Developed Length by the number of bends (shots).

Spacing $= 34.54 \div 20$

Spacing $= 1.727$ or $\approx 1\frac{3}{4}$" between the bend marks

Now that the new terms and formulas are understood, let's put it all together and layout two segment bends.

**EXAMPLE #1:** Layout a 3" rigid pipe that will have a radius of 24" and a 90° stub length of 42". The pipe will be bent in 20 shots of $4\frac{1}{2}$° per shot.

1. **Find developed length:**

   Developed Length = $1.57 \times R$

   Developed Length = $1.57 \times 24$"

   Developed Length = 37.68 or $\approx$ **37 ⅝"**

2. **Determine the location of the start mark.**

   Start Mark = Stub length – (radius + pipe O.D.)

   The O.D. for 3" Rigid is 3.5"

   Start Mark = 42 – (24 + 3.5)

   Start Mark = 42 – 27.5

   Start Mark = 14.5" or **14½"**

3. **Spacing between the bend marks:**

   Spacing = Developed Length ÷ Number of bends

   Spacing = $37.68 \div 20$

   Spacing = 1.884 or $\approx$ **1 ⅞"**

Starting at 14½" from the end of the pipe, place 20 marks 1⅞" apart, as shown in Figure 15-9.

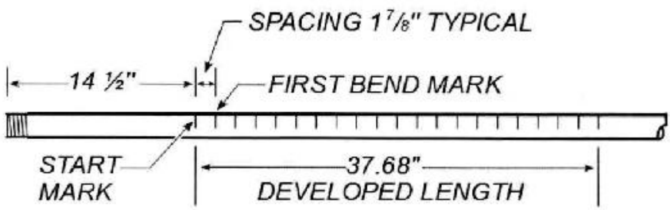



**Figure 15-9**

4. Conduit is placed in the bender and bent 20 times. Twenty bends of $4\frac{1}{2}^{\circ}$ will equal $90^{\circ}$.

★ Remember, the start mark is not a bend mark.

**NOTE:** Complete bending instructions are covered in the next Chapter.

**EXAMPLE #2:** Layout a 4" pipe that has a stub height of 51", a 30" radius, and bent in 15 shots ($6^{\circ}$ per shot).

1. **Find the Developed length:**
   Developed length = 1.57 × 30" (radius)
   Developed length = **47.1"**

2. **Locate the Start Mark:**
   Start Mark = Desired Stub height (51") minus the radius (30") + O.D. of the pipe (4½")
   Start Mark = 51" – (30" + 4½")
   Start Mark = 51" – 34½"
   Start Mark = **16½"**
   Locate the Start Mark 16½" from the end of the pipe.

3. **Find spacing between the bend marks.**
   Spacing = Developed length ÷ shots (15)
   Spacing = 47.1" ÷ 15
   Spacing = 3.14" or ≈ **3⅛"**

4. Starting at the Start Mark 16½" from the end of the pipe place 15 marks 3⅛" apart on the pipe. The pipe is now ready to bend.

**Problems:**

1. Find the Start Mark and bend spacing for a 2½" conduit with a 24" radius, a 62" stub using 20 shots.
2. Find the start mark and bend spacing for 4" pipe with a 40" radius, a 68" stub using 30 shots.

Of the several methods of layout in use for segment bending, the author has elected to use the one he feels is easiest to remember. The success of the method describe, as with any method or technique, depends on the electrician's mechanical ability and the equipment being used.

**NOTE:** No matter which bending method is used, if for some reason your stub lengths are consistently too high or too low, make certain you are are performing the bending procedures correctly, then adjust your layout to compensate.

It is extremely important that you check your developing stub length and angle of bend when you have 4 or 5 shots left to bend. Corrections and/or adjustments can be easily made during these last few bends to bring the stub to the correct length or to complete a full $90^{o}$ bend.

If the stub is coming up long, bend more degrees of bend for each remaining shot to bring it up to a full $90^{o}$ without adding additional stub height. If the stub is coming up short, lengthen the spacing between the bend marks to pick-up the necessary added stub length without bending over a $90^{o}$ bend.

**NOTE:** A wallet sized cut-out card with the formula for segment bending is located on the last page of the book on green card stock.

# SEGMENT BENDING TECHNIQUES 16

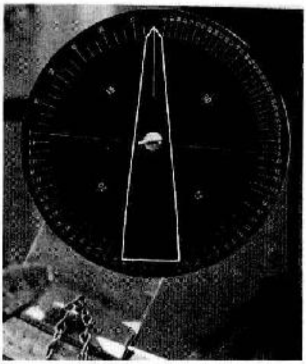
Now that the procedure to layout the conduit with bending marks is understood, the next step is bending the conduit using a hydraulic bender.

As segment bending requires several small angle bends to complete a 90° stub, some method to measure the amount of bend in degrees will be required.

Determining the degree of bend can be done basically four ways:

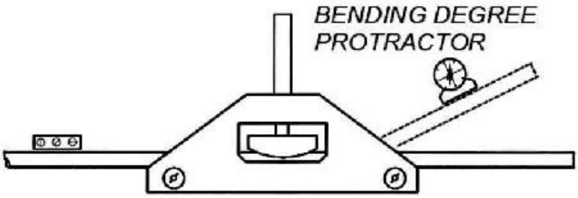
**1. Greenlee Bending Degree Protractor**
The Greenlee Bending Degree Protractor hooks onto the pipe being bent using a spring and chain assembly. The circular face of the protractor is divided into four (4) sections. The sections are marked in increments of 18, 20, 21, and 30 as shown in Figure 16-1.

**Figure 16-1**



**Step 1:** The bender frame is in the upright position and the pipe is leveled as shown in Figure 16-2. Once the conduit is secured in the bender and the bender shoe center mark is on the first **bend mark** (not the start mark) the face of the protractor is rotated to the segment that corresponds to the number of bends (shots) being used. The scale is then "fine" adjusted so the pointer is on 0.

**Figure 16-2**



**Step 2:** The pipe is then bent using the hydraulic pump until the pointer reaches the first mark—bend a little past to compensate for ***spring-back****, release the pressure and check the pointer.

> ****Spring-back*** is a term used to describe the amount a bent pipe tends to straighten after the bending force is removed.

Only a few bends will be needed and you will find just how much you must bend past the mark (over-bend) to compensate for spring-back. Care must be taken with each bend, as a small error multiplied 20 or 30 time is a ***large error***.

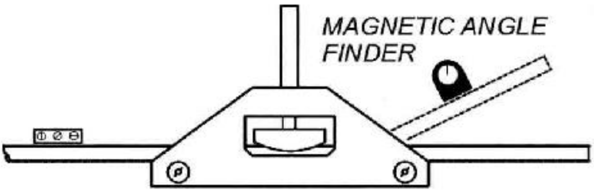
**Step 3:** The pipe is moved forward in the bender to the second bend mark and bent until the pointer reaches the second mark on the protractor face—again bend past the mark to compensate for spring-back.

**Step 4:** The conduit is moved to the third bending mark and the pipe is bent so the pointer is at the third mark—again over bending to allow for spring-back. This procedure is followed at each bend mark until the 90° stub has been achieved.

**NOTE:** It is a good idea to check the developing stub length before the last few bends are made. Make spacing corrections as required. Shorten spacing if stub is coming up long—lengthen spacing if stub is coming up short. If the stub length is reached before the pipe is at 90°—or plumb, **don't bend** any of the remaining bend marks, move the pipe in the bender and bend at the **start mark** to get to 90°. This brings the pipe to plumb without adding to the stub length.

2. **Magnetic Angle Finder** The pipe must be kept level and the bender frame must be upright as shown in Figure 16-3.

**Figure 16-3**



When a magnetic angle finder is used, as with the bending protractor, care must be taken with each bend to eliminate errors.

**Step 1:** Level the conduit and place the magnetic-base angle finder on the stub end of the conduit. The angle finder will indicate the degree of each bend as determined by the number of shots you are using i.e. for 20 shots each bend would be 4½°.

**Step 2:** Pipe is bent until the angle finder indicates just past the desired degree of bend to compensate for spring-back. If the right amount of over-bend was made, the angle finder should read the desired angle of bend. If you over-bent too much at one of the bend marks you can compensate by under bending at the next mark. In two or three bends you will find just the right amount of over-bend to allow for spring-back.

**Step 3:** If the first bend was a 4½° bend the next bend will move the pointer on the angle finder to 9°. The third bend will be completed when the pointer is at 13½° and so on until the 90° bend is completed.

**NOTE:** As with the Bending degree Protractor, check the developing stub length before bending the last few bends so you can adjust the spacing or degree of bend as required.

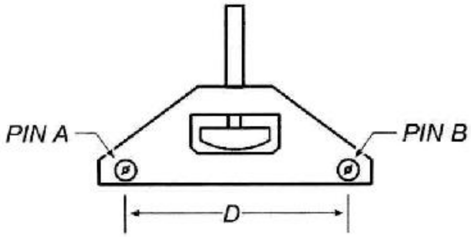
**3. Amount of Travel Method**

With this method the pipe can be bent in **any position** without the pipe having to be level. This method is very similar to the Amount of Travel Method discussed in the "Chicago" bending Chapter 13. It varies only in the method in which the travel figures are found. To find the amount of theoretical travel for a 90° bend, proceed as follows:

**Step 1:** Set up the bender with the pivot shoes in the proper holes for the conduit size that is to be bent.

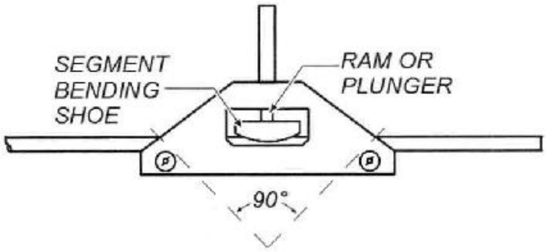
**Step 2:** Measure the distance (D) center-to-center between the pivot shoe pins as shown in Figure 16-4.

**Figure 16-4**



The plunger (also called the ram) will have to travel half this distance to bend a fill 90° stub as shown in Figure 16-5.

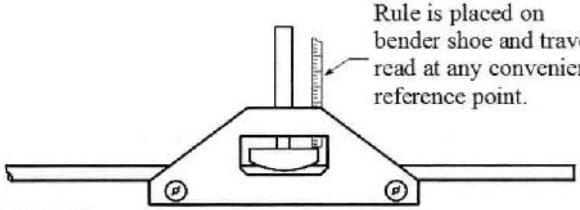
Figure 16-5




The travel required per shot then is ½ the distance from pin to pin divided by the number of shots.

**EXAMPLE:** The distance from the center of the pins is 24" and the pipe is to be bent in 18 shots.
Travel per shot = ½ the distance from center of pins, which is 12", divided by the number of shots which is 18.
Travel per shot = 12 ÷ 18
Travel per shot is .666. .666 is between 5/8" and 11/16". To make the measurements easier, measure 5/8" heavy (+) or measure 11/16" light (−).
Bending using this method will follow a different procedure.
**Step 1:** The center of the bending shoe is placed on the first bending mark (not the Start Mark) and the hydraulic pump is activated until 5/8" + of ram travel is measured as shown in Figure 16-6. ***DO NOT*** allow for spring back with this method.

Figure 16-6




**Step 2:** The pipe is moved to the next bend mark and the pump is activated until another 5/8" + of ram travel has been measured. Continue to move the pipe and measure ram travel. As you approach the last few bending marks (4 or 5), check both the developing stub length and the angle of bend. Spacing and/or amount of travel can be adjusted on the last marks to bring the stub on the "money" or for final truing.

**NOTE:** Once you have found the amount of travel for 90°, we can also find the amount of travel for any other angle for offsets, kicks, etc. Divide amount of travel by 90 and multiply the answer by the desired angle of bend.

**EXAMPLE:** If 90° travel is 12". What is the travel for 22½° ?

12" ÷ 90 = .1333

.1333 × 22½ = 2.999" or 3" of ram travel.

**4. Number of Pumps Method**

With this method the pipe and bender can be **in any position**. This method depends on the idea that a given number of pumps on a manual hydraulic pump will produce the same amount of travel each time. This method may work well today, but next week the same number of pumps may not produce the same amount of travel. The change in travel is caused by a change in fluid level, O-ring condition, and the condition of the pump.

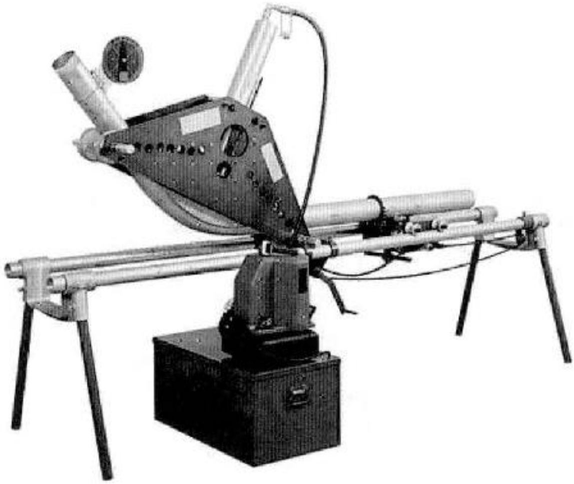
**EXAMPLE:** Using the one-shot shoe—***not the segment shoe***—and a manual hydraulic pump, count each pump until a full 90° bend has been achieved.

If it takes 40 pumps to bend a 90° stub, it should only take 20 pumps to achieve a 45° bend, 10 pumps for 22½°, 2 pumps for a 4½°, etc. As you can see this method should work very well, but will require additional time to determine pump/degree values. But the extra time initially is offset by not having to measure ram travel at each bend mark as required by the Amount of Travel method.

Use the same procedure for bending as outlined in Amount of Travel Method. Check developing stub length and degree of bend prior to bending the last few shots. Use the remaining shots for final adjustments in stub length and truing the 90° bend.

**NOTE:** Use any of one of the four methods that is most convenient, but remember that extreme care and attention to details is required for each method. A small amount of error at each vend will compound itself and accuracy in bending will be impossible to achieve.

To make hydraulic bending easier, a bending table, either a commercial model (Greenlee 1802 Bending Table) as shown in Figure 16-7, or one constructed on the job site. The table will hold the conduit and the bender, making leveling and plumbing easier and produce more accurate bends. The table will also eliminate the need to continually ***wrestle*** the conduit and the bender.

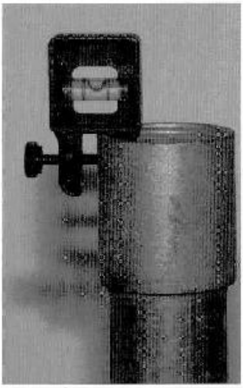


**Courtesy of Greenlee-A Textron Company**

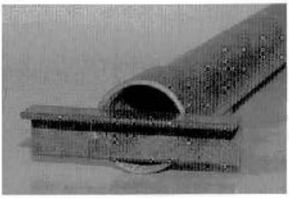
**Figure 16-7**

In the event a table is not available, or impractical due to job conditions, and indispensable bending aid is the WOW Watcher®, or no-dog as shown in Figure16-8. The WOW Watcher® is attached to the end of the conduit and is used for leveling and/or alignment to eliminate wows and dog-legs as the conduit is moved in the bender. The WOW Watcher® is also an indispensable tool when bending offsets, saddles and other multiple-bend pipe jobs. The WOW-Watcher® is made of Vertron®, a space age material that produces a light-weight but strong tool. The tool uses a straight bubble vial so it can accurately indicate level in more than one plane or position. You can order a WOW Watcher® at www.coxco.net.

Figure 16-8



Figures 16-9a and 16-9b show how a leveling device can easily be fabricated on the job by welding a piece of angle iron to a coupling if you don't have a WOW Watcher®.



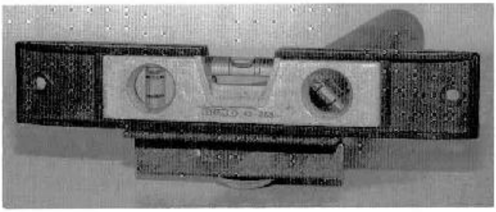


**Figure 16-9a** **Figure 16-9b**

If no welder is available, an alternate method is to clamp uni-stut onto the conduit as shown in Figure 16-10a and b for a base for your level.

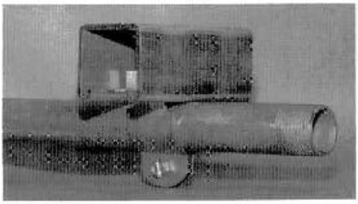


**Figure 16-10a**

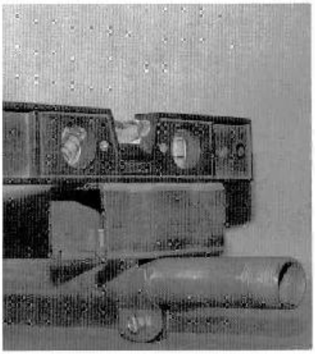


**Figure 16-10b**

Although not as mechanically sound, a hacksaw blade and a coupling may be used as shown in Figures 16-11a and b. Saw a slot across the coupling and insert a saw blade, the slot is then peened to hold the blade fast.

**Figure 16-11a**

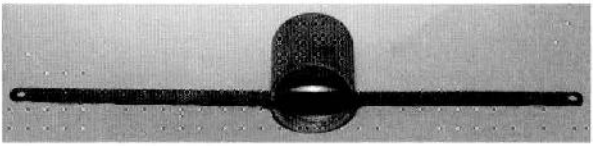
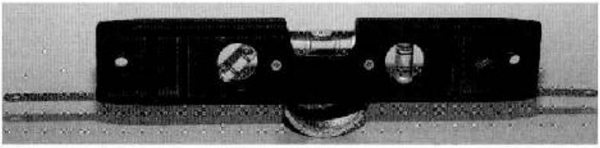


**Figure 16-11b**



## Segment Offsets

To bend offsets or any other bend of less than 90° will require little new information.

We will need to determine the radius, find the developed length and spacing between bend marks, much the same way we did for 90° stubs.

The formula we use if the bend is less than 90° is:

Developed Length for < 90° = Radius × Degree of bend × .0175*

*.0175 is 1.57 ÷ 90

**EXAMPLE:** Find the developed length for a 30° bend with a 20" radius.

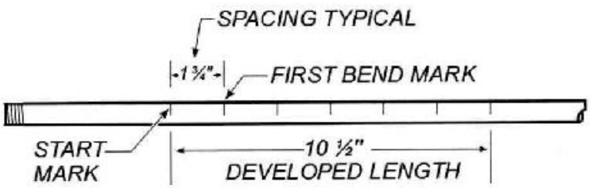
Radius (20") × Degree of bend (30°) × .0175 = **10.5"** Developed length.

Next we need to determine spacing.

Remember the rule for smooth bends, not less than 3° nor more than 6° bends. Let's do this job using 5° bends. It will take 6 bends of 5° to make our 30° bend. (6 × 5° = 30°)

Developed length ÷ number of shots (6) = 1.75" spacing as shown in Figure 16-13.

Figure 16-13




**EXAMPLE**: Consider a typical offset bending job: an 8" offset in a 3" pipe:

1. Determine the radius: If space is no problem, 8 times the trade size of the conduit would be 24" radius. 8 × 3" = 24"
2. Determine the angle of offset to use. If space is not a problem, smaller bends make easier wire pulling. Let's use 20° bends.
3. Find the Developed length (D.L.):
   Radius (24") × Degree of bend (20°) × .0175 = 8.4" D.L.
4. Number of bends (shots): For smoothness of bend, use 4° bends. 5 shots will give us 20° offset bends.
5. Spacing between shots = D.L. ÷ Shots
   8.4" ÷ 5 = 1.68" or ≈ 11 1/16"—rounded to the nearest 1/16"

***For accuracy we will round to the nearest 16th of an inch bend spacing measurements.***

6. Spacing between offset bends: Height of the obstruction was 8". 8" × 2.92 (offset multiplier for 20°) = 23.39 or ≈ **23⅜"** between the bend A and B.
7. Layout pipe and bend as shown in Figure 16-14.

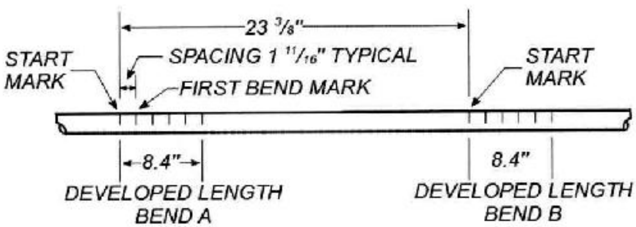



**Figure 16-14**

It should be noted at this point that all multipliers and shrink values listed and discussed earlier in the text may be applied to segment bending regardless of pipe size.

Bending offsets of more than 30° and larger than normal radius the pipe may end up too long when shrink is used and the pipe is cut and threaded before bending. This is caused by gain in the two offset bends. Although correction factors will depend on the equipment being used, Table 16-15 should be close enough for most equipment.

**Table 16-15**

| Angle of Offset Bend | 30° | 37½° | 45° | 60° |
|---|---|---|---|---|
| Correction Factor | .0124 | .0212 | .0430 | .1076 |

To apply the correction factor:
Locate the correction factor under the angle of offset bend. Multiply this value times the radius of bend. The answer (product) is deducted from the total pipe length after all other standard calculations have been made.

**EXAMPLE:** Using the offset as shown in Figure 16-16 find:

Total Shrink:

Height of obstruction (18") × ⅜" = 6⅜"

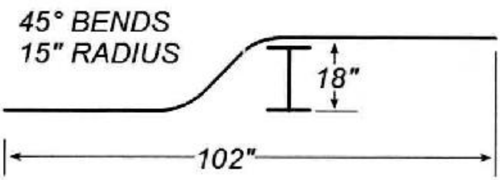
Total Pipe Length:

Total Dimension (102") + Shrink (6⅜") = 108¾"

Under the 45° column is listed a correction factor of .0430. This value (.0430) is multiplied by the radius of the bend (15").

.0430 × 15" = .654 or ≈ ⅝"

A correction factor of ⅝" is subtracted from the total pipe length. 108¾" − ⅝" = **108⅛"** for the adjusted total pipe length as shown in Figure 16-16.




This correction factor as indicated is very general and may have to be adjusted up or down as you find necessary.

## Segment Saddles

Regular saddles will be bent as outlined earlier in the text. A saddle is simply two offsets, so using the previous information and that just covered in Segment Offsets, bending hydraulically should pose no problem.

The ***three bend saddle*** bent hydraulically must be changed a bit and bend as two complete offsets tight together. This type of saddle is still used primarily for bridging round obstructions as shown in Figure 16-17.

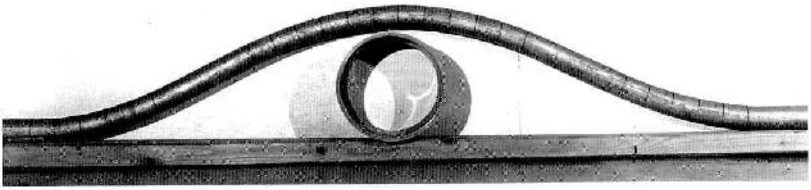


**Figure 16-17**

The angle selected for the bends should be as small as possible to leave plenty of straight pipe between Bends 1 and 2 and also between Bends 3 and 4. The minimum length of straight pipe required will be determined by the distance from the center of the bending shoe to the pivot shoe. If the length is not long enough you will take bend out of Bend 1 when trying to bend at Bend 2.

Bends 1 and 2 are identical to Bends 3 and 4, so the layout is also identical as shown in Figure 16-18.

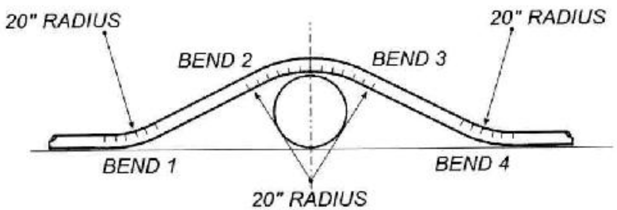
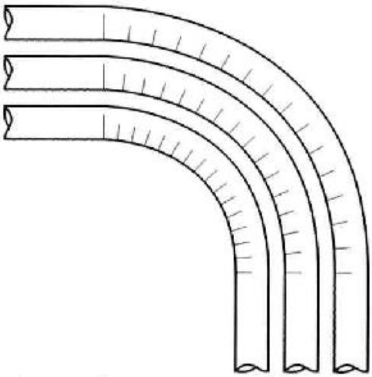



**Figure 16-18**

## Concentric 90° Bends

Concentric is defined as having a common center or axis. Notice in Figure 17-1 that starting from the inside pipe, each pipe has an increasing radius.

**Figure 17-1**



Concentric pipe work requires no new layout techniques, only increasing the radius of the next pipe to maintain even spacing.

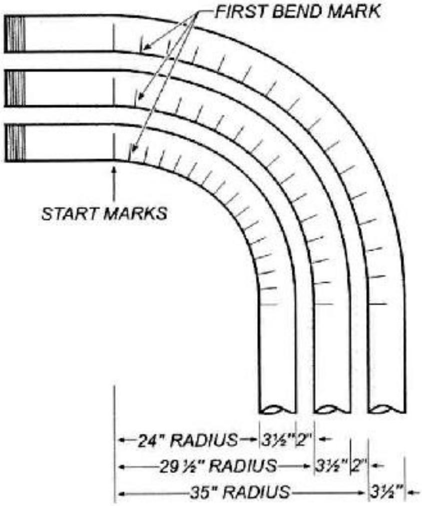
The layout for concentric pipe is quite simple then. The radius of the first pipe is determined and the bend marks which were discussed earlier are laid out for a segment bent 90° stub. The second radius is found by adding to the radius of the first pipe, the O.D. of the first pipe, and the desired spacing between pipes.

**EXAMPLE:** As shown in Figure 17-2 the radius of the first pipe is 24", the O.D. of the first pipe is 3½" and the spacing is 2". By adding the radius of the first pipe (24") + O.D. of the first pipe (3½") + the spacing (2") between the first and second pipe we get a value of 29½". The value of 29½" then will be the radius of the second pipe as shown in Figure 17-2.

Once the Developed length of the second radius is found, the spacing between the bend marks can determined. Notice in Figure 17-2 that the Start mark for the second pipe is the same distance from the end of the pipe as the first pipe. This will be true for each additional pipe as well.

The spacing will increase between bend marks as the radius of the pipes increase. This is due to the increasing Developed length. All three pipes in Figure 17-2 are 3" rigid pipe laid out with 15 shots.

**Figure 17-2**




If the spacing between the bend marks becomes too wide, the radius will not appear smooth. To compensate, increase the number of shots, which will make the marks closer together and smooth out the radius. The start mark, however, must remain the same as the previous pipes.

**EXAMPLE:**

Determine the concentric layout for three pipes.

**#1 pipe** will be the inside pipe and is 2" rigid with a stub length of 48" and a radius of 18".

**#2 pipe** is 3½" rigid.

**#3 pipe** is 2½" rigid.

Spacing between the pipes is **2"**.

All pipe to be bent with 20 shots

**Pipe #1—Figure 17-3**

Developed length (D.L.) = Radius (18") × 1.57

D. L. = 28.26" or ≈ **28¼"**

Spacing = D.L. ÷ shots  Spacing = 28.26" ÷ 20

Spacing = 1.413 or ≈ **1 7/16"** rounded to the nearest 1/16th

Start mark = Stub length – (radius + O.D.)

Start mark= 48" – (18 + 2⅜")

Start mark = 48" – 20⅜"

**Start Mark = 27⅝"**

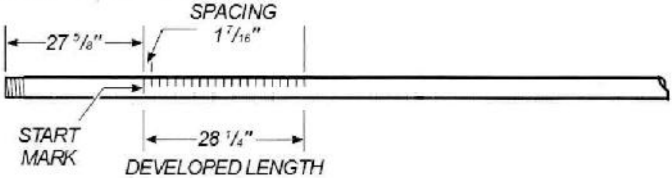



**Figure 17-3**

**Pipe #2—Figure 17-4**

Radius = Pipe #1 radius + Pipe #1 O.D. + Spacing

Radius = 18" + 2⅜" + 2"

**Radius = 22⅜"**

Developed length = Radius × 1.57

Developed length = 22⅜" × 1.57

Developed length = 35.129" or ≈ **35⅛"**

Spacing = D. L. ÷ shots     Spacing = 35.125" ÷ 20

Spacing = 1.756 or ≈ **1¾"**

Stub length = Pipe #1 stub + spacing + O.D. Pipe #2

Stub length = 48" + 2" + 4"

**Stub length = 54"**

Start mark = Stub length – (radius + O.D.)

Start mark = 54" – (22⅜" + 4")

Start mark = 54" – 26⅜"

**Start mark = 27⅝"**

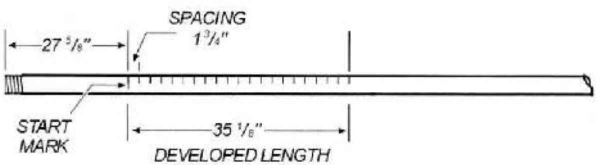



**Figure 17-4**

**NOTE:**

Start mark for Pipe #2 is the same as the start mark for Pipe #1

**Pipe #3—Figure 17-5**

Radius = Pipe #2 radius + Pipe #2 O.D. + Spacing

Radius = 22⅜" + 4" + 2"

Radius = 28⅜" or **28.375"**

Developed length = Radius × 1.57
Developed length = 28.375 × 1.57
Developed length = 44.548 or **44.½"**
Spacing = D. L. ÷ shots Spacing = 44.5" ÷ 20
Spacing = 2.225 or ≈ **2¼"**
Stub length = Pipe #2 stub + spacing + O.D. Pipe #3
Stub length = 54" + 2" + 2.875"
Stub length = 58.875" or **58⅞"**
Start mark = Stub length – (radius + O.D.)
Start mark = 58.⅞" – (28⅜" + 2⅞")
Start mark = 58.⅞" – 31¼"
**Start mark = 27⅝"**

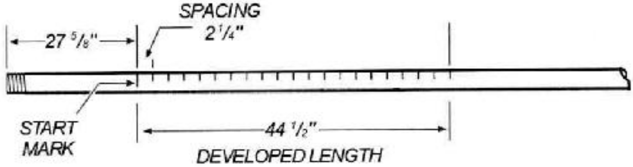



**Figure 17-5**

**NOTE:**
Start mark for Pipe #3 is the same as the start mark for Pipe #1 and #2.

## Concentric Offsets

Use the same procedure as with 90° stubs. Increase the radius of the second pipe, an amount equal to the radius of the first pipe, **plus** O.D. of the first pipe, **plus** the spacing desired between the pipes as shown in Figure 17-6.

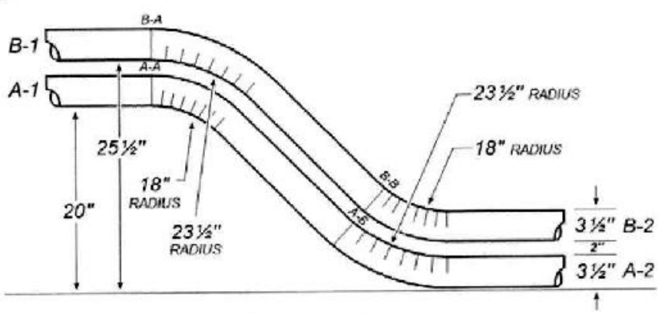



**Figure 17-6**

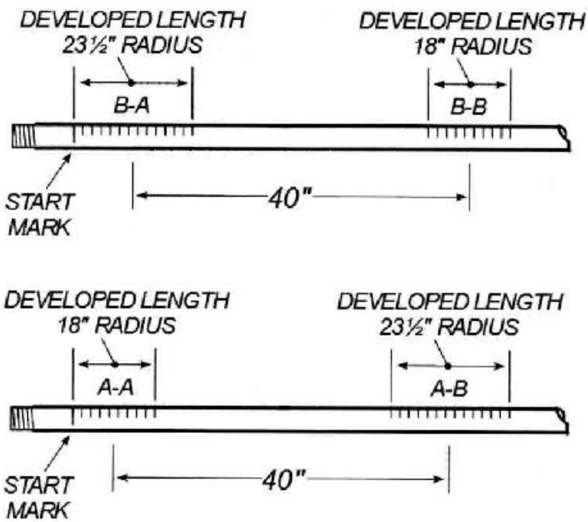
This applies to ends A-1 and B-1, notice, however, the ends A-2 and B-2 are in reverse order.

This layout will be necessary if perfect fitting parallel run conduits are to be achieved.

Spacing between bend marks A-A and A-B is found as with any offset:

> Desired offset height (20") × Offset multiplier for 30° (2) = 40" between A-A and A-B. As the offset will be bent using two different radii, the spacing (40") must be from the ***center*** of developed length A-A to ***center*** of developed length A-B as shown in Figure 17-7.

**Figure 17-7**




Although the examples used to explain offset bending had several shots per bend, it should be clearly understood that fewer shots can be used. Successful offsets can be made with only 2 or 3 shots per bend.

Bending parallel offsets in this manner is rewarding from a technical standpoint, but is, however, time consuming.

It is the author's contention that with offsets, 90° bends, or any other segment bends, that the additional time spent bending smoother radius bends (more shots) is gained back when it is time to pull the wires into the completed raceway.

## One-Shot Parallel Offsets

Parallel offsets of different pipe sizes can still be bent and aligned perfectly if all pipe are bend with the same one-shot shoe. This will work with 2", 1½", and 1¼" pipe sizes and depending on the manufacturer and the ductility of the pipe 2½", 2", 1½", and 1¼" can all be bent on the same 2½" one-shot shoe. 3", 3½" and 4" pipes can usually be bent on the 4" shoe. Again it will depend on the ductility of the pipe and you will just have to experiment with the different sizes of pipe and shoes to find out what will work with the equipment you are using.

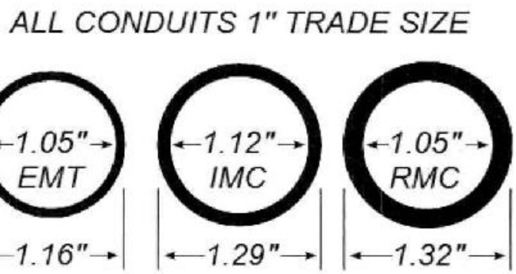
# INTERMEDIATE METAL CONDUIT (IMC) 18

Intermediate metal conduit, or IMC for short, is a rigid steel electrical conduit that is lighter in weight than standard rigid metal conduit (RMC). It offers the same protection to conductors as Rigid, but with much less weight and wall thickness.

IMC has other advantages over Rigid, it has a larger interior diameter and the smoother interior of the pipe allows for easier wire pulling through the conduit.

Intermediate Metal Conduit as the name implies is intermediate (between) EMT and Rigid. Figure 18-1 shows a comparison of wall thickness. Even with its reduced wall thickness IMC is cut, reamed and threaded with standard pipe equipment.

**Figure 18-1**




IMC is available in trade sizes: ½", ¾", 1", 1¼", 1½", 2", 2½", 3", 3½" and 4". Intermediate Metal Conduit is manufactured in standard lengths and is threaded on each end. The standard thread, called the National Pipe Thread (NPT) is a U.S. standard for tapered threads used on threaded pipes. The taper rate for all NPT threads is $\frac{1}{16}$ ($\frac{3}{4}$ inch per foot) measured by the change of diameter (of the pipe thread) over distance.

The threaded couplings that are used to connect, or join two pieces of IMC together have no taper, or have straight threads (NPS). By not having a taper, more threads can be engaged, making for a better electrical connection which enables the conduit to be used as an equipment grounding conductor.

The thread protectors for IMC are a different color than Rigid to make it easy to distinguish IMC from Rigid. The thread protectors are ***Yellow*** for sizes ½", 1½", 2½", and 3½". ***Green*** is used for sizes ¾" and 1¼" and ***Orange*** is used for 1", 2", 3", and 4".

NEC® Article 345 governs the use and installation of IMC.

## Bending IMC

With the difference in O.D., thinner wall thickness and the hardness of the metal that gives it its strength, additional support must be provided to the sidewalls for successful bending larger sizes.

**Hand Bending:** ½", ¾", and 1" trade sizes can be accomplished with hand benders that are designed to bend IMC.

Hickey bending of IMC is not recommended. The design of the Hickey does not give the required support to the sides of the conduit. If there is no other way available, IMC can be bent with a Hickey, but it must be done with very small "bites" to avoid collapsing the pipe.

**"Chicago" type Benders:** IMC can be bent using existing rigid shoes for sizes ½", ¾", and 1". Bending shoes rated for IMC and Rigid can also be used for bending 1¼" and 1½".

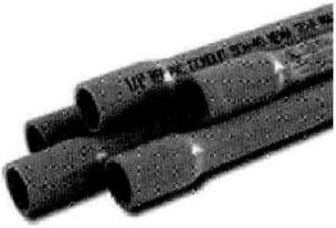
**Electric Benders:** Electric benders are available that will bend ½" through 2" IMC. One such bender is the Greenlee 555, often referred to as the **triple nickel** in the field, and one of the most popular benders is shown in Figure 18-2.

**Figure 18-2**

**Greenlee 555 Electric Bender**

**Hydraulic Benders:** Hydraulic benders can be used for bending ½" through 4" IMC. Older hydraulic benders may need conversion attachments for successful bending IMC. There are hydraulic benders designed specifically for bending IMC. A quick check on the internet will provide you with a list of equipment that will bend IMC.

# RIGID NONMETALIC CONDUIT (RNC) 19



Rigid Nonmetallic Conduit (RNC) is the lightest weight of all the conduits and is available in Schedule 40, Schedule 80, and Type A and are available in trade sizes ½" through 6". The pipe is made with Polyvinyl Chloride and is referred to in the field as PVC.

Type A is a thin wall rigid non-metallic conduit referred to as EPT and is listed for concrete encasement **only**.

While Schedule 40 PVC conduit has a thicker wall thickness than Type A, it is **not allowed** to be used in areas of physical damage.

Schedule 80 PVC conduit has the thickest wall thickness and is listed for uses in areas of **physical damage**.

PVC is manufactured in standard 10′ length which includes a coupling. The coupling may be molded into the conduit when it was manufactured, as shown above, or a separate coupling is cemented (glued) to the pipe by the manufacturer. For specific applications it may be shipped in shorter or longer lengths, with or without a coupling.

## Bending PVC

PVC is heated and then bent. This is normally done by one of two methods. One method is to use a Heat box with an electrical heating element, while the other method uses propane to heat a liquid for heating and bending the PVC.

Heat box benders come in different sizes to handle all sizes of PVC. Figure 19-1 shows a larger heat box bender.

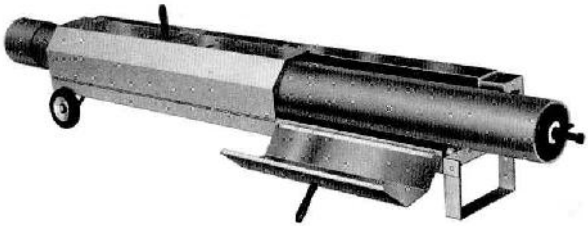


**Figure 19-1**
**Courtesy Carlton**

The conduit is placed in the box and slowly rotated on the rollers so heat is evenly distributed. When the pipe become flexible, it is removed from the box, shaped to the desired bend configuration and set, or cooled, by wiping with wet rags. Figure 19-2 shows a pipe being removed from the box after being heated.

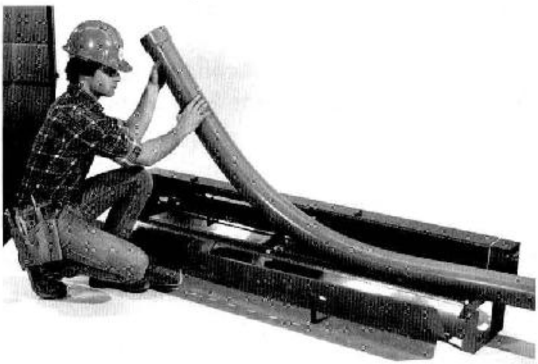
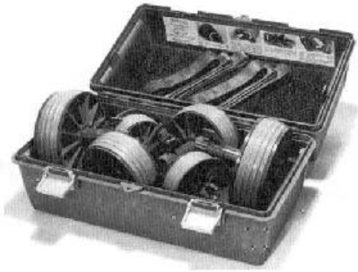


**Figure 19-2**
**Courtesy Carlon**

**NOTE:** The author has found that wearing standard household hot mitts (oven mitts) and dipping them in a bucket of cold water is easier and faster than using rags. The mitts allow the hands to form around the pipe making cooling and setting the hot pipe is quicker.

Bending PVC pipe 2" and larger with a heat box will require using an air-tight plug in each end of the conduit as shown in Figure 19-1. The plugs hold the hot expanding air inside the pipe. This heats the inside of the conduit and the expanded air make bending possible without collapsing the pipe walls. The plugs ***must*** remain in place until the pipe is cooled and set. Figure 19-3 shows a box of pipe plugs.

Figure 19-3
Courtesy Carlon

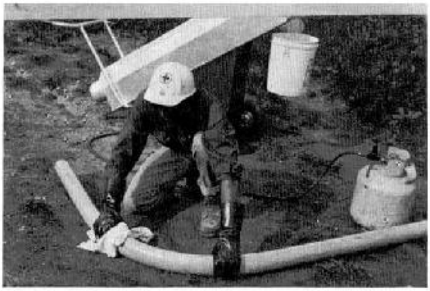


The PVC bender in Figure 19-4 operates on propane gas that heats a liquid (Triethylene Glycol) that surrounds the pipe. The pipe is left in the heated fluid until the pipe is pliable. It is then removed from the bender, formed (Figure 19-5) and the cooled to set as shown in Figure 19-6.

**Figure 19-4**
**Heating**
Courtesy Greenlee


**Figure 19-5**
**Forming**
Courtesy Greenlee


**Figure 19-6**
**Cooling**
Courtesy Greenlee



Another method of bending PVC is by using an electric Bender Blanket as illustrated in Figure 19-7. The blanket is wrapped around the PVC pipe which heats it for bending.

**Figure 19-7**
Courtesy Enerpac

**NOTE:** Field bends can be made with some success using a torch. Care must be exercised as the PVC will take on a brownish color if the flame is brought too close to the conduit. Placing the PVC inside a piece of larger EMT and then heating as shown in Figure 19-8 helps eliminate the chance of scorching. Packing the EMT pipe with wet rags will help hold the heat in to soften the PVC quicker. Scorched pipe may be rejected by some inspection authorities.

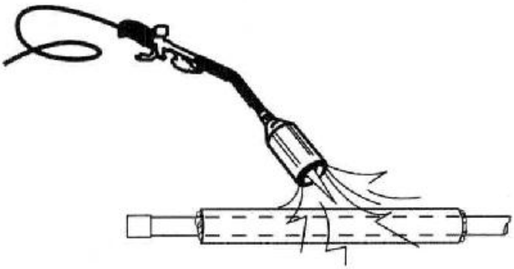
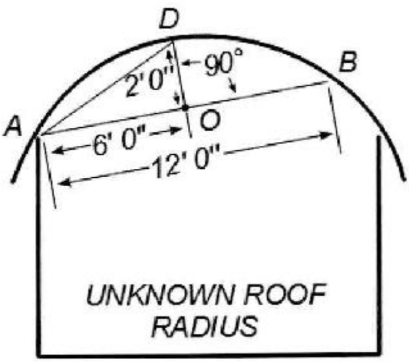


**Figure 19-8**

# FINDING AN UNKNOWN RADIUS 20

The following procedure may be used to find the radius for large tanks, silos, or curved roofs as shown in Figure 20-1.

**Figure 20-1**




**Formula:** Radius equals the cord of half the arc squared divided by twice the height of the arc.

$$R = \frac{C^2}{2A}$$

***R*** = Radius ***C*** = Cord of Half the Arc ***A*** = Height of Arc

The cord of the arc is found by laying out two points on the circle—**A** and **B** and measure between the points. Figure 20-1 shows points A and B and shows a measurement of 12′ 0″. For ease of figuring, Point A and B can be set at even spacing, i.e. 8′, 10′, 12′, etc. This makes locating the ***center of the cord*** easier and facilitates finding the height of the arc (A-O in Figure 20-1 illustrates the center of the cord) .

The ***height of the arc*** is found by measuring at a right angle from the center of the ***cord of the arc*** to the outside of the circle. Line **O-D** in Figure 20-1 would be the height of the arc.

***Cord of half the arc*** is the measurement from Point **A** to Point **D** which is the hypotenuse of the ***right triangle*** created by Point A to Point O and Point O to Point D as shown in Figure 20-1. Using Pythagorean Theorem (as discussed in Chapter 1) we can find the value of the hypotenuse—or the ***cord of half the arc***.

Using Pythagorean Theorem

$H = \sqrt{A^2 + O^2}$ ***H*** = Hypotenuse or ***Cord of half the arc*** (A-D)
***A*** = Adjacent side (A-O)
***O*** = Opposite side (O-D)

**Substitute and Solve:**
$H = \sqrt{6^2 + 2^2}$ $H = \sqrt{36 + 4}$ $H = \sqrt{40}$ $H = 6.32$

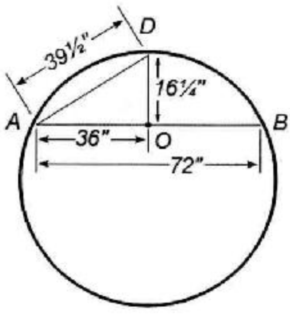
***Cord of half the arc = 6.325′***

Using the formula $\boldsymbol{R} = \frac{C^2}{2A}$
Substitute and solve: $R = \frac{6.325^2}{2 \times 2}$ $R = \frac{40.00}{4}$ $\boldsymbol{R = 10.00'}$
***Radius*** = 10′-0″

If the cord of half the arc can be measured as shown in Figure 20-2, the radius can be determined without using Pythagorean Theorem and applying the values directly to the formula:
$\boldsymbol{R} = \frac{C^2}{2A}$ ***R*** = Radius ***C*** = Cord of half the Arc ***A*** = Height of Arc

Substitute and solve: $R = \frac{C^2}{2A}$ $R = \frac{39.5^2}{2 \times 16.25}$ $R = \frac{1560.25}{32.5}$ $\boldsymbol{R = 48.0}$

***Radius of the circle is 48″***

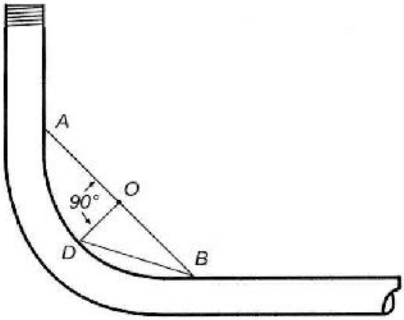



**A-B** = Cord of Arc
**O** = Center point Cord of Arc
**O-D** = Height of Arc
**A-D** = Cord of Half the Arc

**Figure 20-2**

The radius can be found of an existing pipe as shown in Figure 20-3 by using the same procedure as outlined for the curved roof (Figure 20-1) or the silo (Figure 20-2).

**Figure 20-3**




**EXAMPLE:**

1. Find the radius of an existing pipe if the cord of arc is 20" and the height of the arc is 3".

   If the cord of arc is 20" (A-B) the center of the arc will be 10" (A-O).
   Height of arc is 3" (O-D)

   $Cord\ of\ half\ the\ arc = \sqrt{10^2 + 3^2}$

   $Cord\ of\ half\ the\ arc = \sqrt{100 + 9}$

   $Cord\ of\ half\ the\ arc = \sqrt{109}$ ***Cord of half the arc = 10.44***

   $R = \frac{C^2}{2A}$ $R = \frac{10.44^2}{2 \times 3}$ ***Radius = 18.165 or ≈ 18 3/16"***

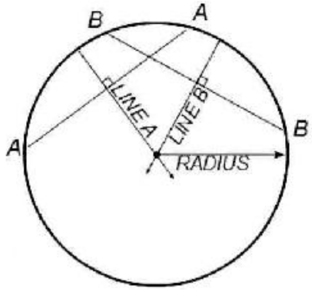
**PROBLEM:**

1. Find the radius of a silo with the following dimensions: Cord of the arc is 4′ 10"; height of the arc is 5′ 4". It may easier if you convert feet to inches, do the calculations and then convert back to feet and inches. The answer at the back of the book will solve the problem using feet and then inches.

**ALTERMATE METHODS**

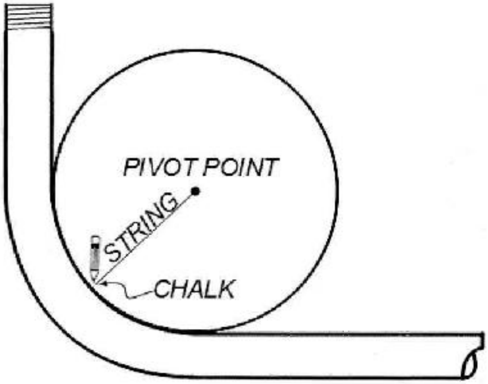
Another method of determining an unknown radius is to establish two cord of arc lines and locate the center of each cord. Lines are then established at right angles from the center of each cord. The intersection of these lines will be the center of the circle. The radius may then be found by measuring from this point to the outside of the circle as shown in Figure 20-4.

Figure 20-4




An alternate and purely trial and error method to determine the radius of an existing bend requires only a string and a piece of chalk, or other suitable marking device. The chalk is attached to one end of the string and a pivot point is found that will duplicate the shape of the bend. When this point is located a complete circle is drawn. The radius can now be found by measuring from the pivot point to the outside edge of the circle as shown in Figure 20-5.

Figure 20-5



# BENDING PIPE WITH LARGER THAN NORMAL RADIUS 21

Once the radius has been determined as outlined in Chapter 20 or obtained from the job plans or prints, the layout for bending pipe that must conform to the walls of large grain silos, circular storage tanks, etc. is basically a segment layout calculated from the radius expressed in feet.

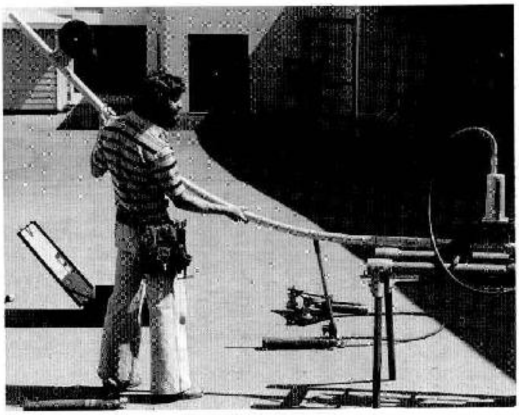
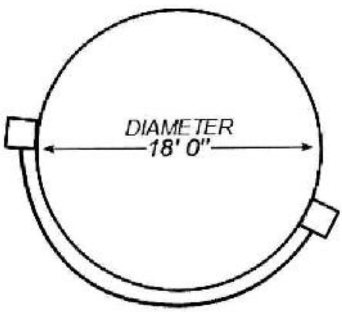


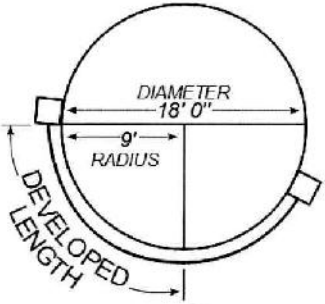
Figure 21-1 shows a larger than normal radius bending job. The Figure shows a storage tank that is 18′ in diameter with rigid conduit running between two junction boxes.

**Figure 21-1**




If the diameter of the tank is 18 feet, the radius will be 9 feet (½ the diameter = Radius) as shown in Figure 21-2. The radius of 9′ will be used for calculating the spacing between the bend marks for segment bending the conduit.

**Figure 21-2**




Regardless of the actual distance between the boxes, we must first calculate the developed length for a radius of 9 feet to determine the spacing between the bend marks. This spacing will then be typical for the entire length of the conduit run.

**NOTE:** The formulas for segment layout are covered in detail in Chapter 15.

To find the developed length or the amount of pipe that will be required to bend a given radius. ***Developed Length = Radius × 1.57***

First, convert any radius in feet to radius in inches. 9' × 12" = 108"

Developed Length = 108" × 1.57 ***Developed Length = 169.56"***
The developed length of 169.56" is the amount of conduit that will be required to bend a pipe with a 108" (9 foot) radius.

The developed length can now be divided into segments for bending. Remember from our previous discussion on segment bending that the smaller the degree of bend, the smoother the radius will be. This is especially important with larger than normal radius bending if the finished pipe is to look right and conform well to the tank wall.

Bending 5° per segment (shot) will give us the smooth appearance we want. The radius of 108" with a developed length of 169.56" will require 18 shots. 90° ÷ 5° = **18 shots**.

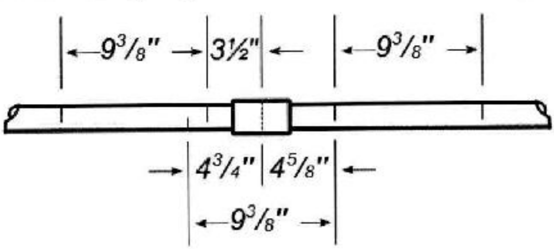
By dividing the developed length of 169.56" by 18, we get a spacing between bend marks of: $\frac{169.56}{18} = 9.42"$ or $\approx$ **9⅜".**

Referring back to Figure 21-2, it is important to remember that the developed length only make up one quarter (¼) of the circumference of the storage tank. The actual pipe between the junction boxes is greater than ¼ of the circumference of the tank. The actual distance can be measure to determine the total pipe required. The spacing between bend marks and degree of bend will be the same for the entire length of pipe required.

For this problem we will assume the actual measurement between the boxes is 38′ 9⅞" or 465⅞". By dividing this value of 465⅞" by 120" (the nominal length for one stick of rigid conduit including the coupling) we get 3.88. This means that this job will require 4 sticks of rigid conduit.

The only thing left to consider before starting the layout is the couplings that will be required to connect the pieces of pipe together. We cannot bend on the couplings, so the layout must be adjusted accordingly. If 9⅜" is the spacing between the bend marks, we should have bend marks 4 11/16" (9⅜" ÷ 2) or approximately 4¾" on either side of the center of the couplings. This will probably require that one or more pieces of pipe will need to be cut and threaded to make the layout come out right. If the layout, however, comes within 1" or 1½" of the desired measurement of the coupling, the marks can be adjusted to approximately the desired spacing without adversely affecting the total pipe job and thus eliminate the need for cutting and threading. Figure 21-3 illustrates the concept.

**Figure 21-3**




The first pipe should be laid out with the first bend mark at 4¾" (approximately half of 9⅜") from the end of the pipe and the remaining marks placed 9⅜" apart. This will give the conduit run the same smooth appearance from the junction box and at each coupling as shown in Figure 21-4.

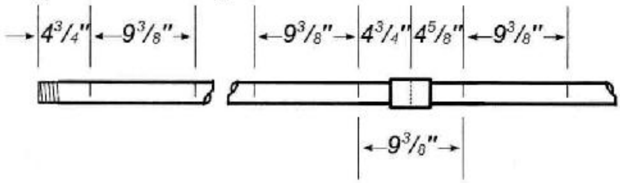
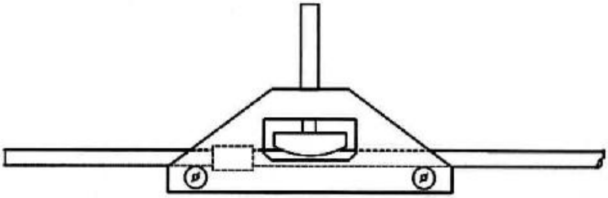



**Figure 21-4**

To make the bends at the first few bend marks when using a hydraulic bender, screw a short piece of pipe on the end of the conduit you are bending so the conduit can be supported on the pivot shoe as shown in Figure 21-5.

**Figure 21-5**



This method can also be used when short stubs are required for regular radius segment bends.

**NOTE:** Be sure the coupling and the short piece of pipe are made up wrench tight when employing this technique to prevent damage to the threads.

When bending larger than normal radius pipe with a "Chicago" style bender the pipe will need to be removed from the bender and reversed for the last few bends.

## DECIMAL AND METRIC EQUIVALENT OF COMMON FRACTIONS OF AN INCH

| FRACTION | DECIMAL | METRIC EQUIVALENT |
|---|---|---|
| 1/32 | .03125 | .794 |
| 1/16 | .06250 | 1.588 |
| 3/32 | .09375 | 2.381 |
| 1/8 | .12500 | 3.175 |
| 5/32 | .15625 | 3.969 |
| 3/16 | .1875 | 4.763 |
| 7/32 | .21875 | 5.556 |
| 1/4 | .25000 | 7.938 |
| 9/32 | .28125 | 7.144 |
| 5/16 | .31250 | 7.938 |
| 11/32 | .40625 | 8.731 |
| 3/8 | .37500 | 9.525 |
| 13/32 | .40625 | 10.319 |
| 7/16 | .43750 | 11.113 |
| 15/32 | .46875 | 11.906 |
| 1/2 | .5000 | 12.700 |
| 7/32 | .53125 | 13.494 |
| 9/16 | .56250 | 14.288 |
| 19/32 | .59375 | 15.081 |
| 5/8 | .62500 | 15.875 |
| 21/32 | .65625 | 16.669 |
| 11/16 | .68750 | 17.483 |
| 23/32 | .71875 | 18.256 |
| 3/4 | .75000 | 19.050 |
| 25/32 | .78125 | 19.844 |
| 13/16 | .81250 | 20.638 |
| 27/32 | .84375 | 21.431 |
| 7/8 | .87500 | 22.225 |
| 29/32 | .90625 | 23.019 |
| 15/16 | .93750 | 23.813 |
| 31/32 | .96875 | 24.606 |
| 1 | 1.0000 | 25.400 |

# TRIGONOMETRIC TABLE

| ANGLE | SINE | COSINE | TANGENT | COTANGENT | COSECANT |
|---|---|---|---|---|---|
| 1 | .0175 | .9998 | .0175 | 57.2900 | 57.2987 |
| 2 | .0349 | .9994 | .0349 | 28.6363 | 28.6537 |
| 3 | .0523 | .9986 | .0524 | 19.0811 | 19.1073 |
| 4 | .0698 | .9976 | .0699 | 14.3007 | 14.3356 |
| 5 | .0872 | .9962 | .0875 | 11.4301 | 11.4737 |
| 6 | .1045 | .9945 | .1051 | 9.5144 | 9.5668 |
| 7 | .1219 | .9925 | .1228 | 8.1443 | 8.2055 |
| 8 | .1392 | .9903 | .1405 | 7.1154 | 7.1853 |
| 9 | .1564 | .9877 | .1584 | 6.3138 | 6,3925 |
| 10 | .1736 | .9848 | .1763 | 5.6713 | 5.7588 |
| 11 | .1908 | .9816 | .1944 | 5.1446 | 5.2408 |
| 12 | .2079 | .9781 | .2126 | 4.7046 | 4.8097 |
| 13 | .2250 | .9744 | .2309 | 4.3315 | 4.4454 |
| 14 | .2419 | .9703 | .2493 | 4.0108 | 4.1336 |
| 15 | .2588 | .9659 | .2679 | 3.7321 | 3.8637 |
| 16 | .2756 | .9613 | .2867 | 3.4874 | 3.6280 |
| 17 | .2924 | .9563 | .3057 | 3.2709 | 3.4203 |
| 18 | .3090 | .9511 | .3249 | 3.0777 | 3.2361 |
| 19 | .3256 | .9455 | .3443 | 2.9042 | 3.0716 |
| 20 | .3420 | .9397 | .3640 | 2.7475 | 2.9238 |
| 21 | .3584 | .9336 | .3839 | 2.6051 | 2.7904 |
| 22 | .3756 | .9272 | .4040 | 2.4751 | 2.6695 |
| 23 | 3907 | .9205 | .4245 | 2.3559 | 2.5593 |
| 24 | .4067 | .9135 | .4452 | 2.2460 | 2.4586 |
| 25 | .4226 | .9063 | .4663 | 2.1445 | 2.3662 |
| 26 | .4384 | .8988 | .4877 | 2.0503 | 2.2812 |
| 27 | .4540 | .8910 | .5095 | 1.9626 | 2.2027 |
| 28 | .4695 | .8829 | .5317 | 1.8807 | 2.1301 |
| 29 | .4848 | .8746 | .5543 | 1.8040 | 2.0627 |
| 30 | .5000 | .8660 | .5774 | 1.7321 | 2.0000 |
| 31 | .5150 | .8572 | .6009 | 1.6643 | 1.9416 |
| 32 | .5299 | .8480 | .6249 | 1.6003 | 1.8871 |
| 33 | .5446 | .8387 | .6494 | 1.5399 | 1.8361 |
| 34 | .5592 | .8290 | .6745 | 1.4826 | 1.7883 |
| 35 | .5736 | .8192 | .7002 | 1.4281 | 1.7434 |
| 36 | .5878 | .8090 | .7265 | 1.3764 | 1.7013 |
| 37 | .6018 | .7986 | .7536 | 1.3270 | 1.6616 |
| 38 | .6157 | .7880 | .7813 | 1.2799 | 1.6243 |
| 39 | .6293 | .7771 | .8098 | 1.2349 | 1.5890 |
| 40 | .6428 | .7660 | .8391 | 1.1918 | 1.5557 |
| 41 | .6561 | .7547 | .8693 | 1.1504 | 1.5243 |
| 42 | .6691 | .7431 | .9004 | 1.1106 | 1.4945 |
| 43 | .6820 | .7314 | .9235 | 1.0724 | 1.4663 |
| 44 | .6947 | .7193 | .9657 | 1.0355 | 1.4396 |
| 45 | .7071 | .7071 | 1.0000 | 1.0000 | 1.4142 |

| ANGLE | SINE | COSINE | TANGENT | COTANGENT | COSECANT |
|---|---|---|---|---|---|
| 46 | .7193 | .6947 | 1.0355 | .9657 | 1.3902 |
| 47 | .7314 | .6820 | 1.0724 | .9325 | 1.3673 |
| 48 | .7431 | .6691 | 1.1106 | .9004 | 1.3456 |
| 49 | .7547 | .6561 | 1.1504 | .8693 | 1.3250 |
| 50 | .7660 | .6428 | 1.1918 | .8391 | 1.3054 |
| 51 | .7771 | .6293 | 1.2349 | .8098 | 1.2868 |
| 52 | .7880 | .6157 | 1.2799 | .7813 | 1.2690 |
| 53 | .7986 | .6018 | 1.3270 | .7536 | 1.2521 |
| 54 | .8090 | .5878 | 1.3764 | .7265 | 1.2361 |
| 55 | .8192 | .5736 | 1.4281 | .7002 | 1.2208 |
| 56 | .8290 | .5592 | 1.4826 | .6745 | 1.2062 |
| 57 | .8387 | .5446 | 1.5399 | .6494 | 1.1924 |
| 58 | .8480 | .5299 | 1.6003 | .6249 | 1.1792 |
| 59 | .8572 | .5150 | 1.6643 | .6009 | 1.1666 |
| 60 | .8660 | .5000 | 1.7321 | .5774 | 1.1547 |
| 61 | .8746 | .4848 | 1.8040 | .5443 | 1.1434 |
| 62 | .8829 | .4695 | 1.8807 | .5317 | 1.1326 |
| 63 | .8910 | .4540 | 1.9626 | .5095 | 1.1223 |
| 64 | .8988 | .4384 | 2.0503 | .4877 | 1.1126 |
| 65 | .9063 | .4226 | 2.1445 | .4663 | 1.1034 |
| 66 | .9135 | .4067 | 2.2460 | .4452 | 1.0946 |
| 67 | .9205 | .3907 | 2.3559 | .4245 | 1.0864 |
| 68 | .9272 | .3746 | 2.4751 | .4040 | 1.0785 |
| 69 | .9336 | .3584 | 2.6051 | .3839 | 1.0711 |
| 70 | .9397 | .3420 | 2.7475 | .3640 | 1.0642 |
| 71 | .9455 | .3256 | 2.9042 | .3443 | 1.0576 |
| 72 | .9511 | .3090 | 3.0777 | .3249 | 1.0515 |
| 73 | .9563 | .2924 | 3.2709 | .3057 | 1.0457 |
| 74 | .9613 | .2756 | 3.4874 | .2867 | 1.0403 |
| 75 | .9659 | .2588 | 3.7321 | .2679 | 1.0353 |
| 76 | .9703 | .2419 | 4.0108 | .2493 | 1.0306 |
| 77 | .9744 | .2250 | 4.3315 | .2309 | 1.0263 |
| 78 | .9781 | .2079 | 4.7046 | .2126 | 1.0223 |
| 79 | .9816 | .1908 | 5.1446 | .1944 | 1.0187 |
| 80 | .9848 | .1736 | 5.6713 | .1763 | 1.0154 |
| 81 | .9877 | .1564 | 6.3138 | .1584 | 1.0125 |
| 82 | .9903 | .1392 | 7.1154 | .1405 | 1.0098 |
| 83 | .9925 | .1219 | 8.1443 | .1228 | 1.0075 |
| 84 | .9945 | .1045 | 9.5144 | .1051 | 1.0055 |
| 85 | .9962 | .0872 | 11.4300 | .0875 | 1.0038 |
| 86 | .9976 | .0698 | 14.3010 | .0699 | 1.0024 |
| 87 | .9986 | .0523 | 19.0810 | .0524 | 1.0014 |
| 88 | .9994 | .0349 | 28.6360 | .0349 | 1.0006 |
| 89 | .9998 | .0175 | 57.2900 | .0175 | 1.0002 |
| 90 | 1.0000 | .0000 | INFINITY | .0000 | 1.0000 |

## EMT

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.706 | 0.622 | .042 | 30 | 100 |
| 3/4 | 0.922 | 0.824 | .049 | 45 | 100 |
| 1 | 1.163 | 1.049 | .057 | 65 | 100 |
| 1 1/4 | 1.510 | 1.380 | .065 | 96 | 50 |
| 1 1/2 | 1.740 | 1.610 | .065 | 111 | 50 |
| 2 | 2.197 | 2.067 | .065 | 141 | 30 |
| 2 1/2 | 2.875 | 2.731 | .072 | 230 | 10 |
| 3 | 3.500 | 3.356 | .072 | 270 | 10 |
| 4 | 4.500 | 4.334 | .083 | 400 | 10 |

## RIGID STEEL

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.622 | .109 | 80 | 100 |
| 3/4 | 1.050 | 0.824 | .113 | 106 | 50 |
| 1 | 1.315 | 1.049 | .133 | 153 | 50 |
| 1 1/4 | 1.660 | 1.380 | .140 | 201 | 30 |
| 1 1/2 | 1.900 | 1.610 | .145 | 249 | 30 |
| 2 | 2.375 | 2.067 | .154 | 334 | 10 |
| 2 1/2 | 2.875 | 2.469 | .203 | 527 | 10 |
| 3 | 3.500 | 3.068 | .216 | 690 | 10 |
| 3 1/2 | 4.000 | 3.548 | .226 | 831 | 10 |
| 4 | 4.500 | 4.026 | .237 | 982 | 10 |
| 5 | 5.563 | 5.047 | .258 | 1344 | 10 |
| 6 | 6.625 | 6.065 | .280 | 1770 | 10 |

## RIGID ALUMINUM

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.622 | .109 | 30 | 100 |
| 3/4 | 1.050 | 0.824 | .113 | 37 | 100 |
| 1 | 1.315 | 1.049 | .133 | 60 | 100 |
| 1 1/4 | 1.660 | 1.380 | .140 | 78 | 100 |
| 1 1/2 | 1.900 | 1.610 | .145 | 100 | 50 |
| 2 | 2.375 | 2.067 | .154 | 125 | 30 |
| 2 1/2 | 2.875 | 2.469 | .203 | 200 | 10 |
| 3 | 3.500 | 3.068 | .216 | 260 | 10 |
| 3 1/2 | 4.000 | 3.548 | .226 | 330 | 10 |
| 4 | 4.500 | 4.026 | .237 | 370 | 10 |
| 5 | 5.563 | 5.047 | .258 | 530 | 10 |
| 6 | 6.625 | 6.065 | .280 | 660 | 10 |

## IMC

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.815 | 0.675 | .070 | 58 | 100 |
| 3/4 | 1.029 | 0.879 | .075 | 79 | 100 |
| 1 | 1.290 | 1.120 | .085 | 114 | 50 |
| 1 1/4 | 1.638 | 1.468 | .090 | 146 | 30 |
| 1 1/2 | 1.883 | 1.703 | .095 | 179 | 30 |
| 2 | 2.360 | 2.170 | .130 | 239 | 10 |
| 2 1/2 | 2.857 | 2.597 | .130 | 402 | 10 |
| 3 | 3.476 | 3.216 | .130 | 495 | 10 |
| 3 1/2 | 3.971 | 3.711 | .130 | 576 | 10 |
| 4 | 4.466 | 4.206 | .130 | 642 | 10 |

## PVC TYPE A

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.720 | .060 | 11 | 100 |
| 3/4 | 1.050 | 0.930 | .060 | 13 | 100 |
| 1 | 1.315 | 1.195 | .060 | 17 | 100 |
| 1 1/4 | 1.660 | 1.520 | .070 | 25 | 50 |
| 1 1/2 | 1.900 | 1.740 | .080 | 32 | 50 |
| 2 | 2.375 | 2.175 | .100 | 50 | 10 |
| 2 1/2 | 2.875 | 2.655 | .110 | 67 | 10 |
| 3 | 3.500 | 3.250 | .125 | 90 | 10 |
| 4 | 4.500 | 4.200 | .150 | 146 | 10 |

## PVC TYPE 40 (Schedule 40)

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.622 | .109 | 16 | 100 |
| 3/4 | 1.050 | 0.824 | .113 | 22 | 100 |
| 1 | 1.315 | 1.049 | .133 | 32 | 100 |
| 1 1/4 | 1.660 | 1.380 | .140 | 43 | 50 |
| 1 1/2 | 1.900 | 1.610 | .145 | 52 | 50 |
| 2 | 2.375 | 2.067 | .154 | 69 | 10 |
| 2 1/2 | 2.875 | 2.469 | .203 | 109 | 10 |
| 3 | 3.500 | 3.068 | .216 | 142 | 10 |
| 3 1/2 | 4.000 | 3.548 | .226 | 170 | 10 |
| 4 | 4.500 | 4.200 | .237 | 202 | 10 |
| 5 | 5.563 | 5.047 | .258 | 271 | 10 |
| 6 | 6.625 | 6.065 | .280 | 350 | 10 |

## PVC TYPE 80 (Schedule 80)

| Trade Size | Outside Diameter | Inside Diameter | Wall Thickness | Weight Per 100' | Feet Per Bundle |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.546 | .147 | 21 | 100 |
| 3/4 | 1.050 | 0.742 | .154 | 28 | 100 |
| 1 | 1.315 | 1.179 | .179 | 41 | 100 |
| 1 1/4 | 1.660 | 1.278 | .191 | 57 | 50 |
| 1 1/2 | 1.900 | 1.500 | .200 | 68 | 50 |
| 2 | 2.375 | 1.939 | .218 | 94 | 10 |
| 2 1/2 | 2.875 | 2.323 | .276 | 142 | 10 |
| 3 | 3.500 | 2.900 | .300 | 190 | 10 |
| 3 1/2 | 4.000 | 3.364 | .318 | 232 | 10 |
| 4 | 4.500 | 3.826 | .337 | 278 | 10 |
| 5 | 5.563 | 4.813 | .375 | 385 | 10 |
| 6 | 6.625 | 5.761 | .432 | 530 | 10 |

## CONDUIT SPACING CHART

This chart gives the center-to-center measurements for conduit layout. Locate the smallest conduit across the bottom line and then locate the larger conduit on the vertical line. The value shown is the center-to-center measurement of the conduits. To this value add the desired spacing between conduits. **EXAMPLE:** layout a 2 ½" and a 3 ½" conduit with 2" spacing. The center-to-center measurement is 3.438 (as shown in the shaded area of the chart) add 2" for spacing gives a center-to-center measurement of 5.438 or ≈ 5 7/16". This chart can also be used punching knockouts or any other job that requires center-to-center conduit measurements.

**LARGEST**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ½ | 0.840 | | | | | | | | | | | |
| ¾ | 0.945 | 1.050 | | | | | | | | | | |
| 1 | 1.078 | 1.183 | 1.315 | | | | | | | | | |
| 1 ¼ | 1.250 | 1.355 | 1.488 | 1.660 | | | | | | | | |
| 1 ½ | 1.370 | 1.475 | 1.608 | 1.780 | 1.900 | | | | | | | |
| 2 | 1.608 | 1.713 | 1.846 | 2.018 | 2.138 | 2.375 | | | | | | |
| 2 ½ | 1.858 | 1.963 | 2.096 | 2.268 | 2.388 | 2.626 | 2.876 | | | | | |
| 3 | 2.170 | 2.275 | 2.408 | 2.580 | 2.700 | 2.938 | 3.188 | 3.500 | | | | |
| 3 ½ | 2.420 | 2.525 | 2.658 | 2.830 | 2.950 | 3.188 | 3.438 | 3.750 | 4.00 | | | |
| 4 | 2.670 | 2.775 | 2.908 | 3.080 | 3.200 | 3.438 | 3.688 | 4.00 | 4.250 | 4.50 | | |
| 5 | 3.202 | 3.307 | 3.440 | 3.612 | 3.732 | 3.970 | 4.220 | 4.532 | 4.782 | 5.032 | 5.564 | |
| 6 | 3.733 | 3.838 | 3.971 | 4.143 | 4.263 | 4.501 | 4.751 | 5.063 | 5.313 | 5.563 | 6.095 | 6.626 |
| | ½ | ¾ | 1 | 1 ¼ | 1 ½ | 2 | 2 ½ | 3 | 3 ½ | 4 | 5 | 6 |

**SMALLEST**

# GLOSSARY

**ARC:** Any part of the circumference of a circle.
**Back-to-Back:** Two 90° bends in one conduit, usually with both stubs turned up on the same plane forming a "U".
**BENDERS:**

**"Chicago" style:** A general term applied to all hand ratcheted, frame mounted benders.

**Hand Benders:** benders having a full shoe that the pipe is formed around. Used for hand bending EMT, IMC and Rigid pipe.

**Hickey:** A hand-held bender with no bending shoe that is used to bend ½", ¾", and 1"Rigid conduit.

**Hot Box:** A broad term used to describe head devices used to soften PVC pipe for bending.

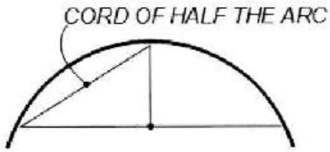
**Hydraulic:** A bender consisting of a hydraulic pump (hand or electric), ram assembly, frame, bending shoe (one-shot or segment), bending supports and pins. Use for bending larger sizes of conduit.

**Bending Shoe:**

**One-shot:** A full 90° radius shoe used with hydraulic benders.

**Segment:** A bending shoe with a very small radius intended to bend pipe in multiple bends or shots.

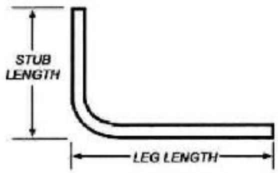
**Bending Table:** A table used for hydraulic benders It has a movable pipe vise for securing the conduit during bending.
**Bite:** Placing the bender or Hickey on the conduit and bending a small amount of bend. Several small bends are used to complete a 90° bend.
**Circumference:** The distance around a circle.
**Concentric Bends:** Pipe having a common center with increasing or decreasing radii.
**Cord of Arc:** A straight line joining the ends of an arc. A distance less than the diameter of a circle.
**Cord of Half the Arc:** The length of a line if it was placed diagonally from the edge of the cord of arc to the high point of the arc.



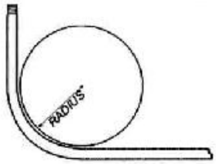

**Degrees per Shot:** The amount of bend in degrees a pipe is to be bent for each bend mark of a segment bend.
**Developed Length:** The amount of straight pipe needed to bend a given radius.
**Diameter:** The distance across the center of a circle.
**Dog-Leg:** A unwanted alignment between bends of an offset or saddle that make the pipe look like a dog's hind leg. Also called a WOW.
**Ductility:** Ability for a material to be shaped or formed.
**Gain:** The amount of pipe gained (saved) by bending on a radius and not at right angles.

**Hickey:** See benders
**Kick:** A bend of less than 90° placed in a conduit to change direction.

**Leg Length:** The length of pipe measure from the back of the bend.



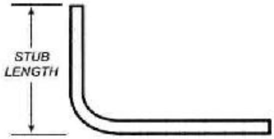

**Ninety Degree Bend:** Any radius bend in a conduit that changes the direction of the pipe 90°.
**Number of Bending Shots:** The number depends on the size of the radius and the smoothness required of the bend.
**O.D. Size:** Outside diameter of a pipe.
**Offset:** Two identical bends placed in a conduit to change direction or elevation of the pipe run.
**Oh-Oh:** A pipe bent wrong that can't be used. Usually thrown out or said to be put in the Oh-Oh pile.
**Pivot Shoes (Pipe Supports):** Castings formed to the shape of each conduit size and held in the bender frame by pins.
**Plunger (Ram):** The rod in the hydraulic cylinder which is attached to the bending shoe and moves forward when hydraulic pressure is applied.
**Radius:** The relative size of the bent portion of a pipe.




**Reference Point:** A mark used to locate the edge of an obstruction for bending saddles.
**Segment Bend:** Any bend formed by a series of bends of a few degrees each, rather than a single one-shot bend.
**Shot:** One bend in a segment bend.
**Shrink:** The amount of bent conduit reduces in total length after an offset is bent.
**Spring Back:** The amount a bent pipe tends to straighten after the bending force is removed.
**Start Mark:** A mark placed on the pipe to start a segment bend layout. The start mark is not a bend mark and is only used as a bend mark if final

adjustment to the pipe requires more degree of bend without adding to the stub height.

**Stub:** The distance from the back of the bend to the end of the conduit.



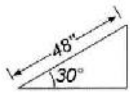

**Sweep:** A 90⁰ bend with a radius larger than a standard one-shot shoe.

**Take-Up (Come-Back):** The amount that must be subtracted from the desired stub length to make the pipe come out at the correct length.

**WOW (Dog-Leg, Hoop-De-Do):** An improperly made bend where the conduit was not held secure and the bend is not aligned right. The term is also used to indicate a slight bend made by hand or over the Knee for correction or direction change.

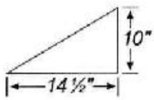
# ANSWERS TO PROBLEMS

## Chapter 1

1. 

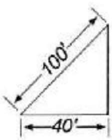

$O = S \times H \quad O = .5 \times 48 \quad O = 24"$

$24" \div 48" = .5 \quad .5 \times 12" =$ **6" rise/ft**

2. 


$T = O \div A \qquad T = O \div 14.5$

$T = .6896$ or $\approx$ **35°**

3. 


$C = A \div H \quad C = 40 \div 100 \quad C = .4$ or $\approx$ **66°**

$O = S \times H \quad O =$ Sine of $66^\circ \times 100 \quad O = .9135 \times 100 = 91.350'$

To convert .350 feet into inches multiply the value by 12.

$.350 \times 12 = 4.2$ or 4.2 inches

To convert the .2 inches into the closest ⅛" multiply .2 and 8

$.2 \times 8 = 1.6$ eights or $\approx$ ¼"

Height of the pole (O) is **= 91′ 4¼"**

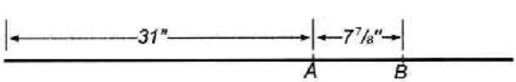
## Chapter 6

1. (a) $22 \times 1.414 = 31.108"$ or $\approx$ 31⅛"

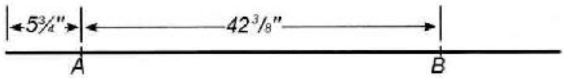
(b) $22 \times 2.000 = 44"$

(c) The Cosecant for $15^\circ$ is 3.864 (rounded to three digits)
$22 \times 3.864 = 84.9992$ or $\approx 85"$

## Chapter 7 Method #1

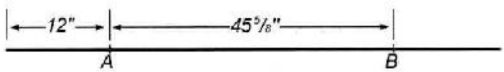
1. 

2.




3.

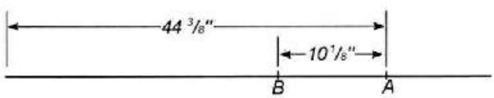

4.



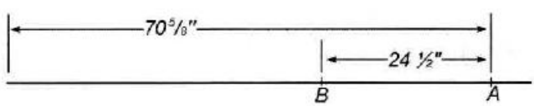

5.


## Chapter 7 Method #2

1.

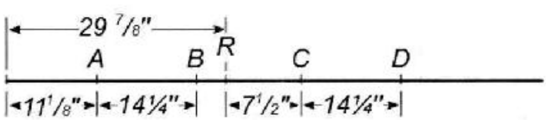



2.

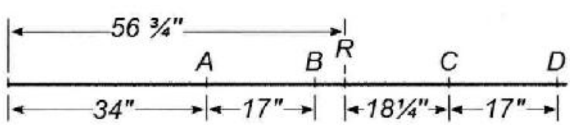



## Chapter 9 Method #1

1.

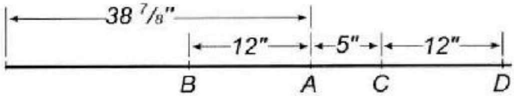



2.

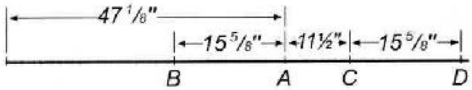


## Chapter 9 Method #2

1.

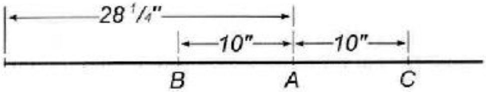



2.

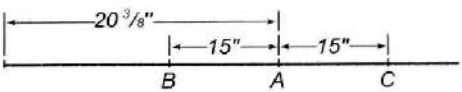



## Chapter 10 Using a multiplier of 2.5

1.

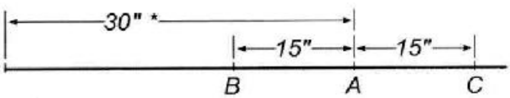



2.

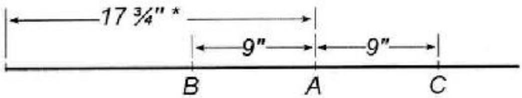



## Chapter 10 Using a multiplier of 3

1.




2.




## Chapter 13 Page 81

1. (a) 1-25/32" (Round up to 1-13/16")
   (b) 3-17/32" (Round up to 3-9/16")

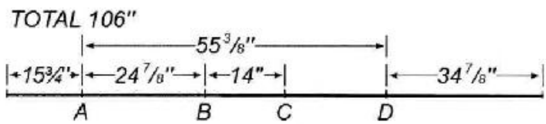
2. (a) 5-29/32" (Round up to 5-15/16)
   (b) 4-7/16"

## Chapter 13 Page 88

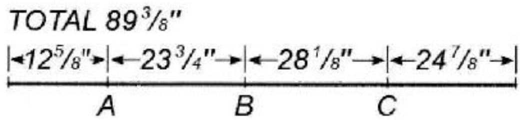
1. 76¼"   2. 77½"   3. 73⅜"   4. 86½"

## Chapter 13 Page 99

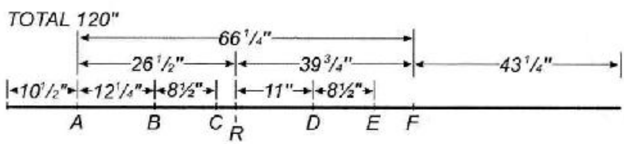
1.




2.




3.

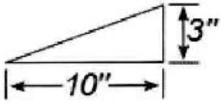



## Chapter 15

1. Start Mark 35⅛" Spacing 1⅞"
2. Start Mark 23½ Spacing 2⅛"

**Chapter 20**

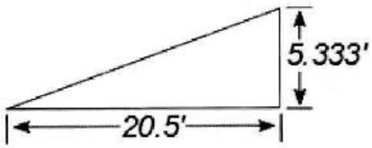
1.




$$H = \sqrt{10^2 + 3^2} = 10.440$$

$$R = \frac{C^2}{2A} = \frac{10.440^2}{2 \times 3} = 18.16 \ or \approx 18\ 1/8''$$

2.




Solve using measurements in **feet**

Cord of Arc is 41′ - 0"
41′ - 0" ÷ 2 = **20.5′ - 0"** for A – O ***Adjacent side***

Height of the arc is 5′ - 4" or **5.333′** O – D ***Opposite side***
Convert 4" into feet 4" ÷ 12 = .333′

Cord of half the arc A – D ***Hypotenuse***

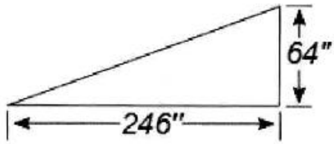
$H = \sqrt{a^2 + o^2}$ $H = \sqrt{20.5^2 + 5.333^2}$ $H = 21.182'$

Cord of half the arc = 21.182′

$$R = \frac{C^2}{2A} \quad R = \frac{21.182^2}{2 \times 5.333} \quad R = \frac{448.677}{10.666} \quad R = 42.066'$$

To convert a radius of 42.066 feet into feet and inches:
Multiply .066′ × 12 = .792"
Multiply the .792" × 8 = 6.336 eights or ≈ ⅞" rounded up
Radius is ≈ **42′ ⅞"**

2. Continued




Solve using measurements in **inches**

Cord of Arc is 41′ - 0″

41′ - 0″ ÷ 2 = **20.5′ - 0″** for A – O ***Adjacent side***

Convert 20.5 feet into inches 20.5 × 12 = **246″**

Height of the arc is 5′ - 4″ O – D ***Opposite side***

Convert 5′ - 4″ to inches 5′ × 12 = 60″ + 4″ = **64″**

Cord of half the arc A – D ***Hypotenuse***

$$H = \sqrt{a^2 + o^2} \quad H = \sqrt{246^2 + 64^2} \quad H = 254.189''$$

Cord of half the arc = 254.189″

$$R = \frac{\boldsymbol{C^2}}{\boldsymbol{2A}} \quad R = \frac{254.189^2}{2 \times 64} \quad R = \frac{64612.05}{128} \quad R = 504.782''$$

To convert a radius of 504.782 inches into feet:

Divide 504 by 12 504 ÷ 12 = 42′

Multiply .782″ × 8 = 6.256 eights or ≈ ⅞″ rounded up

Radius is ≈ **42′ ⅞″**

Notes:

Notes:

## ELECTRICIANS

Do you bend conduit?

Do you take pride in your work?

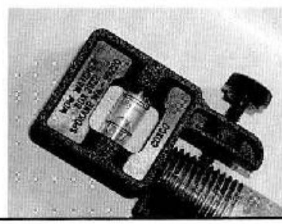
If the answer is yes, then the "wow-watcher" is a tool you should have.

The "wow-watcher" is an indispensable tool if you want to bend precision offsets, saddles, stubs, etc., without dog legs, wows or hoop-de-doos.

The "wow-watcher" is made of Vertron, a space-age thermoplastic made with fiberglass and nylon compounds. This combination of materials provides a tough, but light-weight tool. A thumb screw with a brass insert is used for securing the device to any type of conduit, in sizes $^1/_2$" through 6". The precision bubble vile is made of acrylic, giving you a tool that is as tough as it is accurate.

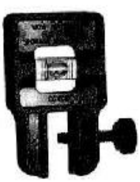
> "I've been bending conduit and writing about conduit bending for over 25 years and this is the BEST device of this type I've ever seen or used. I really like its light weight and indestructible construction."
>
> *– Richard A. Cox, Author*
> ***"Electricians Guide to Conduit Bending"***

If you are really serious about conduit bending, order one today



# Order at
# www.coxco.net

**Information**
**1-800-257-0941**



SPECIAL

Buy "Electricians Guide to Conduit Bending"
AND a Calculating Tape Measure
and receive a **FREE** "wow-watcher"

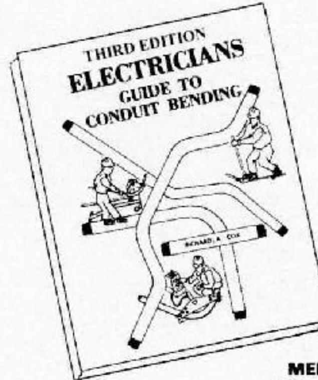
Notes:

Notes:

| ANGLE | SINE | COSINE | TANGENT | COTANGENT | COSECANT |
|---|---|---|---|---|---|
| 1 | .0175 | .9998 | .0175 | 57.2900 | 57.2987 |
| 2 | .0349 | .9994 | .0349 | 28.6363 | 28.6537 |
| 3 | .0523 | .9986 | .0524 | 19.0811 | 19.1073 |
| 4 | .0698 | .9976 | .0699 | 14.3007 | 14.3356 |
| 5 | .0872 | .9962 | .0875 | 11.4301 | 11.4737 |
| 6 | .1045 | .9945 | .1051 | 9.5144 | 9.5668 |
| 7 | .1219 | .9925 | .1228 | 8.1443 | 8.2055 |
| 8 | .1392 | .9903 | .1405 | 7.1154 | 7.1853 |
| 9 | .1564 | .9877 | .1584 | 6.3138 | 6.3925 |
| 10 | .1736 | .9848 | .1763 | 5.6713 | 5.7588 |
| 11 | .1908 | .9816 | .1944 | 5.1446 | 5.2408 |
| 12 | .2079 | .9781 | .2126 | 4.7046 | 4.8097 |
| 13 | .2250 | .9744 | .2309 | 4.3315 | 4.4454 |
| 14 | .2419 | .9703 | .2493 | 4.0108 | 4.1336 |
| 15 | .2588 | .9659 | .2679 | 3.7321 | 3.8637 |
| 16 | .2756 | .9613 | .2867 | 3.4874 | 3.6280 |
| 17 | .2924 | .9563 | .3057 | 3.2709 | 3.4203 |
| 18 | .3090 | .9511 | .3249 | 3.0777 | 3.2361 |
| 19 | .3256 | .9455 | .3443 | 2.9042 | 3.0716 |
| 20 | .3420 | .9397 | .3640 | 2.7475 | 2.9238 |
| 21 | .3584 | .9336 | .3839 | 2.6051 | 2.7904 |
| 22 | .3756 | .9272 | .4040 | 2.4751 | 2.6695 |
| 23 | .3907 | .9205 | .4245 | 2.3559 | 2.5593 |
| 24 | .4067 | .9135 | .4452 | 2.2460 | 2.4586 |
| 25 | .4226 | .9063 | .4663 | 2.1445 | 2.3662 |
| 26 | .4384 | .8988 | .4877 | 2.0503 | 2.2812 |
| 27 | .4540 | .8910 | .5095 | 1.9626 | 2.2027 |
| 28 | .4695 | .8829 | .5317 | 1.8807 | 2.1301 |
| 29 | .4848 | .8746 | .5543 | 1.8040 | 2.0627 |
| 30 | .5000 | .8660 | .5774 | 1.7321 | 2.0000 |
| 31 | .5150 | .8572 | .6009 | 1.6643 | 1.9416 |
| 32 | .5299 | .8480 | .6249 | 1.6003 | 1.8871 |
| 33 | .5446 | .8387 | .6494 | 1.5399 | 1.8361 |
| 34 | .5592 | .8290 | .6745 | 1.4826 | 1.7883 |
| 35 | .5736 | .8192 | .7002 | 1.4281 | 1.7434 |
| 36 | .5878 | .8090 | .7265 | 1.3764 | 1.7013 |
| 37 | .6018 | .7986 | .7536 | 1.3270 | 1.6616 |
| 38 | .6157 | .7880 | .7813 | 1.2799 | 1.6243 |
| 39 | .6293 | .7771 | .8098 | 1.2349 | 1.5890 |
| 40 | .6428 | .7660 | .8391 | 1.1918 | 1.5557 |
| 41 | .6561 | .7547 | .8693 | 1.1504 | 1.5243 |
| 42 | .6691 | .7431 | .9004 | 1.1106 | 1.4945 |
| 43 | .6820 | .7314 | .9325 | 1.0724 | 1.4663 |
| 44 | .6947 | .7193 | .9657 | 1.0355 | 1.4396 |
| 45 | .7071 | .7071 | 1.0000 | 1.0000 | 1.4142 |

| FRACTION | DECIMAL |
|---|---|
| 1/32 | .03125 |
| 1/16 | .06250 |
| 3/32 | .09375 |
| 1/8 | .12500 |
| 5/32 | .15625 |
| 3/16 | .1875 |
| 7/32 | .21875 |
| 1/4 | .25000 |
| 9/32 | .28125 |
| 5/16 | .31250 |
| 11/32 | .40625 |
| 3/8 | .37500 |
| 13/32 | .40625 |
| 7/16 | .43750 |
| 15/32 | .46875 |
| 1/2 | .5000 |
| 7/32 | .53125 |
| 9/16 | .56250 |
| 19/32 | .59375 |
| 5/8 | .62500 |
| 21/32 | .65625 |
| 11/16 | .68750 |
| 23/32 | .71875 |
| 3/4 | .75000 |
| 25/32 | .78125 |
| 13/16 | .81250 |
| 27/32 | .84375 |
| 7/8 | .87500 |
| 29/32 | .90625 |
| 15/16 | .93750 |
| 31/32 | .96875 |
| 1 | 1.0000 |

| ANGLE | SINE | COSINE | TANGENT | COTANGENT | COSECANT |
|---|---|---|---|---|---|
| 46 | .7193 | .6947 | 1.0355 | .9657 | 1.3902 |
| 47 | .7314 | .6820 | 1.0724 | .9325 | 1.3673 |
| 48 | .7431 | .6691 | 1.1106 | .9004 | 1.3456 |
| 49 | .7547 | .6561 | 1.1504 | .8693 | 1.3250 |
| 50 | .7660 | .6428 | 1.1918 | .8391 | 1.3054 |
| 51 | .7771 | .6293 | 1.2349 | .8098 | 1.2868 |
| 52 | .7880 | .6157 | 1.2799 | .7813 | 1.2690 |
| 53 | .7986 | .6018 | 1.3270 | .7536 | 1.2521 |
| 54 | .8090 | .5878 | 1.3764 | .7265 | 1.2361 |
| 55 | .8192 | .5736 | 1.4281 | .7002 | 1.2208 |
| 56 | .8290 | .5592 | 1.4826 | .6745 | 1.2062 |
| 57 | .8387 | .5446 | 1.5399 | .6494 | 1.1924 |
| 58 | .8480 | .5299 | 1.6003 | .6249 | 1.1792 |
| 59 | .8572 | .5150 | 1.6643 | .6009 | 1.1666 |
| 60 | .8660 | .5000 | 1.7321 | .5774 | 1.1547 |
| 61 | .8746 | .4848 | 1.8040 | .5443 | 1.1434 |
| 62 | .8829 | .4695 | 1.8807 | .5317 | 1.1326 |
| 63 | .8910 | .4540 | 1.9626 | .5095 | 1.1223 |
| 64 | .8988 | .4384 | 2.0503 | .4877 | 1.1126 |
| 65 | .9063 | .4226 | 2.1445 | .4663 | 1.1034 |
| 66 | .9135 | .4067 | 2.2460 | .4452 | 1.0946 |
| 67 | .9205 | .3907 | 2.3559 | .4245 | 1.0864 |
| 68 | .9272 | .3746 | 2.4751 | .4040 | 1.0785 |
| 69 | .9336 | .3584 | 2.6051 | .3839 | 1.0711 |
| 70 | .9397 | .3420 | 2.7475 | .3640 | 1.0642 |
| 71 | .9455 | .3256 | 2.9042 | .3443 | 1.0576 |
| 72 | .9511 | .3090 | 3.0777 | .3249 | 1.0515 |
| 73 | .9563 | .2924 | 3.2709 | .3057 | 1.0457 |
| 74 | .9613 | .2756 | 3.4874 | .2867 | 1.0403 |
| 75 | .9659 | .2588 | 3.7321 | .2679 | 1.0353 |
| 76 | .9703 | .2419 | 4.0108 | .2493 | 1.0306 |
| 77 | .9744 | .2250 | 4.3315 | .2309 | 1.0263 |
| 78 | .9781 | .2079 | 4.7046 | .2126 | 1.0223 |
| 79 | .9816 | .1908 | 5.1446 | .1944 | 1.0187 |
| 80 | .9848 | .1736 | 5.6713 | .1763 | 1.0154 |
| 81 | .9877 | .1564 | 6.3138 | .1584 | 1.0125 |
| 82 | .9903 | .1392 | 7.1154 | .1405 | 1.0098 |
| 83 | .9925 | .1219 | 8.1443 | .1228 | 1.0075 |
| 84 | .9945 | .1045 | 9.5144 | .1051 | 1.0055 |
| 85 | .9962 | .0872 | 11.4300 | .0875 | 1.0038 |
| 86 | .9976 | .0698 | 14.3010 | .0699 | 1.0024 |
| 87 | .9986 | .0523 | 19.0810 | .0524 | 1.0014 |
| 88 | .9994 | .0349 | 28.6360 | .0349 | 1.0006 |
| 89 | .9998 | .0175 | 57.2900 | .0175 | 1.0002 |
| 90 | 1.0000 | .0000 | INFINITY | .0000 | 1.0000 |






Cut out and fold for wallet sized reference guide.

**Offset Multiplier** = Cosecant of the Offset Angle

**Spacing between bend marks** = Offset Multiplier × Height of Obstruction

**Offset Location Multiplier** = Cotangent of the angle used to preposition Offsets using Method #1

**Offset Location Multiplier**

| Offset Angle | Location Multiplier |
|---|---|
| 45° | 1.00 |
| 30° | 1.73 |
| 22½° | 2.42 |
| 10° | 5.67 |

**Offset Constants for Predetermining Offset Location Method #1**
**For Hand and "Chicago" Benders**

| | EMT | PIPE | SIZE | RIGID | PIPE | SIZE |
|---|---|---|---|---|---|---|
| Angle | ½" | ¾" | 1" | ½" | ¾" | 1" |
| 45° | 5" | 6¼" | 7½" | 5" | 6" | 8" |
| 30° | 4½" | 5½" | 6" | 4½" | 5½" | 6½" |
| 22½° | 3½" | 4¼" | 4¾" | 4" | 5" | 6" |
| 10° | 3" | 3½" | 4" | 3" | 3½" | 4½" |

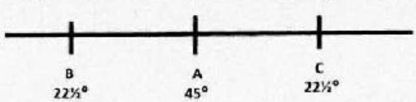
**Shrink Values for Predetermining Offset Location Method #2**

| Angle of Offset | 5° | 10° | 22½° | 30° | 45° | 60° |
|---|---|---|---|---|---|---|
| Shrink Per Inch of Rise | 1/32" | 1/16" | 3/16" | 1/4" | 3/8" | 1/2" |

**Offset Shrink per Inch of Rise for Angles not Listed in Table**
Subtract the cotangent from the cosecant for the angle of offset & convert to fractional equivalent.

**Parallel Offset Adjustment** = Center-to-Center spacing × Tangent of ½ the Offset angle.

**3-Bend Saddle** Hand Benders A-B and B-C = 2½ × Height of Obstruction
"Chicago" benders A-B and B-C = 3 × Height of Obstruction




**Segment Bending**

Developed Length = Radius × 1.57

Start Mark = Desired Stub Length −(Radius + OD)

Spacing Between Shots = $\frac{\text{Developed Length}}{\text{Number of Shots}}$

For smooth radius bends, not less than 3° nor more than 5° per shot. This rule does not apply for segment offsets.

# ABOUT THE AUTHOR

rpc

Richard A. Cox retired as the Chairman of the Electrical/Robotics Department at Spokane Community College in Spokane, Washington. He holds a Bachelor of Science degree from the University of the State of New York and a Master of Science degree from Eastern Washington University and is also a retired member of the International Brotherhood of Electrical Workers, Local 73.

Richard is also the author of the best-selling books "Electricians Guide to AC Motor Controls" and "Technicians Guide to Programmable Controllers"