Conduit Bending

26204-05

Latus Motors Harley-Davidson, Inc.
Gladstone, Oregon
Pre-Engineered Building $2–10 Million Award Winner
Engineered Structures, Inc.

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Conduit Bending

Topics to be presented in this module include:

Overview

Simple one-shot bends in small-diameter conduit can be made using a hand bender, with little or no calculations required. However, when complete conduit systems must be installed on exposed surfaces or pipe racks, many calculated bends may be required using hand- or power-bending equipment.

The *National Electrical Code*® regulates the number of degrees that can be bent into a single run of conduit. A run of conduit is considered to be any conduit installed between outlet or junction boxes, cabinets, or panels. The *NEC*® also states that all rigid conduit bends must be made so that the conduit is not damaged and the internal diameter of the conduit is not reduced. Additional *NEC*® regulations address the bending radius.

Electricians must know how to create offsets, saddles, kicks, and other bends in conduit without relying on the trial-and-error method, which results in wasted conduit and time. Precision bends can be made the first time by knowing and applying formulas such as those associated with the right triangle.

Objectives

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

1. Describe the process of conduit bending using power tools.
2. Identify all parts of popular electric and hydraulic benders.
3. Avoid excessive waste when working with conduit systems.
4. Bend offsets, kicks, saddles, and segmented and parallel bends.
5. Explain the requirements of the *NEC*® for bending conduit.
6. Compute the radius, degrees in bend, developed length, and gain for conduit up to six inches.
7. Explain how to correct damaged conduit and modify existing bends.

Trade Terms

Approximate ram travel
Back-to-back bend
Bending protractor
Bending shot
Concentric bending
Conduit
Degree indicator
Developed length
Elbow
Gain
Inside diameter (ID)
Kicks
Leg length
Ninety-degree bend
Offsets
One-shot shoe
Outside diameter (OD)
Radius
Rise
Segment bend
Segmented bending shoe
Springback
Stub-up
Sweep bend
Take-up (comeback)

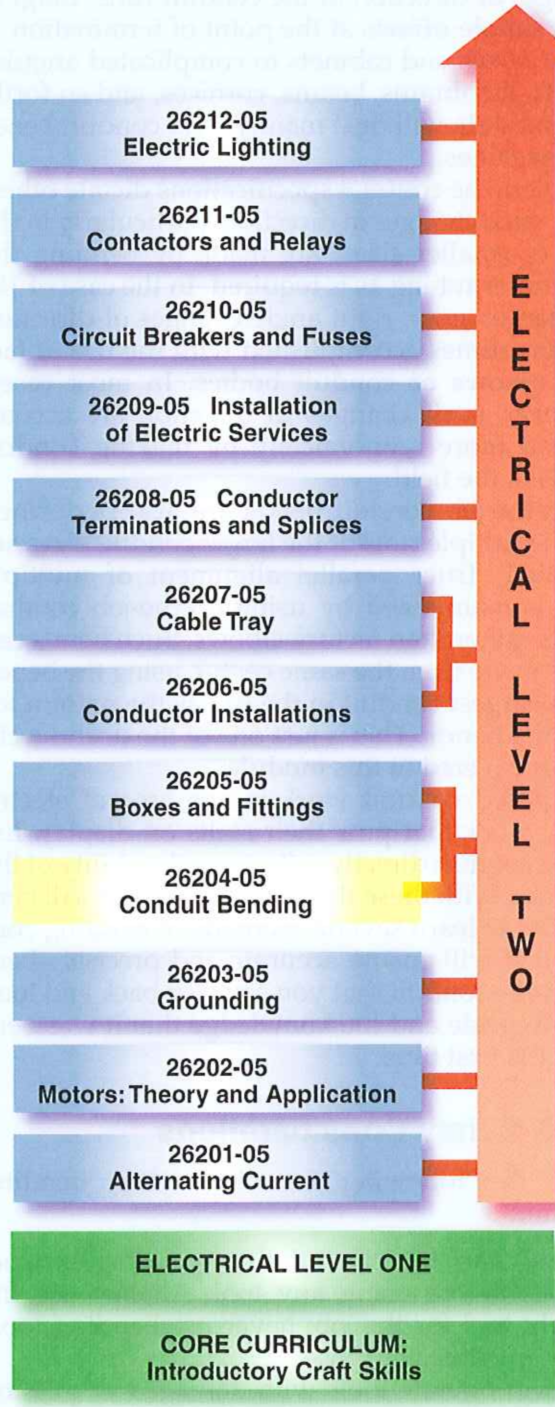
Required Trainee Materials

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

Prerequisites

Before you begin this module, it is recommended that you successfully complete *Core Curriculum; Electrical Level One; Electrical Level Two,* Modules 26201-05 through 26203-05. You should also read *NEC Articles 342, 344, 352, and 358.*

This course map shows all of the modules in *Electrical Level Two.* The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map. The local Training Program Sponsor may adjust the training order.



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1.0.0 ◆ INTRODUCTION

The normal installation of intermediate metal **conduit** (IMC), rigid metal conduit (RMC), and electrical metallic tubing (EMT) requires many changes of direction in the conduit runs, ranging from simple **offsets** at the point of termination at outlet boxes and cabinets to complicated angular offsets at columns, beams, cornices, and so forth. This module will deal mainly with conduit bending machines.

Unless the contract specifications dictate otherwise, such changes in direction, particularly in the case of smaller sizes, are made by bending the conduit or tubing as is required. In the case of 1¼" and larger sizes, right angle changes of direction are sometimes accomplished with the use of factory **elbows** or conduit bodies. In most cases, however, such changes in direction are accomplished more economically by making conduit bends in the field.

On-the-job conduit bends are also performed when multiple runs of the larger conduit sizes are installed. Truer parallel alignment of multiple runs is maintained by using on-the-job conduit bends rather than factory elbows. Such bends can all be made from the same center, using the bends of the largest conduit in the run as the pattern for all other bends. This is just one of the useful techniques covered in this module.

Exposed conduit work is one area of electricians' work that puts their skills on display. Exposed conduit directly reflects on the ability of the installer. With these thoughts in mind, it will benefit you to learn several methods of bending conduit that will ensure accurate and precisely-bent conduit—conduit that you can step back and look at with pride and the knowledge that it was bent right the first time.

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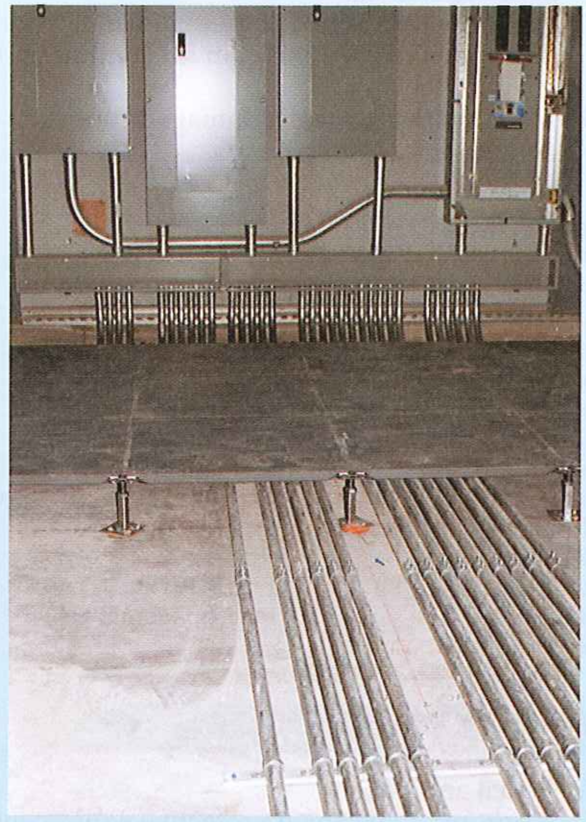
Take Pride in Your Work

Even though the conduit in this installation will be hidden by the flooring and the final wall finish, notice how the installing electrician made a special effort to keep the bends perfectly spaced and aligned. Doing a good job even when it might never be seen or admired is the mark of a true professional.



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1.1.0 Safety Considerations

Keep the following in mind when bending conduit:

- Read and understand the operating instructions before using any tool. Always use the right tool for the job; never use bending tools for any other purpose.
- Never operate tools with damaged or missing parts.
- Watch for pinch points on power bending tools.
- Use tools in a well-lit, uncluttered area, with enough space for the conduit to move while bending.
- Make sure all hydraulic connections are clean and tight. Replace damaged or worn hoses before using.
- Be prepared for the unexpected.
- Make sure tools are complete and properly assembled before operating.
- Bending shoes and follower bars should be treated as precision instruments. Never toss them into a tool chest or allow them to become damaged or bent out of shape. The quality of the final job will depend on using the proper shoes and follower bars in good condition.
- When working with PVC conduit, make sure adequate ventilation is provided to carry off fumes from joint cement or glue.

2.0.0 ◆ *NEC®* REQUIREMENTS

NEC Section 344.24 requires that all rigid metal conduit bends be made so that the conduit will not be damaged and the internal diameter of the conduit will not be effectively reduced. To accomplish this, the *NEC®* further specifies that the minimum **radius** (*Figure 1*) to the centerline of the conduit shall not be less than that listed in *Table 1*. There is a good reason for this rule. When bends are too tight, pulling becomes extremely difficult and the insulation on the conductors may be damaged.

The *NEC®* requirements for other bends are shown in *Table 2*.

2.1.0 Number of Bends per Run

The *NEC®* specifically states that no more than four quarter bends (360° total) may be made in any one conduit run between outlet boxes, cabinets, panels, or junction boxes; that is, between pull points.

Some electricians believe that offsets, **kicks,** and saddles are not bends, especially in areas where the electrical inspectors are lax. These electricians count only those bends that are actually a quarter circle (90°). The misconception of this is quickly apparent when wires are pulled. Offsets and saddles add just as much resistance to pulling conductors as any 90° elbow. An offset, for example, takes two 45° bends, which equal one 90° bend. A saddle should be counted as two quarter bends or 180°.

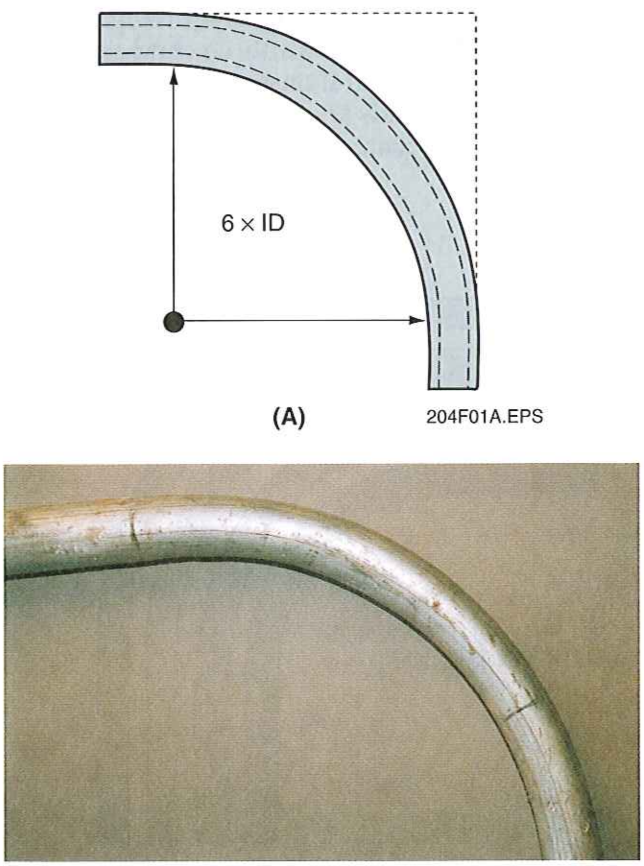

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Figure 1 ◆ Inside radius requirements.

Table 1 *NEC®* Minimum Requirements for Radius of Conduit Bends – One-Shot and Full-Shoe Benders

Trade Size (Inches)	Radius to Center of Conduit (Inches)
½	4
¾	4½
1	5¾
1¼	7¼
1½	8¼
2	9½
2½	10½
3	13
3½	15
4	16
5	24
6	30

Table 2 *NEC®* Minimum Requirements for Radius of Other Conduit Bends

Trade Size (Inches)	Other Bends (Inches)
½	4
¾	5
1	6
1¼	8
1½	10
2	12
2½	15
3	18
3½	21
4	24
5	30
6	36

International Differences

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Everywhere except in the United States, steel conduit is measured using the metric system, so it might be helpful to familiarize yourself with common metric conversion calculations, especially if you live near the Canadian or Mexican border. For example, to convert inches to centimeters (cm), multiply inches by 2.54; to convert yards to meters (m), multiply yards by 0.9.

Don't Ignore the Outside Diameter

Although conduit measurements are based on the inside diameter, don't forget that the outside diameter determines the size of the opening that the conduit must penetrate.

A 15° kick in a conduit run may seem insignificant, but after several dozen of these kicks are incorporated into the run, the difficulty of pulling wire becomes apparent. The number of degrees in each kick should be included in the total count, and in no case should the total number (number of bends × number of degrees in each bend) exceed 360°. This is the maximum number of degrees allowed. This means a maximum of twelve 15° kicks and two offsets; twelve kicks and one saddle; etc. Many electricians prefer to install pull boxes at closer intervals to reduce the number of bends, especially when the larger conductor sizes are being pulled. The additional cost of the pull boxes and the labor to install them is often offset by the labor saved in pulling the conductors during the pull.

3.0.0 ◆ TYPES OF BENDS

There are various types of conduit bends: elbows, offset bends, **back-to-back bends,** saddles, etc. A brief review of each follows:

- *Elbow* – An elbow, or ell, is a 90° bend that is used when a conduit must turn at a 90° angle. In single conduit runs when the larger sizes of conduit are being installed, factory elbows are frequently used to save labor on setting up a power bending machine, calculating and marking the conduit for bending, and finally, making the bend. However, in multiple conduit runs, a neater job will result if on-the-job **sweep bends** or concentric bends are properly calculated and installed. See *Figure 2.*

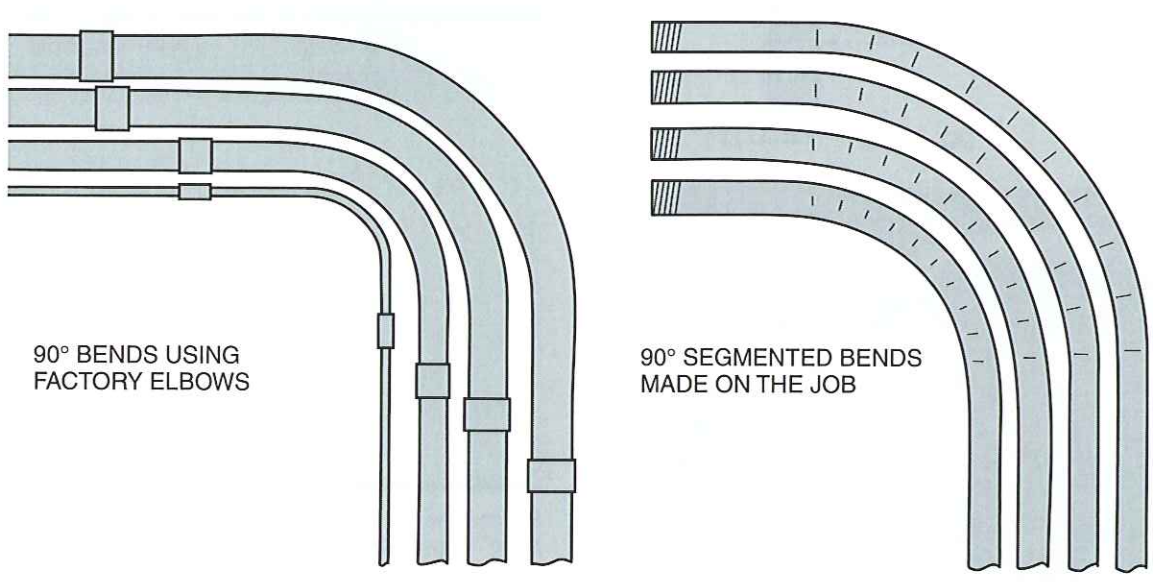
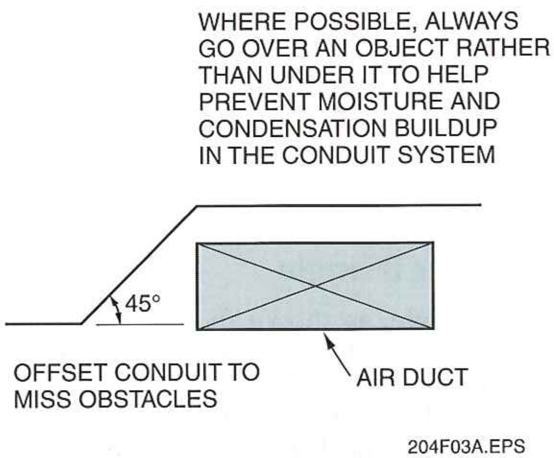


Figure 2 ◆ Typical 90° bends.



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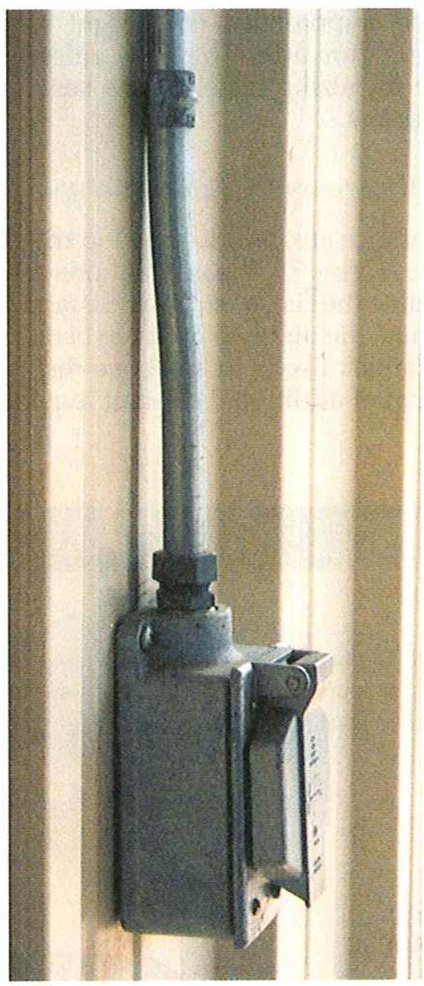

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(B)

Figure 3 ◆ Applications of conduit offsets.

- *Offset* – An offset consists of two equal bends and is used when the conduit run must go over, under, or around an obstacle. An offset is also used at outlet boxes, cabinets, panelboards, and pull boxes. See *Figure 3*.
- *Saddle* – A saddle is used to cross a small obstruction or other runs of conduit. A saddle is made by marking the conduit at a point where the saddle is required and placing a bender a few inches ahead of this point. Bends are made as shown in *Figure 4* in approximately two equal/opposing increments. In most cases, the bends should be as close together as the bender will permit.
- *Kick* – A kick is a change in direction of a conduit run of less than 90°. It is used mostly where the conduit run will be concealed in deck work. The first bend in an offset, for example, is really a kick, as shown in *Figure 5;* another kick in the opposite direction transforms the bend into an offset.

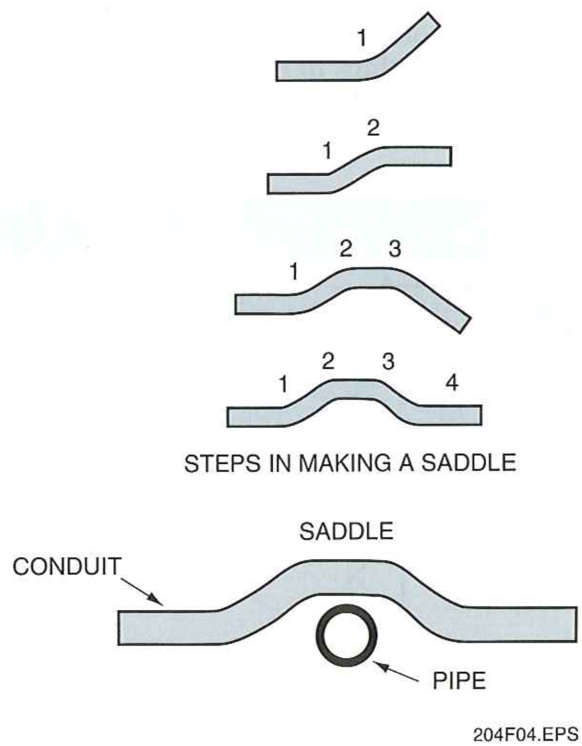

Figure 4 ◆ Practical application of a saddle bend.

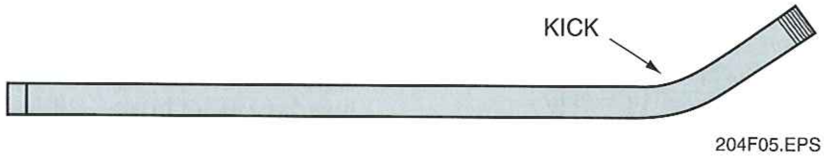

Figure 5 ◆ Kick.

4.0.0 ◆ THE GEOMETRY OF BENDING CONDUIT

Learning to bend conduit involves a thorough knowledge of some basic geometry (the science that deals with the properties of lines, angles, surfaces, and solids). The basic bends discussed previously will handle the majority of the electrician's needs, as these simple bends are merely combined to form more complex bends. When these basic skills are mastered, you will be able to calculate and bend conduit to fit most situations.

The 90° or right angle bend is probably the most basic of all and is used much of the time, regardless of the type of conduit being installed. All other bends are made with angles less than 90°, with the possible exception of short goosenecks used to support a lighting fixture from an outlet box. These goosenecks, however, are seldom seen on modern construction jobs, as there are now a large array of fittings to choose from that obtain the same results in less time and provide for easier conductor installation.

4.1.0 Right Triangle

A right triangle, as shown in *Figure 6(A)*, is defined as any triangle with one 90° angle. The side directly opposite the 90° angle is called the hypotenuse and the side on which the triangle sits is the base. The vertical side is called the height or altitude. For offset bends, right triangle characteristics can also be applied because the offset forms the hypotenuse of a right triangle, as shown in *Figure 6(B)*. There are reference tables available for sizing offset bends based on these characteristics.

4.1.1 Trigonometry Fundamentals

Right triangles are used to develop trigonometric equations (*Figure 7*). These equations can be used to determine the **rise** or **stub-up** distance between bend points, the distance between bend joints, the distance a kick needs to be above the surface, or the amount of additional conduit required. There

INSIDE TRACK

Check It Out

When making complex bends, it is a good idea to test your bends using a piece of wire first, then use the bent wire as a template for your bend. This will give you an idea of whether or not the bend will do the job before wasting expensive conduit.

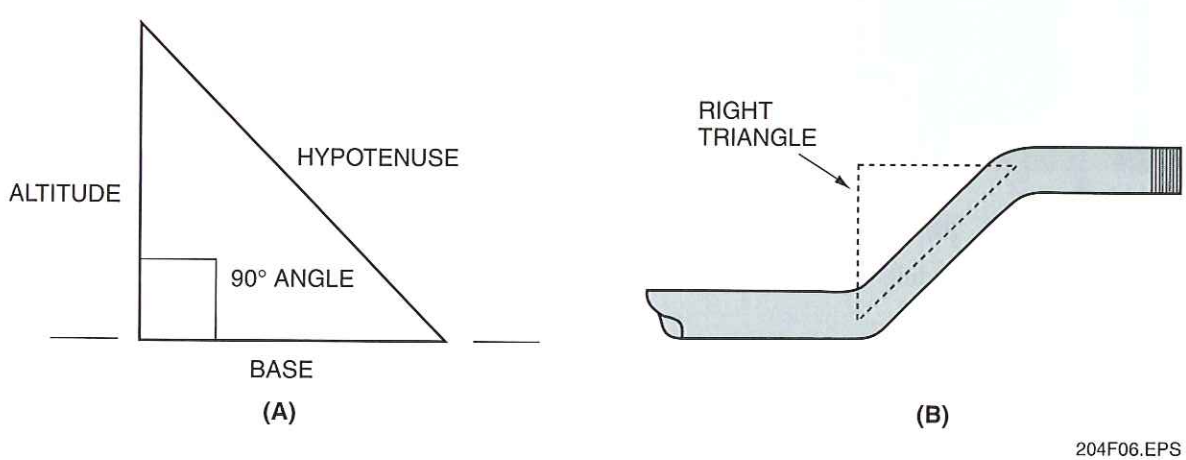

Figure 6 ◆ A right triangle and its relationship to a conduit offset.

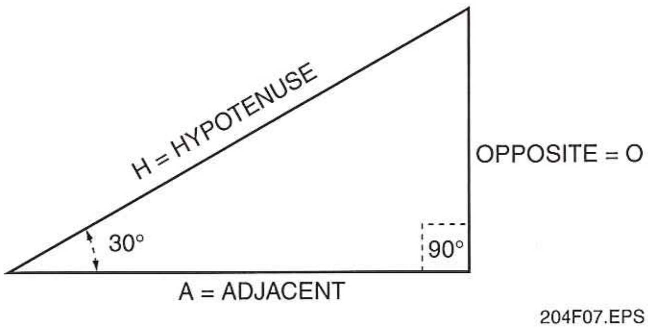

Figure 7 ◆ Trigonometry fundamentals of a right triangle.

are six basic trigonometric functions that will be required:

- Sine
- Cosine
- Tangent
- Cotangent
- Secant
- Cosecant

The sine function can be computed by dividing the hypotenuse by the side opposite the angle being considered. This function can be represented by the following equation:

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

The equations for the other functions are as follows:

$$\text{Cosine} = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{A}{H}$$

$$\text{Tangent} = \frac{\text{opposite}}{\text{adjacent}} = \frac{O}{A}$$

$$\text{Cotangent} = \frac{\text{adjacent}}{\text{opposite}} = \frac{A}{O}$$

$$\text{Secant} = \frac{\text{hypotenuse}}{\text{adjacent}} = \frac{H}{A}$$

$$\text{Cosecant} = \frac{\text{hypotenuse}}{\text{opposite}} = \frac{H}{O}$$

Where:

H = hypotenuse, side facing the right (90°) angle
O = side opposite the angle you are working with
A = side adjacent to the angle you are working with, but not the hypotenuse

Therefore, in *Figure 6(B)*, the hypotenuse or distance between bends could be computed by using the following cosecant trigonometric function:

$$\text{Cosecant} = \frac{\text{hypotenuse}}{\text{opposite}} = \frac{H}{O}$$

Let's say that the angle of the first bend is 30° and the rise or side opposite is 12". Therefore:

$$\text{Cosecant } 30° = \frac{H}{12"}$$

The cosecant of 30° is 2 (check using your calculator).

$$2 = \frac{H}{12"}$$

Cross multiply:

$$H = 2 \times 12"$$
$$H = 24"$$

Therefore, the hypotenuse or distance between bends would be 24".

Now let us complete another example. In this case, a kick is to be made on the end of a piece of conduit (*Figure 8*). The angle of the kick is to be 30°. The hypotenuse of the kick is 20". Determine how far off the surface the end of the kick needs to be.

When calculating the hypotenuse of a bend, the cosecant of the angle is multiplied by the side opposite. If the angle and the hypotenuse are known, then the inverse can be used to determine the side opposite. Therefore, divide 20" by the cosecant of 30°, or:

$$20" \div 2 = 10"$$

The end of the conduit needs to be brought 10" off the surface to acquire a 30° bend. This process eliminates the need for a protractor level.

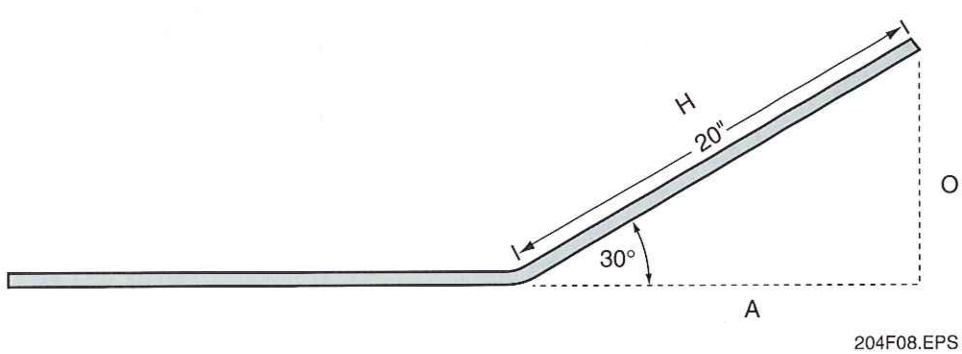

Figure 8 ◆ Kick example.

4.2.0 Circle

A circle is defined as a closed curved line whose points are all the same distance from its center, as shown in *Figure 9(A)*. The distance from the center point to the edge of the circle is called the radius and the length of a straight line from one edge through the center to the other edge is called the diameter. The distance around the circle is called the circumference. A circle can be divided into four equal quadrants, as shown in *Figure 9(B)*. Each quadrant accounts for 90°, making a total of 360°. When making 90° bends, we will be interested in ¼ of a circle, or one quadrant.

Concentric circles, shown in *Figure 9(C)*, are several circles that have a common center but different radii. The concept of concentric circles can be applied to concentric 90° bends in conduit. Such bends have the same center point, but the radius of each is different. *Figure 10* shows how parts of a circle relate to a 90° conduit bend.

For bending conduit, it is necessary to understand the dynamics of the unit circle (*Figure 11*). The unit circle is a circle with a given radius of 1.

In calculating the circumference of a circle, the following formula is used:

$$C = 2\pi R$$

Where:

C = circumference

π = 3.14 (pi)

R = radius

By taking the radius of the unit circle and substituting it into the formula, the result is:

$$C = 2\pi \times 1$$

Any number multiplied by the number 1 is equal to that number, or:

$$1 \times 2 = 2$$

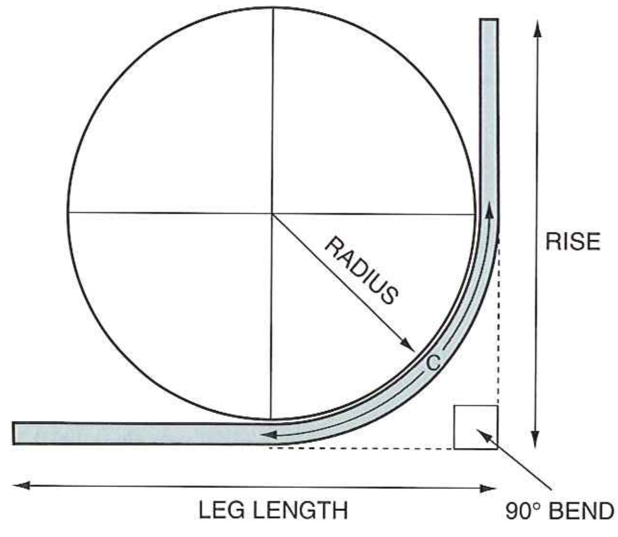

Figure 10 ◆ Parts of a circle related to conduit bending.

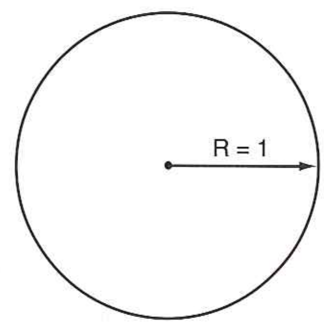

Figure 11 ◆ Unit circle.

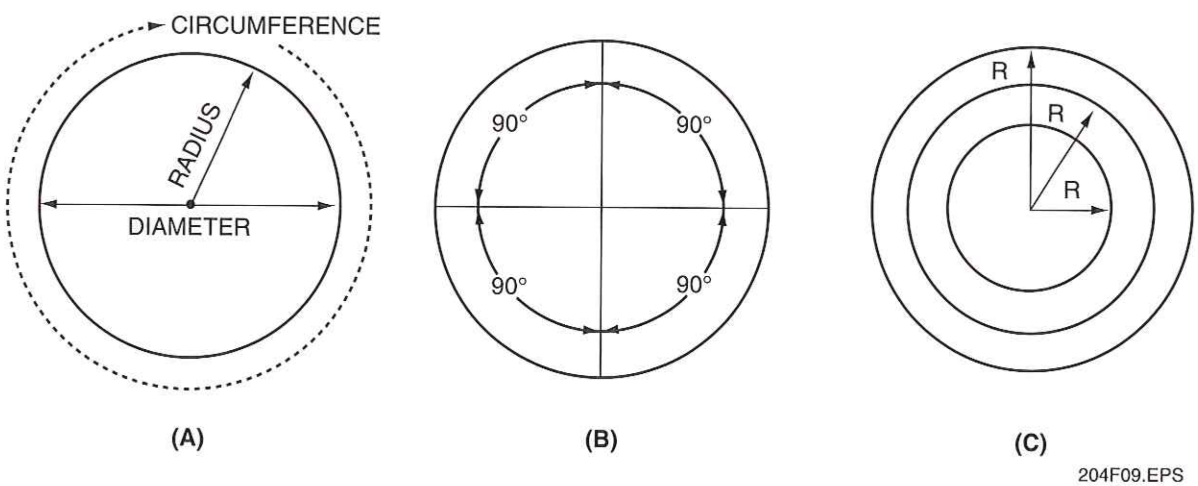

Figure 9 ◆ Characteristics of a circle.

Therefore, $2\pi \times 1 = 2\pi$. This means that in terms of pi, the circumference of the circle is 2π; 360° is 2π and 180° = π. See *Figure 12*.

If we look at 90° in terms of π, 90° is half of 180° or half of π, so 90° is equal to ½ π or $\pi \div 2$. Again, π is a symbol for the numerical value 3.14 (rounded). $\pi \div 2$ is $3.14 \div 2$ or 1.57. Therefore, 90° is represented by the numerical value 1.57. Looking back at the circumference formula tells us that multiplying $2 \times \pi$ or 6.28 times the given radius of the circle will give us the linear distance around the circle. With that in mind, if we multiply 1.57 times the given radius, it will give us the linear distance from 0° to 90° on the circle. This linear distance is known as the **developed length** in regard to the amount of conduit that is required to make a 90° sweep.

4.2.1 Types of Angular Representations

There are three basic ways that angles can be represented or specified. Angles can be stated in degrees, as already mentioned; radians; or gradients.

Angles are measured in degrees from 0° to 360°. They may also be measured in radians from 0 to 6.28 or 0 to 2π. The third way is to specify angles in gradients, from 0 to 400 gradients (grads). These measurements can be equated as follows:

$$90° = \pi \div 2 = 1.57 \text{ radians} = 100 \text{ grads}$$
$$180° = \pi = 3.14 \text{ radians} = 200 \text{ grads}$$
$$270° = 3\pi \div 2 = 4.71 \text{ radians} = 300 \text{ grads}$$
$$360° = 2\pi = 6.28 \text{ radians} = 400 \text{ grads}$$

4.3.0 Equations

To calculate conduit bends accurately, you need to use some basic equations. The equations given here are the most relevant ones for the electrician. Examples are provided for clarification. To calculate the circumference of a circle, use the following equation:

$$C = \pi D$$

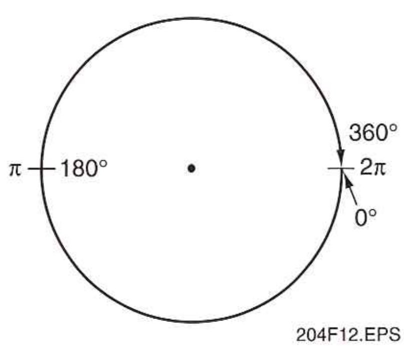

Figure 12 ◆ π and 2π.

Where:

C = circumference
D = diameter
π = 3.14

As discussed earlier, another equation for finding the circumference of a circle is as follows:

$$C = 2\pi R$$

Where:

C = circumference
R = radius (½ the diameter)
π = 3.14

If the radius in a circle (and conduit bend) measures two feet, the circumference of the circle may be found as follows:

$$C = 2\pi R$$
$$C = 2 \times 3.14 \times 2' = 12.56'$$

The arc of a quadrant equals ¼ the circumference of the circle, and its length is found as follows:

$$\text{Length of arc} = (0.25)(2\pi R)$$
$$\text{Length of arc} = (0.25)(2 \times 3.14 \times R)$$
$$\text{Length of arc} = 1.57R$$

Therefore, the length of the arc in the quadrant, if the radius is 2', may be found as follows:

$$\text{Length of arc} = 1.57R$$
$$\text{Length of arc} = 1.57 \times 2' = 3.14'$$

If the radius of the bend and the outside diameter of the conduit are known, then the distance C (the length of the arc) can be calculated. This length, as related to conduit bending, is known as the developed length; it is the actual length of the bend.

Conduit bends with the circumference of the circle (*Figure 13*) and not at right angles. Therefore, the length of the conduit needed for a bend will not equal the right angle distances A and B. **Gain** is the difference between the right angle distances A and B and the shorter distance C, the length of conduit actually needed for the bend.

The gain for a 90° bend is arrived at by multiplying the radius of the bend × 0.43. Therefore, if the radius of the bend in *Figure 13* is 2', the gain may be found as follows:

$$\text{Gain} = 2' \times 0.43 = 0.86' = 10.32"$$

4.3.1 Making a 90° Bend

The 90° stub bend is probably the most basic bend of all. The stub bend is used much of the time, regardless of the type of conduit being installed.

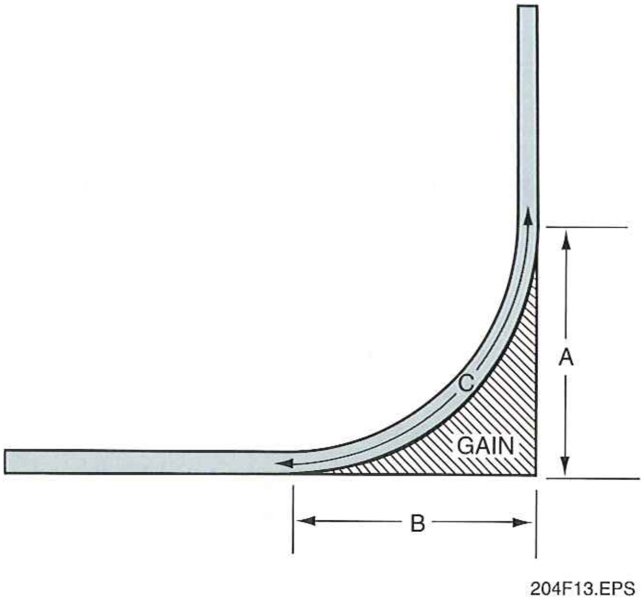

Figure 13 ◆ Gain.

Before beginning to make the bend, you need to know two measurements:

- The desired rise or stub-up
- The **take-up (comeback)** distance of the bender

The desired rise is the height of the stub-up. The take-up is the amount of conduit the bender will use to form the bend. Take-up distances are usually listed in the manufacturer's instruction manual. Once the take-up has been determined, subtract it from the stub-up height. Mark that distance on the conduit (all the way around) at that distance from the end. The mark will indicate the point at which you will begin to bend the conduit. Line up the starting point on the conduit with the starting point on the bender. Most benders have a mark, like an arrow, to indicate the starting point.

> **NOTE**
> When bending conduit using the take-up method, the bender is always placed on the conduit and the bend is made facing the end of the conduit from which the measurements were taken.

As discussed above, if the radius of the bend in *Figure 13* is 2', the gain is 10.32".

Table 3 shows the equivalent fractions for many decimals. For 10.32", search the decimal column for 0.32. The closest decimal in the table is 0.3125, equivalent to $\frac{5}{16}$. Therefore, the number in question becomes $10\frac{5}{16}$".

A decimal may also be mathematically converted to a fraction. A decimal whose denominator is contained in the numerator without a remainder can easily be converted to a fraction by removing the decimal point from the numeral, which then becomes the numerator (the top numeral of the fraction). The denominator is always one plus as many zeros as there are decimal places in the decimal. For example:

$$0.75 = \frac{75}{100} = \frac{3}{4}$$

or:

$$0.375 = \frac{375}{1000} = \frac{3}{8}$$

> **NOTE**
> Decimals may also be converted to fractions by using an electronic calculator, provided the calculator has a fraction key. The exact procedure will vary with the different models of calculators.

Gain factors for 0° to 90° bends are shown in *Table 4*. To demonstrate the use of this table, assume that it is desired to find the gain on a 45° conduit bend with a 15" centerline radius. Referring to *Table 4*, look in the left-hand column; glance down the column until the number 40° is found. Since the bend is 45°, read to the right in this row until the column titled 5° is found; note the figure, 0.043. Therefore, the gain factor for a 45° bend is 0.043.

Multiply the gain factor by the centerline radius (15") to obtain the full gain of a 45° bend.

$$0.043 \times 15" = 0.645"$$

To convert this figure to a readable figure on the foot rule, convert the decimal to a common fraction: $\frac{645}{1000}$ = approximately $\frac{5}{8}$. Thus, the full gain of the 45° bend is $\frac{5}{8}$".

For example, the gain for a given bender is $2\frac{1}{2}$". In *Figure 14*, there are two back-to-back 90° bends.

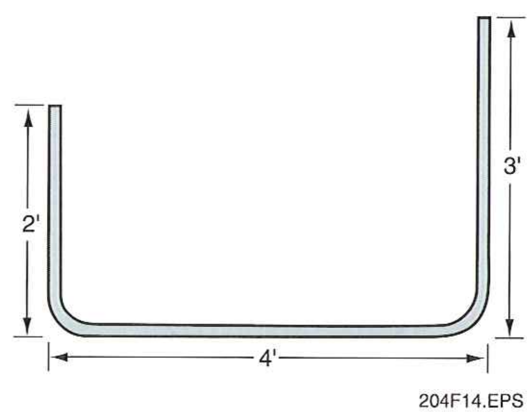

Figure 14 ◆ Back-to-back 90° bends.

Table 3 Decimal Equivalents of Some Common Fractions

Fraction	Decimal	MM	Fraction	Decimal	MM
1/64	0.015625	0.397	33/64	0.515625	13.097
1/32	0.03125	0.794	17/32	0.53125	13.494
3/64	0.046875	1.191	35/64	0.546875	13.891
1/16	0.0625	1.588	9/16	0.5625	14.288
5/64	0.078125	1.984	37/64	0.578125	14.684
3/32	0.09375	2.381	19/32	0.59375	15.081
7/64	0.109375	2.778	39/64	0.609375	15.478
1/8	0.125	3.175	5/8	0.625	15.875
9/64	0.140625	3.572	41/64	0.640625	16.272
5/32	0.15625	3.969	21/32	0.65625	16.669
11/64	0.171875	4.366	43/64	0.671875	17.066
3/16	0.1875	4.763	11/16	0.6875	17.463
13/64	0.203125	5.159	45/64	0.703125	17.859
7/32	0.21875	5.556	23/32	0.71875	18.256
15/64	0.234375	5.953	47/64	0.734375	18.653
1/4	0.25	6.35	3/4	0.75	19.05
17/64	0.265625	6.747	49/64	0.765625	19.447
9/32	0.28125	7.144	25/32	0.78125	19.844
19/64	0.296875	7.54	51/64	0.796875	20.241
5/16	0.3125	7.938	13/16	0.8125	20.638
21/64	0.32812	8.334	53/64	0.828125	21.034
11/32	0.34375	8.731	27/32	0.84375	21.431
23/64	0.359375	9.128	55/64	0.859375	21.828
3/8	0.375	9.525	7/8	0.875	22.225
25/64	0.390625	9.922	57/64	0.890625	22.622
13/32	0.40625	10.319	29/32	0.90625	23.019
27/64	0.421875	10.716	59/64	0.921875	23.416
7/16	0.4375	11.113	15/16	0.9375	23.813
29/64	0.453125	11.509	61/64	0.953125	24.209
15/32	0.46875	11.906	31/32	0.96875	24.606
31/64	0.484375	12.303	63/64	0.984375	25.003
1/2	0.5	12.7	1	1	25.400

Table 4 Gain Factors

	—	1°	2°	3°	4°	5°	6°	7°	8°	9°
0°	0	0	0	0	0	0	0.0001	0.0001	0.0003	0.0003
10°	0.0005	0.0006	0.0008	0.001	0.0013	0.0015	0.0018	0.0022	0.0026	0.0031
20°	0.0036	0.0042	0.0048	0.0055	0.0062	0.0071	0.0079	0.009	0.01	0.0111
30°	0.0126	0.0136	0.015	0.0165	0.0181	0.0197	0.0215	0.0234	0.0254	0.0276
40°	0.0298	0.0322	0.0347	0.0373	0.04	0.043	0.0461	0.0493	0.0527	0.0562
50°	0.06	0.0637	0.0679	0.0721	0.0766	0.0812	0.086	0.0911	0.0963	0.1018
60°	0.1075	0.1134	0.1196	0.126	0.1327	0.1397	0.1469	0.1544	0.1622	0.1703
70°	0.1787	0.1874	0.1964	0.2058	0.2156	0.2257	0.2361	0.247	0.2582	0.2699
80°	0.2819	0.2944	0.3074	0.3208	0.3347	0.3491	0.364	0.3795	0.3955	0.4121
90°	0.4292	—	—	—	—	—	—	—	—	—

The rise for the first 90° bend is 2' and the rise for the second 90° bend is 3'. The back-to-back measurement for these bends is 4'. The task is to determine the amount of straight conduit required to accomplish this task. The conduit is to be cut to length and threaded before bending.

The gain is the amount of conduit that is saved by the radius of the bend. The amount of conduit saved is 2½" per 90° bend. In this situation, there are two 90° bends, or a savings of 5". The total straight lengths add up to 9' of conduit. Therefore:

9' – 5" = 8'-7"

5.0.0 ◆ MECHANICAL BENDERS

Conduit bends are normally made in the smaller sizes of conduit and tubing by hand with the use of hickeys or EMT bending tools. However, on many projects, an advantage can be gained by the use of mechanical bending equipment with suitable adjustable stops and guides. With the use of such equipment, the exact bend can be duplicated in quantity with a minimum of effort. The angle of the bend and the location of the bend in relation to the end of the length of conduit are preset.

A popular mechanical bender is shown in *Figure 15*. This type of bender was originally called the Chicago bender, as it was made by the Chicago Equipment and Manufacturing Company. Today, however, this type of bender is manufactured by several different companies and the correct name is portable mechanical conduit bender. In any event, you may still hear the term Chicago bender on many jobs.

This type of mechanical bender is very popular with many electrical contractors. To use it, a length of conduit is placed in position and secured in place; a long bending handle is then pulled around and the bend completed. This type of bender may be used as a one-shot bender for the smaller sizes of conduit (bypassing the ratchet mechanism). The ratchet mechanism, however, is usually activated when bending the larger sizes of conduit to make the work easier. It is suitable for making bends in conduit sizes up to 2" EMT, 1¼" IMC, and 1½" rigid conduit, provided the proper bending accessories are used (e.g., bending shoes, follower bars, etc.).

Bending shoes and follower bars are designed to form a particular radius bend for a certain type and size of conduit, that is, EMT, IMC, or rigid conduit. These accessories should be treated as precision instruments; any damage will result in inaccurate bends, kinks, and so on. The first consideration is to use only the proper shoe and follower bar for the type and size of conduit being bent. For example, never use an EMT shoe for bending rigid conduit or a 3" shoe for bending 2½" conduit. In general, make certain that the bending shoes and follower bar are compatible with the type of conduit to be bent; to do otherwise may damage the tool and result in inaccurate bends.

The ratchet feature is normally engaged for the larger sizes of conduit, whereas a spring-loaded pawl engages the ratchet for easier bending in segments. For the smaller sizes of conduit, however, the ratchet may be bypassed so that the bend can be made in one shot.

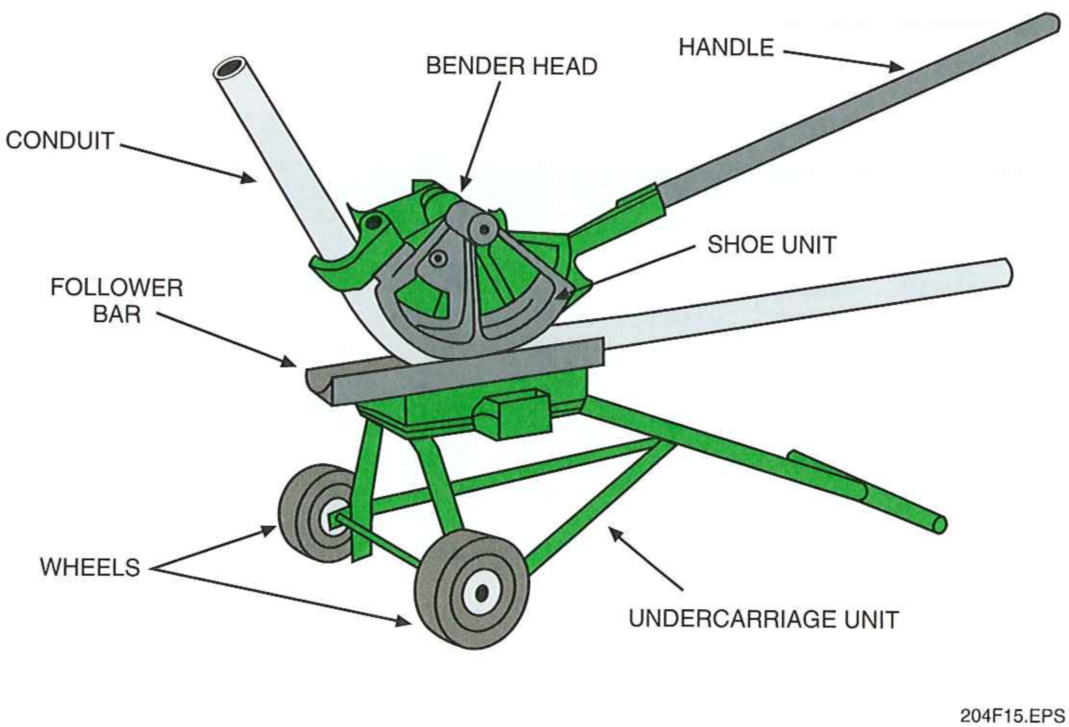

Figure 15 ◆ Typical mechanical bender.

A bending gauge with an adjustable pointer on the bender is helpful when making multiple bends at the same angle. This pointer is set at the desired angle and then the setscrew is tightened. As the bend is being made, the handle is operated until the pointer reaches the index mark. To ensure the correct angle of bend, the first bend should be checked with a **bending protractor** (*Figure 16*) and any necessary adjustments made to the bending gauge pointer before continuing. All successive bends will be exactly the same as the first.

For example, follow this process for charting a bender. This chart will contain minimum size, gain, and centerline distances from the arrow on the bender to the center of the bend for 15°, 30°, 45°, and 60° bends. This is to be accomplished with one scrap piece of conduit.

For this discussion, the scrap piece will be ½" conduit and will be 3' in length (*Figure 17*).

Place a mark on the conduit at a given distance from the end of the conduit. For this discussion, the mark will be 10" in from the end of the conduit (*Figure 18*).

Take a ½" conduit bender and place the arrow, which represents the take-up or minimum rise of the bender, on the mark 10" in from the end of the bender.

Place a protractor level on the conduit in front of the bender. This will be on the piece of conduit marked for 10" back from the end. Bend the 10" portion until the protractor level reads 15°. Remove the bender from the conduit (*Figure 19*).

Now take a straightedge, such as a ruler or torpedo level, and lay it on the inside of the bend so the straightedge lies across the bend

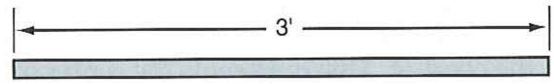

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Figure 17 ◆ Conduit.

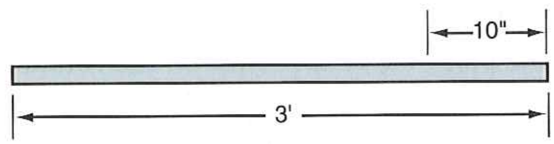

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Figure 18 ◆ Conduit with 10" mark.

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Figure 19 ◆ Kick of 15°.

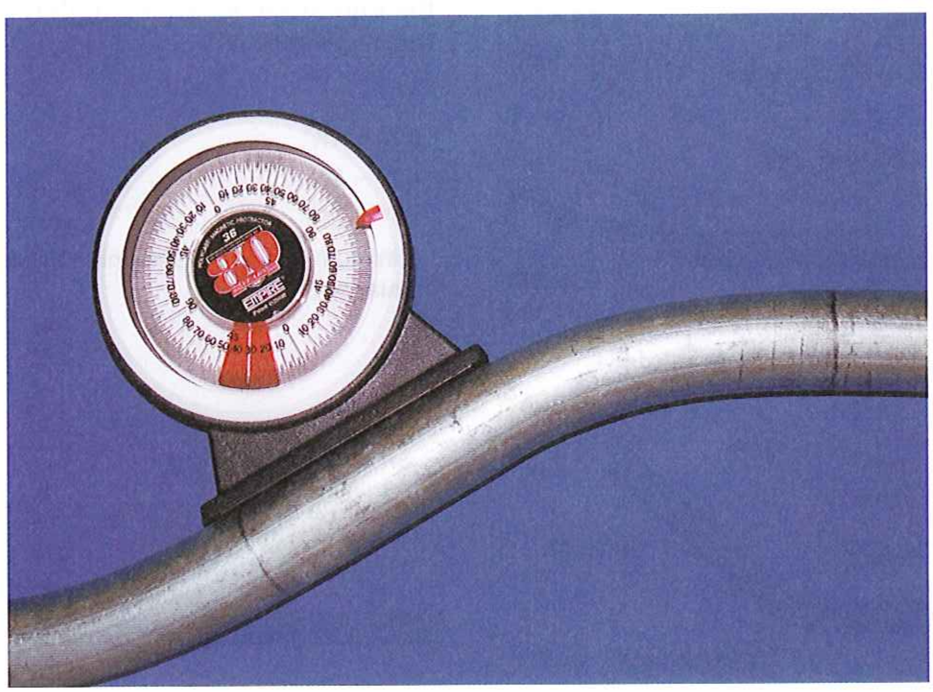

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Figure 16 ◆ Bending protractor.

and rests against the straight portion of the conduit (*Figure 20*).

With a sharp pencil, scribe a line across the bend of the conduit.

Now take the straightedge and lay it across the conduit so the straightedge is against the side adjacent to the previous position. It should extend across the bend once again (*Figure 21*).

Now scribe a line across the bend of the conduit. The two pencil lines should cross to form an X on the conduit. This represents the center of the bend (*Figure 22*).

Now take a tape measure and measure from the 10" mark to the centerline of the bend. Record this distance as follows:

15° – 1" (assuming 1" is the measured distance)

Now place the bender back on the conduit so that the take-up arrow is on the 10" mark on the conduit. Place the protractor level back on the conduit. Bend the conduit until the protractor level reads 30°. Take the bender off the conduit and repeat the line crossing process that was discussed for 15°, using the same straightedge. Once again, measure from the 10" mark to the point where the pencil lines cross in the center of the bend. Record this measurement.

15° – 1"

30° – 1½" (assuming this is the measured distance)

Repeat the previous process for 45°. Record this measurement.

15° – 1"

30° – 1½"

45° – 2" (assuming this is the measured distance)

Repeat the previous process for 60°. Record this measurement.

15° – 1"

30° – 1½"

45° – 2"

60° – 2¼" (assuming this is the measured distance)

The centerline distances for the different bends from the take-up mark of the bend have now been recorded. This portion of the chart is now completed.

The next step is to determine the minimum rise of the bender. Place the bender back on the conduit so the take-up mark of the bender is on the 10" mark on the conduit. Place the protractor level back on the conduit and bend the conduit until the protractor level reads 90°. Take the bender off the conduit. Measure from the back of the conduit to the 10" mark. The reading on the tape is 5". This is the minimum 90° stub length (*Figure 23*). Record this measurement.

15° – 1"

30° – 1½"

45° – 2"

60° – 2½"

Minimum rise – 5" (assuming this is the measured distance)

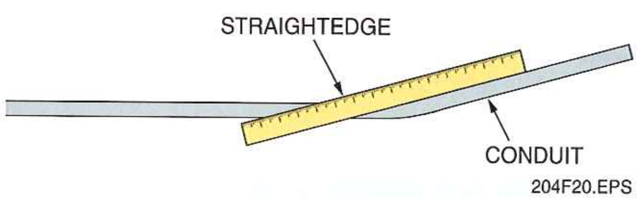


Figure 20 ◆ Conduit and straightedge.

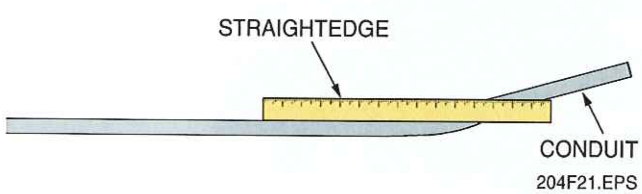


Figure 21 ◆ Conduit and horizontal straightedge.

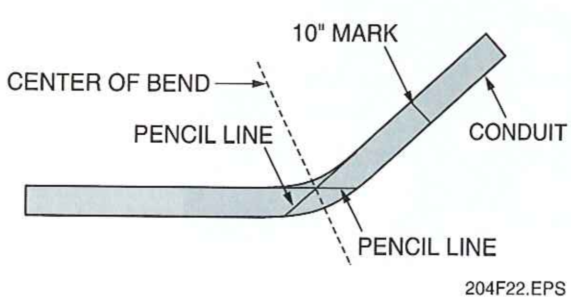


Figure 22 ◆ Center of bend.

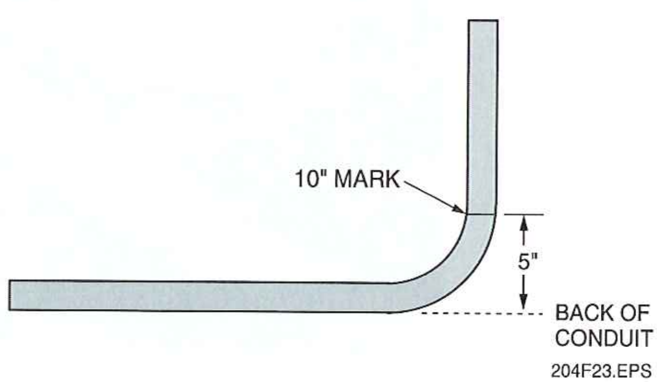


Figure 23 ◆ 90° stub-up.

The next step is to determine the gain of the bender for 90°. Measure the length of both sides of the scrap piece of conduit (*Figure 24*).

Add the two measured stub lengths together.

15" + 1'-11⅝" = 3'-2⅝"

Subtract the original length of the conduit, which was 3', from 3'-2⅝".

3'-2⅝" − 3' = 2⅝"

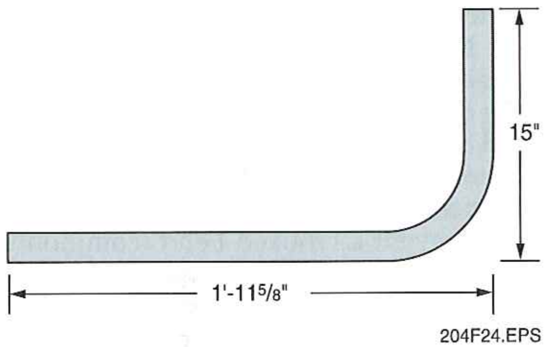


Figure 24 ◆ 90° elbow.

This is the gain for this particular ½" conduit bender. Record this information.

15° – 1"
30° – 1½"
45° – 2"
60° – 2½"
Minimum rise – 5"
Gain – 2⅝" (assuming this is the measured distance)

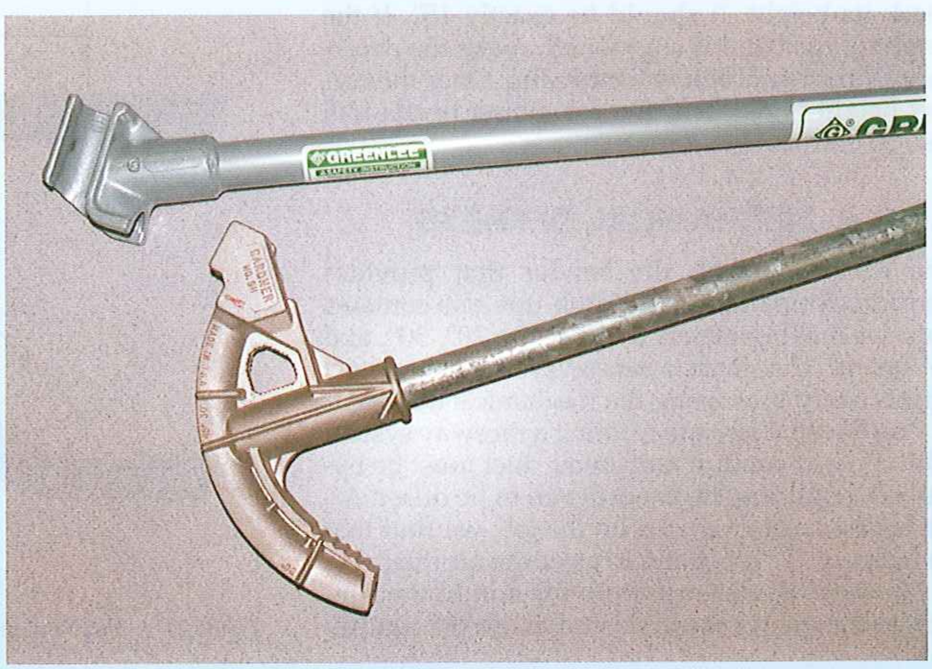
The ½" bender has now been charted. This same process would need to be repeated for a ¾" bender, 1" bender, 1¼" bender, 1½" bender, etc.

This charting process should help you to understand how the manufacturer of a bender comes up with the marks that determine the ability to bend exact 90° bends of any length, which is the minimum rise mark. The star mark seen on many benders is used for back-to-back bends. The star mark is 2⅝" back from the minimum rise mark (take-up). In other words, it is the measured gain distance back from the minimum rise mark. The

INSIDE TRACK

Hickeys and Hand Benders

Hickeys and hand benders are not interchangeable. Hickeys do not support the conduit walls the way hand (shoe) benders do, so they are typically used for making segmented bends rather than one-shot 90° bends. Making too large of a bend at one time with a hickey may cause the conduit to kink.



centerline marks are used in lining up the centers of bends for various sizes of conduit. The centerline marks can also be used in lining up saddles on the centerlines of I-beams and process piping. This information is good for charting any type of wrap-around bender.

6.0.0 ◆ MECHANICAL STUB-UPS

Stub-ups are quickly and easily made with mechanical benders. A deduct decal is provided on many benders, but sometimes these decals become damaged, making them difficult to read. Therefore, backup charts should be provided on all jobs. With this deduct chart on hand, the following is an example of making a 90° stub-up to a given height.

Assume that you are working on a deck job and need a number of 1" rigid stub-ups with a rise of 15" each. When you check the deduct chart on the bender for a 15" stub-up using 1" rigid conduit, you note that 11" should be deducted from the total rise of 15". Since 15" − 11" = 4", measure back from the end of the conduit by 4" and make a mark. Encircle the entire conduit at this point so you will not lose the mark once the conduit is placed in the bender. Many electricians like to use a black felt-tip marker for marking conduit.

Load the conduit into the bender with the mark lined up with the front of the bender hook. Engage the ratchet and start pumping the bender handle until the bender pointer reaches the preset index mark for 90°. Move the bender handle forward, then remove the conduit from the bender and check its height. It should be exactly 15". If the height of the bend is slightly off, make the necessary adjustments before continuing. Once the correct height is reached, the remaining bends will also be correct.

7.0.0 ◆ MECHANICAL OFFSETS

The decal chart on the bender that provides deduct information for the stub-ups also contains data for making offsets that require 20°, 30°, and 45° bends. This chart is necessary to make perfect offsets every time using the mechanical bender.

Assume that you are running a raceway system with ½" rigid conduit and an air duct must be bypassed, requiring the conduit run to be offset. After taking measurements on the job, we find that an offset of 12" is needed to clear the air duct.

Measure the distance from the end of the conduit to the start of the first bend; mark the conduit as before. Referring to the chart on the bender with offset information, we decide to make the offset with two 45° bends. The chart indicates that the distance between bends is 16$\frac{5}{16}$". Therefore, measure and mark this distance back from the first mark.

Insert the conduit into the bender and line up the first mark with the front of the bender hook. The ratchet may be used, but for ½" conduit, the ratchet override on the front of the bender shoe is normally employed. Make the first 45° bend. Move the bender handle forward to release the conduit. Now slide the conduit forward through the bender hook until the second mark lines up with the front of the bender hook, and then turn the bend over so the end of the conduit is pointing downward toward the deck. Also, make sure that the first bend lines up with the next bend to be made to prevent a crooked bend (commonly referred to as a dog leg) in the conduit. Once everything is aligned, engage the bender handle and make another 45° bend. The height of the offset should be exactly 12" (see *Figure 25*).

The distances between marks for offset bends will vary depending upon the size and type of conduit being bent, so always check the offset information on the bender.

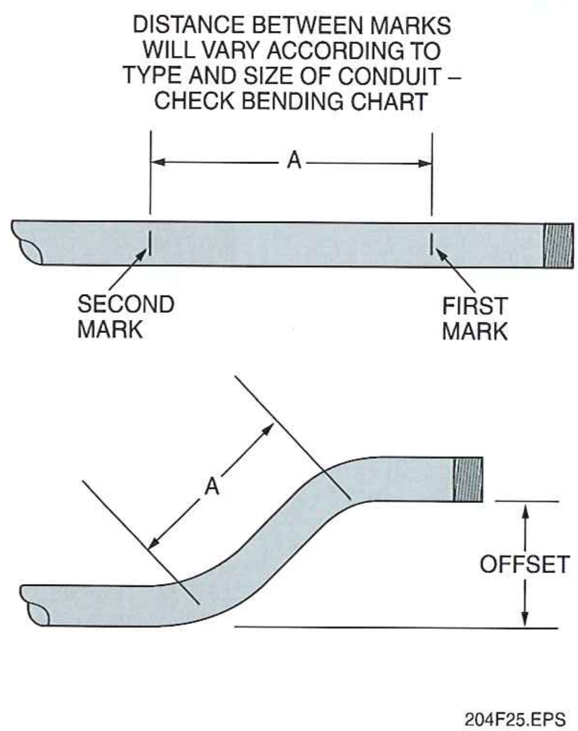


Figure 25 ◆ Bending offsets in conduit.

INSIDE TRACK

Making Accurate Offsets

Be sure to use the same angle for both bends of an offset. To avoid dog legs, make sure your first bend lines up evenly with the rest of the conduit, the handle, and the bender. Take your time, and be sure of proper alignment before making the second bend. A No-Dog® is a simple, pocket-sized device that may be used to prevent crooked bends. It is screwed onto the end of the conduit and has a built-in level to ensure straight bends.

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7.1.0 General Tips for Bending with the Chicago Bender

The following are some general tips to keep in mind when bending with the portable mechanical conduit bender:

- An engineer's rule marked in hundredths will simplify formula bending by eliminating the need to convert to fractions.
- When minimum length stubs are being bent, the shoe tends to creep and deforms the end of the conduit and threads. Screwing a coupling onto the pipe stops the shoe from creeping forward and protects the threads.
- When bending offsets, the front of the bender can be temporarily elevated for clearance requirements.
- Most bender shoes are made of cast aluminum and are easily pitted and gouged if foreign material gets between the shoe and the pipe. For longer shoe life, keep the pipe clean and the shoes wiped down.
- When the remaining pipe length is not long enough to reach the roller or pipe support, a larger diameter conduit can be slid over the pipe being bent to complete the bend; or, if the pipe has threads, screw on a coupling and a short piece of scrap pipe.
- Segment and concentric bending of smaller sizes of pipe can be performed with this bender. Bend a scrap piece of pipe and measure from the center of the bend to the front of the bending shoe. Use this measurement to adjust the start mark using the segment and concentric bending procedures.

NOTE

For matching bends in sizes ½", ¾", and 1" rigid conduit and IMC, bend all pipes with the 1" shoe.

8.0.0 ◆ ELECTRIC AND HYDRAULIC CONDUIT BENDERS

Bends in larger sizes of conduit (over 2" EMT, 1¼" IMC, or 1½" rigid conduit) are normally made using hydraulic benders. In some instances, bending tables have been developed for use with bending tools or hydraulic benders to simplify making bends to certain dimensions. Various adaptations of benders have been developed to serve certain specific purposes. For example, one type of hydraulic bender is designed for making bends in a section of conduit that has been installed in a raceway system.

8.1.0 Electric Conduit Benders

Electric conduit benders operate on the same basic principle as the mechanical benders described previously except that the bending is accomplished by a gear motor rather than manual power. There are several types of electric benders on the market. A typical electric unit is shown in *Figure 26*. This bender will make stub-ups, offsets, and saddles quickly and easily at any location where a 120V receptacle is available. Furthermore, this bender will make 180° one-shot bends in ½" through 2" EMT, IMC, or rigid conduit.

Bending charts are often included in the form of decals attached to the bender for quick reference on the job. These include deduct and **springback** figures along with information for making offsets.

Many electric benders are sold as a power unit and the bending shoes for various types of conduit are sold as accessories. These shoes quickly snap into place on the power unit, ready for use in seconds.

To describe the operation of the example bender, assume that we need a 16" stub-up in a piece of 1¼" rigid conduit. Measure and mark a piece of conduit 16" from one end. When we check the deduct chart on the bender for this size conduit, the figure is 12¾". Therefore, 12¾" must be deducted from 16", which leaves 3¼". So a mark is made at this distance from the end of the conduit. Encircle the conduit with this mark so it will be plainly visible during the bend.

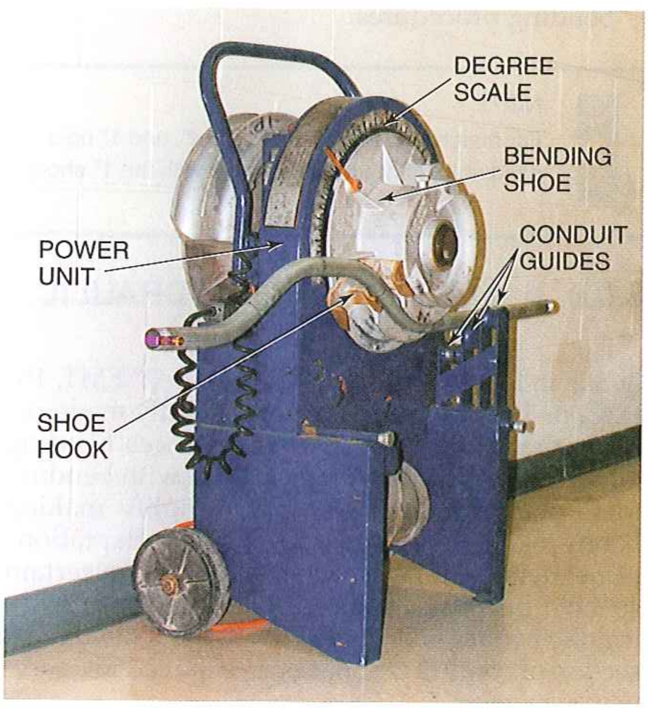

Figure 26 ◆ Typical electric bender.

Insert the conduit in the bender with the mark lined up with the front of the bender hook. For this particular bend, the mark is 3¼" from the end of the conduit.

The three-position operating switch on the example bender is attached to a flexible cord. The center position de-energizes the machine, the up position (forward) is for bending, and the down position (reverse) is for unloading the conduit after the bend has been made. When released, the switch automatically springs to the center or off position. A pointer on the shoe indicates the degree of bend as the bend is being made.

The machine is jogged or inched up until the shoe pointer lines up with the zero mark on the degree scale. The switch is then pressed upward and held in this position to start the bend. As the pointer approaches the 90° mark, refer to the springback chart for the size and type of conduit being bent. In this case, 1¼" rigid conduit, the chart indicates 95°. Therefore, the pointer should pass the 90° mark and stop at 95° to allow for springback when the conduit is removed from the bender; the stub-up is ready for installation.

An offset is made in the electric bender similar to the method described for the mechanical bender; that is, the first mark is located on the conduit and then offset information is obtained from the bender chart. In the case of a 16" offset in a length of 1¼" rigid conduit, the chart indicates a distance of 22⅝" between marks for a 16" offset using 45° bends.

Mark the conduit and insert the conduit into the bending shoe, positioning the mark so that it is even with the front of the bender hook. Start the bend as discussed previously until the pointer reaches the 45° mark on the scale; allow for any springback as indicated in the chart. Reverse the motor until the conduit is loose, then turn the conduit upside down. Position the second mark at the front of the bender hook, making certain the conduit is aligned to prevent a dog leg in the bend. Start the second bend until the pointer reaches the 45° mark, reverse the bender, and unload the conduit. A magnetic torpedo level placed on the side of the conduit will help align bends for offsets. An anti-dog device can also be used for this.

Finally, check the bends for accuracy. Although rebending is possible, it is not a good practice. Rebending puts considerable strain on the conduit, and while it may not break, the coating may crack and cause corrosion.

8.1.1 Speed Benders

A speed bender operates basically the same as the standard bender except the speed bender utilizes remote digital control with easy-to-use bending charts and instructions to ensure fast, accurate, and consistent bends in conduit sizes from ½" to 2".

This bender can be operated upright or laid on its back for large offsets and saddles. In operation, rather than holding the switch up in the bend position as with the standard bender, the operator sets the bend wanted via digital controls and the bender automatically bends to that degree once the conduit is placed in the bending shoe and the start control is activated. Otherwise, the conduit is marked and bent in the same way as described for the standard bender.

8.2.0 Hydraulic Conduit Benders

The hydraulic bender is indispensable for bending large conduit. 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 hydraulic bender (*Figure 27*) provides extended bending capability, but also requires additional responsibility. Hydraulic bending equipment represents a large initial investment, and the bender must be properly cared for if it is to last and give the service necessary to justify the cost.

WARNING!

Dangerous pressures are used in hydraulic benders. Exercise care when working with or around hydraulic benders.

The bender frame, pivot shoes, and bending shoes will require little more than occasional wiping down to remove the dirt and oil film. The pump, cylinder, and hydraulic hoses, however, will demand more attention.

The pump should have its fluid level checked periodically. Low fluid pressure will keep the pump from developing its rated hydraulic pressure. When the level is low and fluid must be added, use only approved hydraulic oil. Ordinary oil will cause damage to the pump assembly.

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 an indicating mark at its center. If take-up values are not listed on the bender frame or bender storage case, scrap pipe can be bent and take-up figures found. All the methods and layout techniques discussed for EMT and rigid metal conduit 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 is far enough apart to allow the first bend to be rolled 180° and advanced enough to clear the pivot shoe.

Segment shoes are shorter and have a radius that is far less than 90°. A **ninety-degree bend** cannot be made in one operation, as the conduit walls would collapse. Bends, then, must be made in several steps (as few as four and as many as 30) to form a smooth radius. The **segmented bending shoe** allows pipe to be bent to larger size radii.

Segmented shoes are used for concentric bending (bending several conduits with increasing or decreasing radii). One-shot shoes can be used for a **segment bend,** but are not as convenient. Concentric bending is covered in detail later in this module.

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.

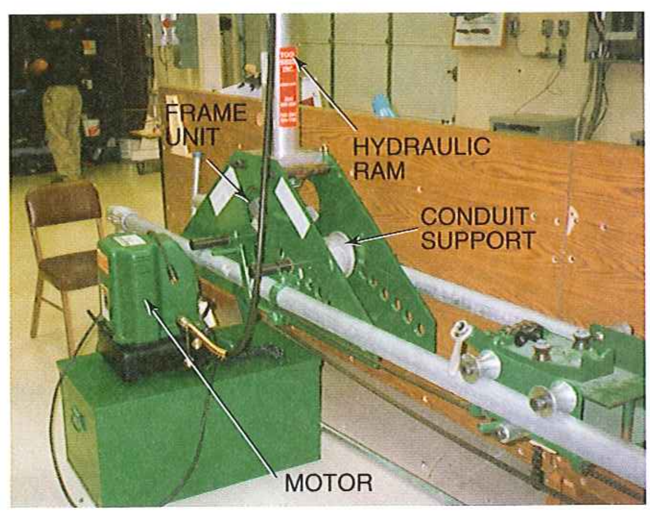

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Figure 27 ◆ Hydraulic conduit bender.

8.2.1 Bending Tips for Rigid Aluminum

Aluminum conduit is available in all trade sizes from ½" through 6". It is lightweight, corrosion resistant, and has low ground impedance. It is, however, difficult to bend consistently and accurately. Two pipes out of the same bundle will act differently when bent. Even if two pipes are bent using the same layout, they do not always come out the same. Do not be discouraged by this; it is the nature of the metal and it cannot be helped.

Another disadvantage of aluminum is that a one-shot bending shoe will dig in and score the pipe. Also, where the pipe rides on the pivot shoe, it is prone to wrinkling and scoring. Applying petroleum jelly or a lubricant such as WD-40® to the shoe will allow the pipe to slide without the shoe digging in. Petroleum jelly will also make it easier to remove the conduit when the bend is complete.

> INSIDE TRACK
>
> **Hydraulic Bender Safety**
>
> A hydraulic bender generates a tremendous amount of power and operates under dangerous pressures. Do not attempt to use a hydraulic bender unless you have been properly trained and are thoroughly familiar with the unit's operating and safety instructions. Even then, exercise extreme caution and always work in conjunction with a bending partner.

8.2.2 One-Shot Bending

Accurate one-shot stub-ups are easily made on hydraulic benders by applying a little basic geometry in making calculations, and then knowing the operating principles of the bender. *Figure 28* shows the reference points of a common 90° bend. To make one-shot 90° bends, first determine the **leg length** and rise, the gain, the radius of the bend, and the half-gain.

Use the following procedure for laying out accurate stub-ups:

Step 1 Determine lengths A and B.

Step 2 Add lengths A and B. Subtract X for the length of pipe required.

Step 3 Subtract Y from length A or B to get the center of the bend.

Step 4 Calculate the developed length and the length of conduit required.

Step 5 Determine the center of the bend. This can be done by taking the half-gain value from the distance A or B. See *Table 5*.

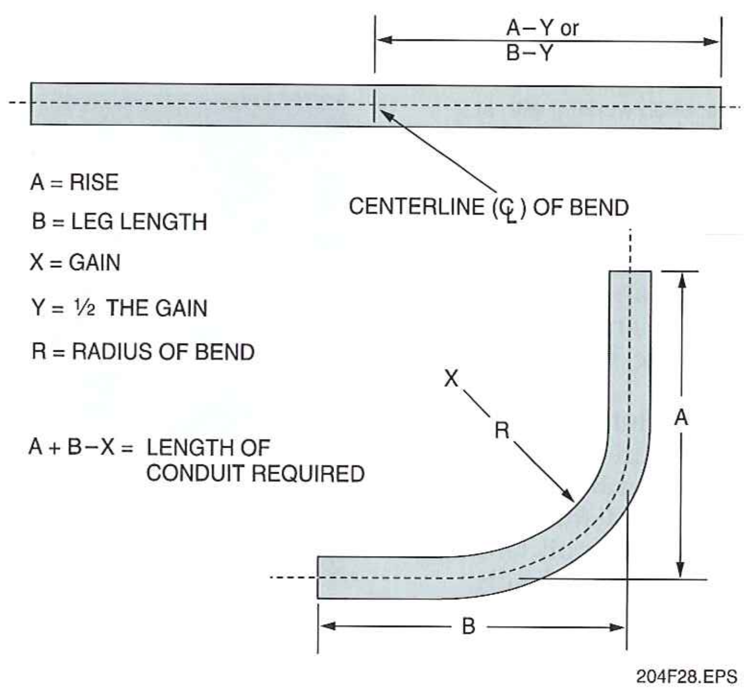

Figure 28 ◆ Laying out stub-ups.

Table 5 Dimensions of Stub-Ups for Various Sizes of Conduit

Pipe and Conduit Size	Radius of Bend R	Minimum Developed Length 90°	Gain X	½ Gain Y
½"	4"	6⁵⁄₁₆"	1¹¹⁄₁₆"	²⁷⁄₃₂"
¾"	4½"	7¹⁄₁₆"	1¹⁵⁄₁₆"	³¹⁄₃₂"
1"	5¾"	9"	2½"	1¼"
1¼"	7¼"	11⅜"	3⅛"	1⁹⁄₁₆"
1½"	8¼"	13"	3½"	1¾"
2"	9½"	14¹⁵⁄₁₆"	4¹⁄₁₆"	2¹⁄₃₂"

8.2.3 90° Segment Bends

When bending conduit in segments with a hydraulic bender, the following factors must be determined:

- The size of conduit to be bent
- The radius of the bend
- The total number of degrees in the bend
- The developed length
- The gain of the bend

To determine the developed length for a 90° bend, multiply the radius by 1.57. The next step is to locate the center of the bend. Most benders have the center mark indicated on the bending shoes. Once the center mark on the conduit is found, it is easy to locate the other bend marks (see *Figure 29*).

You must now determine the number of **bending shots** that will make the bend to suit the requirements, preferably an odd number so that there are an equal number of bends on each side of the center mark. Next, calculate the width of the spaces for each segment bend and make the layout on the conduit. Make an equal number of spaces on each side of the center mark. The gain need only be determined if the bend is being fitted between two existing conduit runs or junction boxes.

To determine the bending data for a 90° bend using 3" conduit with a rise of 48", a leg length of 46", and a centerline radius of 30", proceed as follows (see *Figure 30*).

Step 1 Multiply the radius by 1.57 to determine the developed length. Therefore:

30" × 1.57 = 47.10" (47⅛") developed length

Step 2 Determine the gain for a 90° bend.

Gain = (2 × R) − developed length

Gain = (2 × 30") − 47⅛" = 12⅞"

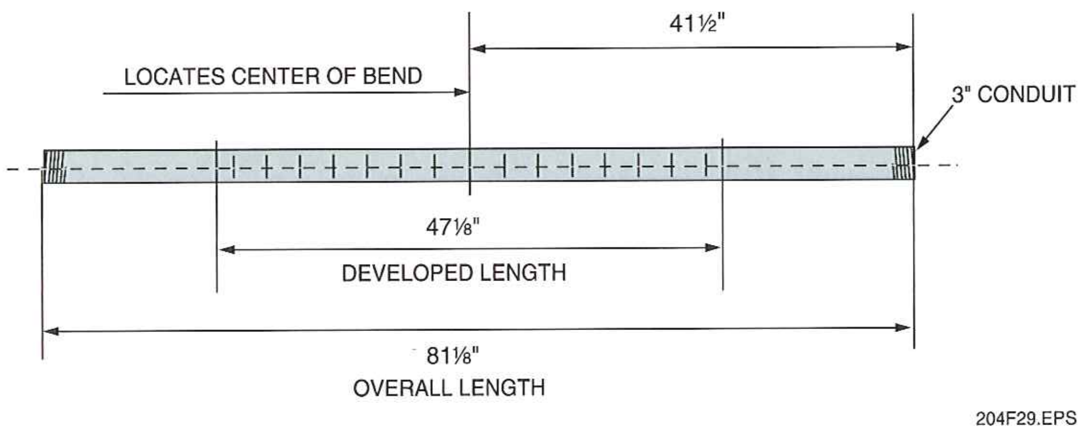

Figure 29 ◆ Laying out segment bends.

THINK ABOUT IT

Developed Length

Why is the radius multiplied by a factor of 1.57 to determine the developed length for a 90° bend?

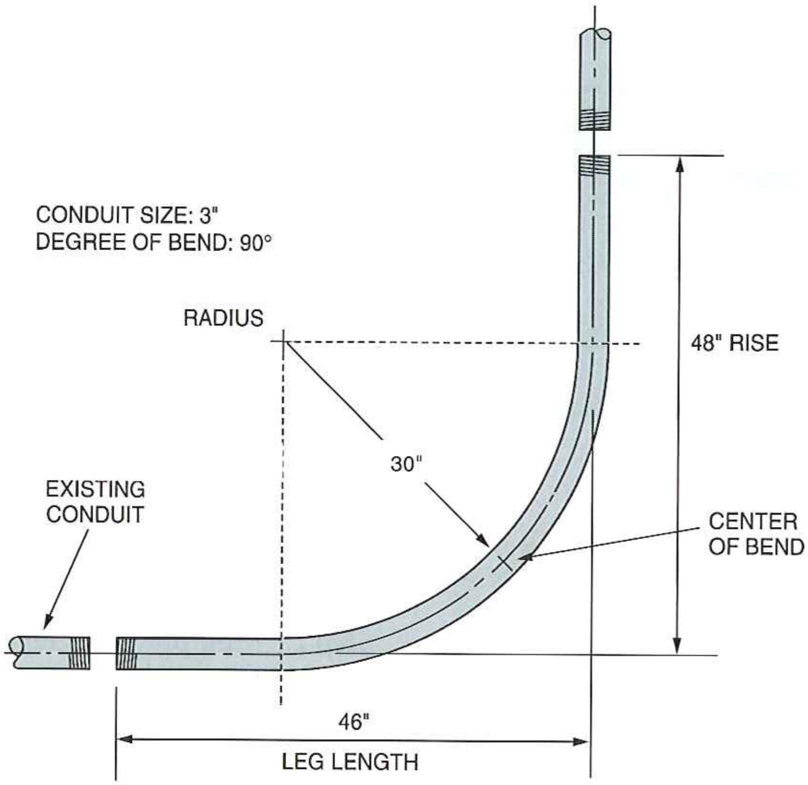

Figure 30 ◆ Specifications for sample bend.

Step 3 To calculate the overall length (OL) of the conduit, add the leg and stub-up lengths and subtract the gain. See *Figure 30.*

OL = leg length + rise − gain

OL = 46" + 48" − 12⅞"

OL = 81⅛"

Step 4 Now locate the center of the required bend. First, determine one-half of the developed length:

½ (47⅛") = 23.56" = 23½"

Use the rise or stub-up dimension of 48". Subtract the radius (30") and add one-half of the developed length:

48" − 30" + 23½" = 41½"

Step 5 As a rule, 6° or less per bend will produce a good bend for a 30" radius. In this case, 6° per bend will be used, making 15 segment bends (90 ÷ 6 = 15). An odd number of segment bends is easy to lay out after finding the center mark because there will be an equal number of spaces on each side of the center mark.

Step 6 To determine the space between the segment marks, divide the developed length by the total number of segments:

47⅛" = 47.125"

47.125" ÷ 15 = 3.14"

3.14" = 3⅛"

Step 7 Position the conduit in the pipe holders, making sure to clamp them securely.

Step 8 Place the center mark 41½" from one end of the conduit. Next, mark seven points on each side of the center point, 3⅛" apart, for a total of 15 marks. These are the centers of the segment bends.

Step 9 It is a good idea to check the distance between the first and last bend marks to be sure the layout is correct before starting the first bend. The distance from the first mark to the last is the developed length minus the length of one bend. (Actually, you are subtracting one-half of a segment bend from each end of the conduit.)

47⅛" − 3⅛" = 44"

Step 10 After positioning the conduit in the bender (*Figure 31*), attach the pipe bending **degree indicator** in a convenient location.

Step 11 Attach the pipe supports with the proper face toward the conduit and insert the pipe support pins. Lock them in position by turning the small lock pin. Now, proceed to make the series of bends.

Step 12 Begin by bending 6° on the first mark. When this is done, the indicator will read 6°. Release the pressure and check the springback; if any is found, overbend by the same amount.

Step 13 When using a bender with a rigid frame, move the pipe support one hole position in (toward the ram) on the side that you have bent the conduit.

Step 14 Continue to bend to 12° on the second mark. Check for springback. When the first bend in the conduit is moved past the one pipe support, the **approximate ram travel** for the remaining bends will be exactly the same.

Step 15 Follow this procedure until you get to the last mark, where you will be bending to 90°. Stop at exactly 90°, release the pressure, and check for springback, correcting if necessary. The result will be a 90° bend without any bows or twists.

For example, suppose the task is to bend a 90° sweep with a given radius of 25". This particular sweep has no definite height. This is to be done on a hydraulic bender using a segmented bending process.

The first step is to determine the linear length or developed length of the conduit required to be used for the bend. This can be done by multiplying the radius of 25" by $\pi \div 2$ or $3.14 \div 2 = 1.57$. The answer is 39.25, as shown below:

$$1.57 \times 25" = 39.25"$$

Therefore, it takes 39.25" of conduit to accomplish a 90° bend with a 25" radius.

The next step is to decide how to lay out the number of segments to be bent to attain the 90° sweep. A rule of thumb is that there will be 20 segments or 21 shots. A shot is the actual bending process. There are 21 shots because the sweep is always laid out from the center of the developed length (*Figure 32*).

Once the center of the developed length is established, half of the developed length is measured out in each direction from the centerline.

To establish the linear distance between segments, divide the developed length by the number of shots (39.25 ÷ 20) or 1.9625" between segments (*Figure 33*).

Once the 20 segments are laid out, the number of degrees per shot (bend) needs to be determined. There are 21 shots, so dividing 90° by 21 will give you the number of degrees per shot:

$$90° \div 21 = 4.29°$$

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Figure 31 ◆ Conduit placed in hydraulic bender for segment bends.

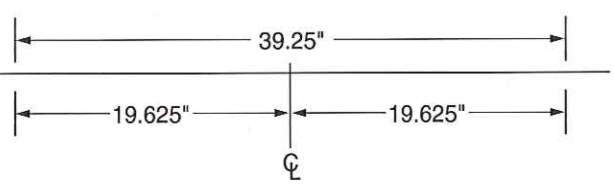

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Figure 32 ◆ Conduit center.

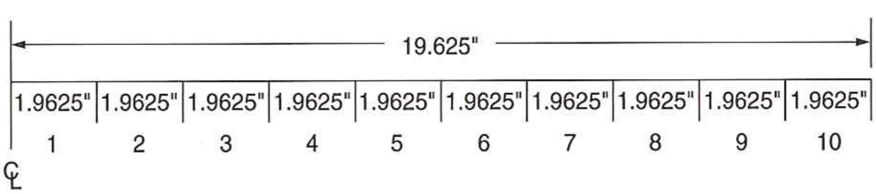

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Figure 33 ◆ Conduit segments.

You are now ready to do the bending. Starting at one end of the developed length, place the centerline of the bending shoe on the first shot mark and bend to 4.29°. Repeat the process for the remaining 20 bend marks. If the bend is not quite 90°, make the final adjustment in the last bend.

There is another way to lay out the segment marks for the developed length of a bend. Take a piece of white elastic band and lay it out on a table. Make sure that it is not stretched. From one end of the elastic, measure 10 marks spaced evenly apart and mark these points with a fine-tip ink pen. Now place the end of the elastic tape on the centerline of the developed bend length. Stretch out the elastic until the 10th mark is on the end of the developed length. Place a mark on the conduit beside each mark on the elastic tape. Repeat this process on the other half of the developed length. You are now ready to do the segmented bends.

9.0.0 ◆ SEGMENT BENDING TECHNIQUES

Now that the procedure for laying out the conduit with bending marks is understood, the next step is bending. Because segment bending requires several small angle bends to complete a 90° stub, some method to measure the amount of bend will be required. This can be done in four ways:

- Bend degree protractor
- Magnetic angle finder
- Amount of travel method
- Number of pumps method

Bend degree protractor – This is a device that hooks onto the pipe being bent. The circular face is divided into four sections (18, 20, 21, and 30 shots) and is capable of being rotated to whichever scale is to be used. The indicating pointer is weighted and swings free. To use this device, proceed as follows:

Step 1 Level the conduit and secure it using a pipe vise or other means.

Step 2 Rotate the face to the desired scale that corresponds to the number of shots being used.

Step 3 Adjust the scale so the pointer is on 0.

Step 4 Bend the pipe until the pointer reaches the first mark. (Bend a little past to compensate for springback, release the pressure, and then check the pointer. Only a few bends will be needed to find out how much you must bend past the mark to account for springback.)

Step 5 Move the pipe forward in the bender to the second bend mark, and bend until the pointer reaches the second mark on the protractor face. (Again, bend past for springback.)

Step 6 Move the conduit to the third mark and bend the pipe so the pointer is at the third mark (after allowing for springback). Follow this procedure at each bend mark until the 90° stub is achieved, the pipe is level, and the bender is in a vertical position.

NOTE

It is a good idea to check the developing stub length before the last few bends are made. Make spacing corrections as required (e.g., shorten the spacing if the stub is coming up short). If the stub length is reached before the stub is plumb, do not bend at any of the remaining marks. Instead, move the pipe in the bender and bend at the start mark. This will make the stub plumb without adding to the stub length.

Magnetic angle finder – With the magnetic angle finder, the pipe must be kept level and bent vertically (the bender is in vertical position). When a magnetic angle finder is used, care must be taken with each bend as a very small error may become multiplied by 15 to 30 times, becoming a large error. To use the angle finder:

Step 1 Level the conduit and place the angle finder on the stub end. The angle finder will indicate the number of degrees in each bend as determined by the number of shots (e.g., for 20 shots, each bend is 4.5°).

Step 2 Bend the pipe until the angle finder indicates that the bend is just past the desired degree of bend. This allows for springback. Release hydraulic pressure. If the right amount of overbend was made to allow for springback, the angle finder should read the desired angle of bend. If you bent too much or too little, make the adjustment on the next bend. In two or three bends, you will find the right amount to overbend at each mark to allow for springback.

Step 3 Move the pipe to the second bend mark. Bend at this mark until the next setting on the angle finder (allowing for springback) is indicated by the angle finder pointer.

(For example, first bend 4½°, second bend 9°, third bend 13½°, etc.)

Step 4 Bend the pipe at each successive bend mark using the angle finder to indicate the proper degree of bend.

> **NOTE**
> Again, check the developing stub length before bending the last few bends. Adjust the spacing or amount of bend as required.

Amount of travel method – The pipe may be bent in any position. 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 to be bent.

Step 2 Measure the distance (D) center-to-center between the pivot shoe pins (i.e., from center of pin A to center of pin B). The plunger (also called the ram) will have to travel half this distance to bend a full 90° stub.

Step 3 The travel per shot is one-half the distance from pin to pin divided by the number of shots. For example, the distance from the center of the pins is 24" and the pipe is to be bent in 18 shots. The travel per shot equals one-half the distance from the center of the pins (12") divided by the number of shots (18), which equals 0.666 or approximately ⅔" travel per shot.

Step 4 Bending with this method will follow a slightly different procedure.

Place the center of the bending shoe on the first bending mark (not the start mark) and activate the pump until ⅔" of ram travel is measured. Do not allow for springback with this method.

Move the pipe to the next mark and activate the pump until another ⅔" of ram travel has been measured. Continue to move the pipe and measure ram travel.

As you approach the last few marks (4 or 5), check both the developing stub length and the angle of the bend. The spacing and/or amount of travel can be adjusted on these last marks, as required.

> **NOTE**
> Once you have found the amount of travel for 90°, you can also find the amount of travel for any other angle for offsets, kicks, etc.

Number of pumps method – The pipe may be bent in any position. This method depends on the fact that a given hydraulic pump will produce the same amount of bend for a given number of pumps of the handle; however, it does not take into account that the number of pumps will change with a change in fluid level, the condition of the pump, and the condition of the O-rings.

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

Use the same procedure for bending as outlined in the amount of travel method. Check the developing stub length and degree of bend prior to bending the last few shots. Use these remaining shots for final adjustments in stub length and for checking the 90° bend.

> **NOTE**
> Use whichever one of the four methods is the most convenient, but bear in mind that extreme care and attention to detail are required in all methods. A small amount of error at each bend will compound itself, and accuracy in bending will be impossible to achieve.

Using a bending table – To make hydraulic bending easier, a bending table, either a commercial model or one constructed on the job, is a necessity. The table will hold the conduit and the bender, make leveling and plumbing easier, and produce more accurate bends. The table will also eliminate the need to continually wrestle with the conduit and bender.

Hydraulic bending example – For example, suppose that the task is to bend an offset containing two sweeping bends. The radius for the two sweeping bends is 30". This is to be done on a hydraulic bender using a segmented bending process. The angles of the sweeping bends are to be 30° each. The height of the offset is to be 30" (*Figure 34*).

In this problem, we continue to work with the concept of the unit circle. This information is brought together with the cosecant trigonometric function.

In continuing with the concept of the unit circle and the linear distance on the circumference of the circle in terms of pi, it is necessary to understand

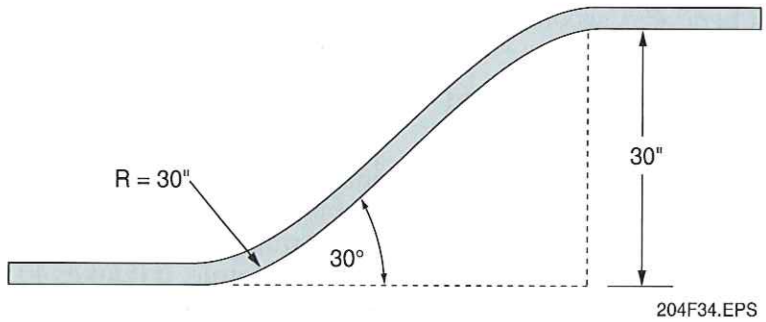


Figure 34 ◆ Two 30° sweeping bends.

the development of the pi relationship from 0° to 90°. All of these relationships from 0° to 90° and other interval angles in the circle are always in reference to 180°. For example: 360° = 2π or 2 × 180°; 180° = π or 1 × 180°; and 90° = π ÷ 2 or ½ × 180°.

The same process holds true for any angle from 0° through 90°. For example: 45° = π ÷ 4 or ¼ × 180°; 60° = ⅓π or ⅓ × 180°; 30° = ⅙π or ⅙ × 180°; and 15° = 1⁄12π or 1⁄12 × 180° (*Figure 35*).

To figure the developed length of the conduit to be used by one swing in our 30" radius, we simply multiply π ÷ 6, which represents pi at 30°, times the 30" radius. It is nothing more than a converted circumference formula.

$C = 2\pi R$ (linear distance around a complete circle)

$C = \frac{\pi}{6}R$ (linear distance from 0° to 30°)

$C = \frac{\pi}{6}R$ or $C = 0.523 \times R$ or $C = 0.523 \times 30" = 15.7"$

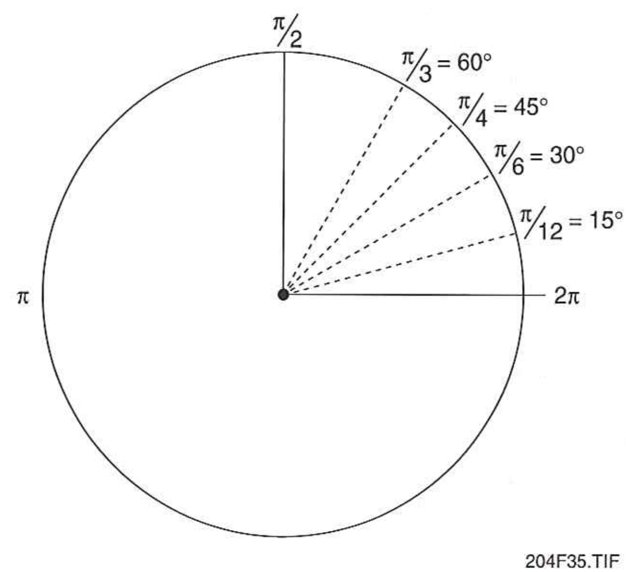


Figure 35 ◆ Radians and degrees.

The developed length for the first radius is 15.7". That means that the developed length for the second sweeping radius is also 15.7". The total amount of conduit used to develop the two sweeps is 31.4".

The next step is to figure out the distance between the centerline of each of these bends on the hypotenuse of our imaginary triangle. To do this, we simply use the cosecant of the angle trigonometric function or Cosecant = H ÷ O. Converting the formula, we get H = O × Cosecant or H = 30" × 2 or 60". The layout of these measurements is shown in *Figure 36*.

Again, laying out the segments for the bending process is done from the centerline of the developed length of each sweeping bend (*Figure 37*). Therefore:

15.7" ÷ 2 = 7.85"

When we build a 90° sweep, the rule of thumb is 21 shots or 20 segments. This gives the conduit the appearance of being a natural sweep and not a line of straight segments. (The same odd shot/even segment process will appear again.) If we choose to have seven shots or six segments within the 15.7" of developed length, each segment will be 15.7" ÷ 6 or 2.62" long. Because there are seven shots (bends), each shot will be 30 ÷ 7 or 4.29°. The layout of the bend is shown in *Figure 38*.

Once you have both sweeps laid out as described previously and the centerlines of these sweeps are 60" apart, you are ready to start the bending process. Again, start at one end of the offset and swing the bender segmented shoe down on the conduit. Because you are working an offset, an anti-dog device should be attached to one end of the conduit. This device maintains the centerline for each bend. Begin bending the first sweep, and once this is accomplished, roll the conduit in the bender and re-level the anti-dog device. Bend the second sweep and your offset

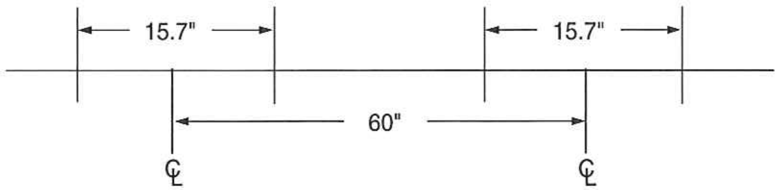


Figure 36 ◆ Bend centerline distance.

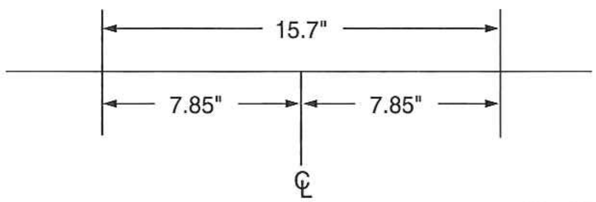


Figure 37 ◆ Bend centerline.

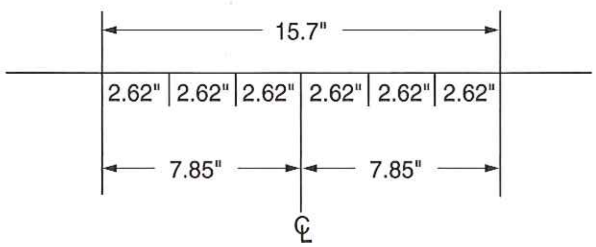


Figure 38 ◆ Bend segments.

is built. The final measurements should be as follows:

Developed length of each sweep = 15.7"

Distance between centerline of each sweep = 60"

Distance between shot marks in each sweep = 2.62"

Degrees per shot in each sweep = 4.29"

9.1.0 Concentric Bending

If two or more parallel runs of conduit must be bent in the same direction, as shown in *Figure 39*, the best results will be obtained by using concentric bends. When laying out concentric bends, the bend for the innermost conduit is calculated first. In the example in *Figure 39*, the first bend has a radius of 20". If this dimension is multiplied by 1.57, it yields a value of $31\frac{13}{32}$". This is the developed length of the shortest radius bend.

The second radius is found by adding the **outside diameter (OD)** size of the first pipe to the radius of the first pipe and the desired spacing between pipes. In this example, the radius of the second bend would be equal to $24\frac{3}{8}$" (see *Figure 39*).

Radius of first pipe = 20"

OD size of first pipe = $2\frac{3}{8}$"

Spacing between pipes = 2"

Radius of second pipe:

20" + $2\frac{3}{8}$" + 2" = $24\frac{3}{8}$" or 24.375"

Once the developed length of the second radius is found, the spacing between marks can be determined. The start mark must be the same distance from the end of the second pipe as it was for the first pipe (*Figure 39*). This will be true for each additional pipe as well. The spacing will increase between marks as the radius of the pipes increases. This is due to increasing developed length. The pipes in *Figure 39* are all laid out for 15 shots.

The equation for the developed length (DL) is 1.57 × R (radius). The developed length for the second bend is found by multiplying 1.57 × 24.375" = 38.27".

The radius and developed length of each successive bend are found in a similar manner. After determining the developed length, you must establish the number of segment bends needed to form each 90° bend. In concentric bending, every bend must receive the same number of segment bends to maintain concentricity. As illustrated, 15 segment bends of 6° each will total 90°.

NOTE

The radius change from one bend to another affects the spacing of segment bends. To find the segment bend spacing, divide the developed length of each bend by 15. For the first bend illustrated, the spacing for each segment bend is $2\frac{3}{32}$"; for the second bend, it is $2\frac{9}{16}$", and so on, as shown in *Figure 39*.

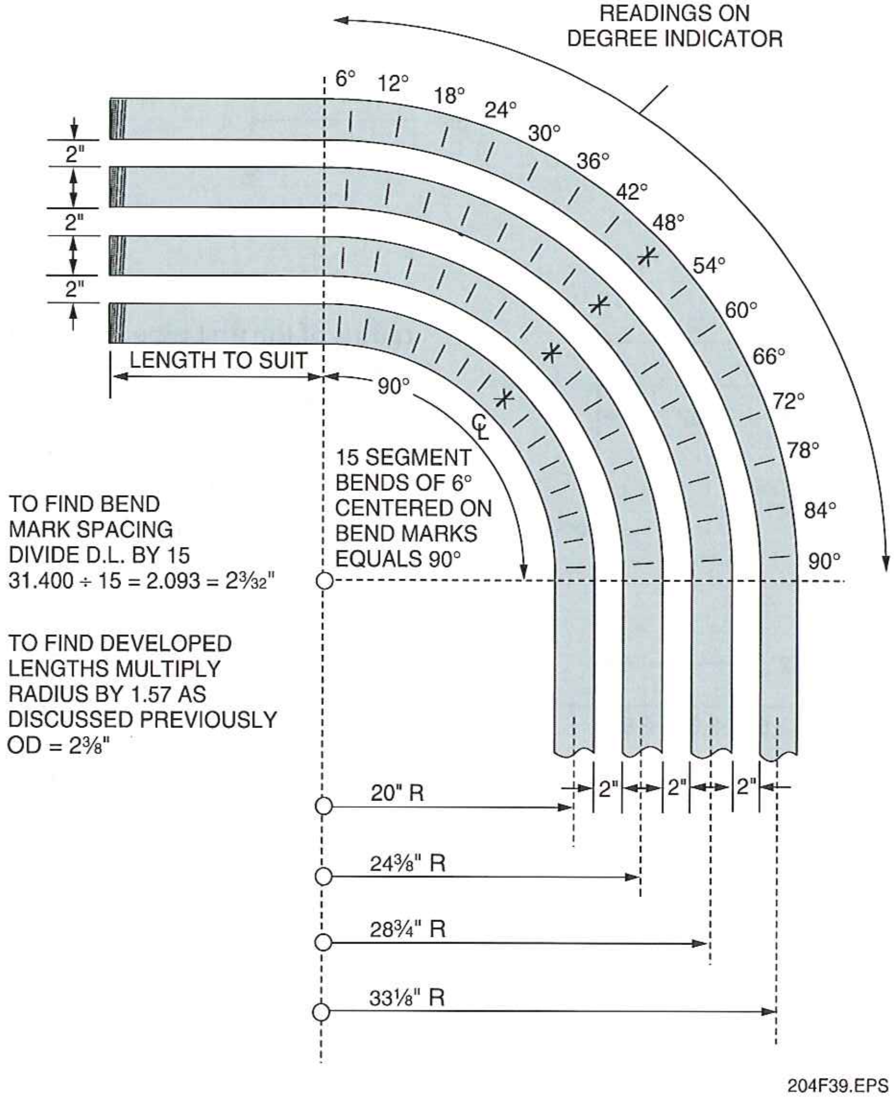


Figure 39 ◆ Principles of concentric bending.

If the legs of the bends have to be a certain length, the gain must be considered just as in any segment bending procedure. When the runs of conduit are not the same size, the radius of each successive bend can be found as follows:

Step 1 Determine the radius of the innermost bend.

Step 2 Calculate one-half the outside diameter of the innermost conduit and of the next adjacent conduit.

Step 3 Note the distance between the two runs of conduit.

Step 4 Add these quantities.

INSIDE TRACK

Segmented Bends

Most electricians find the amount-of-travel method of making segmented bends to be the simplest and most reliable. The number of pumps method can change with the condition of the pump. The bending protractor and mechanical angle methods are accurate but also time consuming.

9.2.0 Offset Bends

Many situations require a conduit to be bent so that it can pass by or over objects such as beams and other conduit or to enter panelboards and junction boxes. The bends used for this purpose are called offsets. To produce an offset, two equal bends of less than 90° are required at a specified distance apart. This distance is determined by the angle of the two bends and can be calculated by using the following procedure and the table in *Figure 40*.

First, determine the offset needed, then find the degree of bend. Next, multiply the offset measurements by the figure directly under the degree of bend (see *Figure 40*). This applies to all sizes of conduit. For example, to form an 18" offset with two 45° bends, first make the following calculation to determine the distance between bends:

18" × 1.414 = 25½"

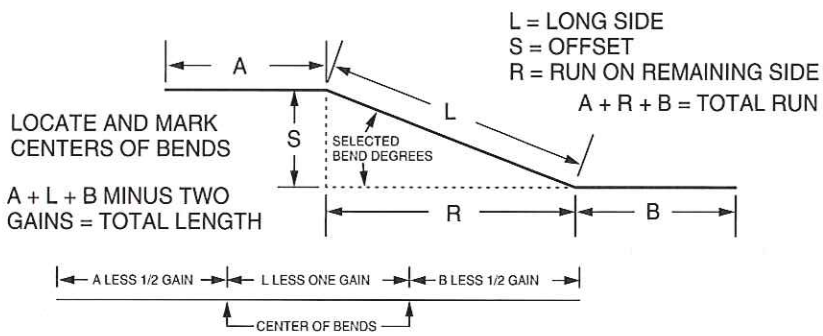
This is the distance between bends and is labeled side *L* (see *Figure 40*). To connect the two ends of an offset to two pieces of conduit that are already in place, it is necessary to know the total or overall length (OL) of the offset from end to end before bending.

Note the following equation:

OL = (A + L + B) − (2 × gain)

Where:

A = 36"
L = 25½"
B = 48"
2 × gain = 1 9/32"



		TIMES CORRESPONDING MULTIPLIER EQUALS								
		TABLE OF MULTIPLIERS FOR SELECTED DEGREES OF BEND								
TO FIND UNKNOWN	KNOWN	5-5/8°	11-1/4°	15°	22-1/2°	30°	37-1/2°	45°	60°	UNKNOWN
L	S	10.207	5.126	3.864	2.613	2.00	1.643	1.414	1.155	L
S	L	.098	.195	.259	.383	.50	.609	.707	.866	S
R	S	10.158	5.027	3.732	2.414	1.732	1.303	1.00	.577	R
S	R	.098	.199	.268	.414	.577	.767	1.00	1.732	S
L	R	1.005	1.02	1.035	1.082	1.155	1.260	1.414	2.00	L
R	L	.995	.981	.966	.933	.866	.793	.707	.50	R
GAIN PER BEND	RADIUS OF SHOE	.0002	.0006	.0015	.0051	.0124	.0212	.0430	.1076	GAIN PER BEND

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Figure 40 ◆ Conduit offset bending table.

INSIDE TRACK

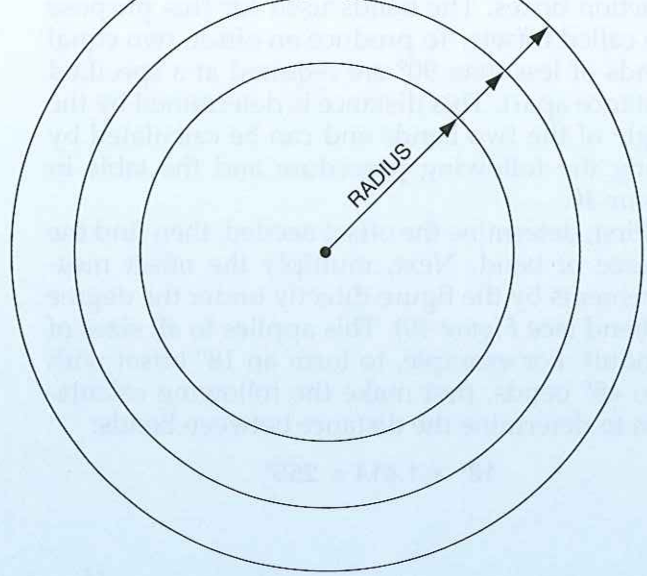
Leave Room for System Expansion

It's a good idea to make your first concentric bend large enough to fit another bend or two inside it in case you have to add additional conduit runs later on. Another method is to add any additional conduit runs on the outside of the original bend. Both methods produce a neat and professional installation.

THINK ABOUT IT

Concentric Bends

What does concentric mean? Why can't you just bend all your conduit sections to the same radius and lay them side by side?



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The gain is calculated by multiplying the shoe radius by the decimal figures shown on the last line under DEGREES OF BEND in *Figure 40*. Let us calculate how an offset might be made in a length of 3" conduit using 45° bends:

$$OL = (A + L + B) - (2 \times \text{gain})$$
$$OL = 109\tfrac{1}{2}" - 1\tfrac{9}{32}" = 108\tfrac{7}{32}"$$

> **NOTE**
> This offset uses a 15" radius.

15" × 0.0430 (from the table in *Figure 40*) = 0.645°

For two gains, we have:

$$1.290 = 1\tfrac{9}{32}$$

Since you already know the long dimension of the offset (25"), to find the amount of offset, refer to the table in *Figure 40*, second line down (to find S), then move across the row until you come to the 45° column. Note that the multiplier is 0.707.

Therefore:

$$25" \times 0.707 = 17.675"$$

This is the height of the offset. To make the offset, the conduit is positioned in the hydraulic bender, as shown in *Figure 41*. The bending shoe makes one 45° bend on the first center mark, the conduit is reversed in the bender, and the next 45° bend is made at the second mark. When making bends, always refer to the bending charts that accompany the bender being used for the operation.

For example, an offset is to be built to go over an I-beam that is 24" in height. The distance from the end of the conduit run to the J box on the opposite side of the I-beam is 8' (see *Figure 42*).

The task is to determine the distance between bend points where a 45° bend is being used. Determine the exact length of conduit needed so threading can occur before bending. The conduit will have no clearance over the top of the I-beam.

To find the distance between bend points, multiply the amount of offset required by the cosecant of the bending angle (in this case, 45°):

$$24" \times 1.41 = 33.84"$$

The straight distance from the end of the conduit run to the J box is 8'. To find the amount of conduit to add to this because of the 45° bend, use the cosine formula ($C = A \div H$). The hypotenuse or the distance between bend points is 33.84". The side adjacent is found by converting $C = A \div H$ to $A = C \times H$, or:

$$A = 0.707 \times 33.84" = 23.92"$$

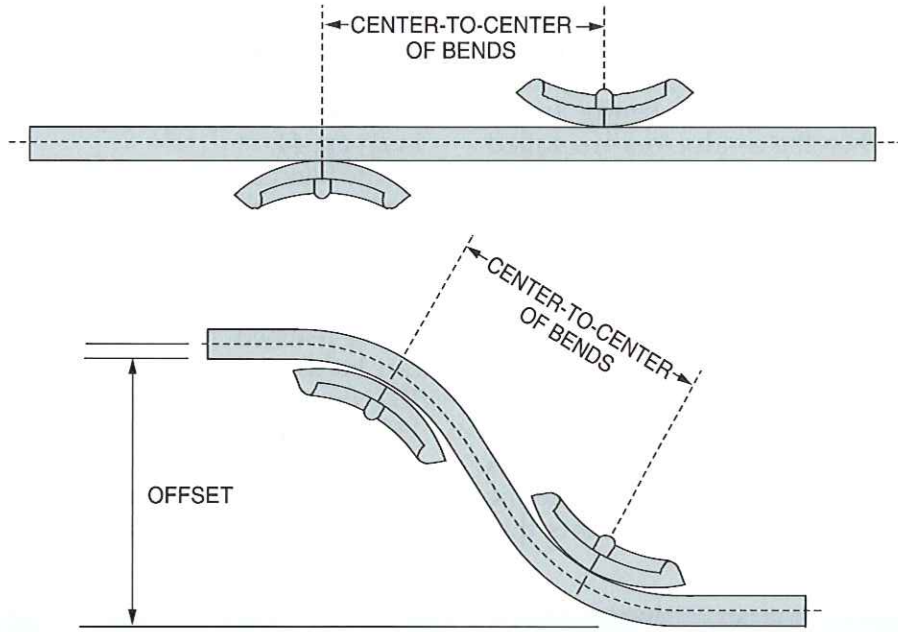

Figure 41 ◆ Position of conduit in bender for making offsets.

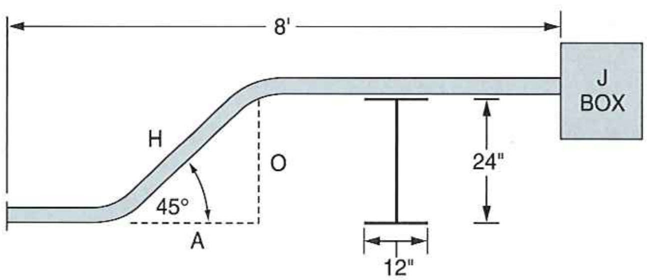

Figure 42 ◆ 24" offset.

Subtract 23.92" from 33.84" and this gives the amount of extra conduit needed when making this 45° bend:

$$33.84" - 23.92" = 9.92" \text{ or } 9\tfrac{92}{100}"$$

Add the 9.92" to 8' and the amount of straight conduit required has been determined:

$$8' + 9.92" = 8'\text{-}9.92" \text{ of straight conduit}$$

The final measurements should be as follows:

Distance between bend points = $33\tfrac{21}{25}$" or 33.84"

Length of straight conduit = 8'-9.92" or 8'-$9\tfrac{92}{100}$"

Now let us complete another example. In this case, an offset is to be made without the use of a protractor level. The offset is to be 20" in height (*Figure 43*). The bend angle is 45°. Explain the process required to accomplish this.

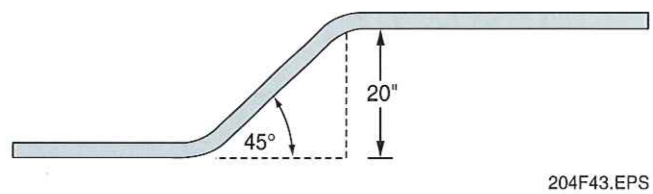

Figure 43 ◆ 20" offset.

The cosecant for 45° is 1.41. The distance between bend points is 1.41 × 20". Therefore:

$$1.41 \times 20" = 28.2"$$

The first mark on the conduit is placed 14.1" back from the end of the conduit. The end of the conduit needs to be brought up 10" to accomplish a 45° bend. The second mark on the conduit is placed 28.2" down the conduit from the first mark. The bender is placed on the second mark. The conduit is bent until the two surfaces are parallel. At this point, a 20" offset has been created.

9.3.0 Concentric Offsets

To make concentric offsets, use the same procedure as for 90° stubs. Increase the radius of the second pipe by an amount equal to the radius of the first pipe plus the OD size of the first pipe plus the spacing desired between pipes. Although the examples used to explain offset bending had several shots per bend, fewer shots can be used.

Successful offsets can be made with only two or three shots per bend. However, with offsets, 90° bends, or any other segment bends, the extra time spent bending smoother radius bends (more shots) is returned when the conductors are pulled into the completed raceway. Parallel offsets of different pipe sizes can still be bent and aligned perfectly if all pipes are bent with the same one-shot shoe.

9.3.1 Saddle Bends

As mentioned previously, saddle bends are used to cross small obstructions or other runs of conduit. Saddle bends in conduit up to four inches **inside diameter (ID)** may be made in hydraulic conduit benders. Always refer to the charts that accompany the bender. For example, to make a saddle bend on a length of 2" rigid conduit so that it can pass over a 3" water pipe with ¼" clearance, three bending operations are required, as shown in *Figure 44*.

The bend is calculated by referring to appropriate bending charts. The one shown in *Table 6* gives measurements for 2" conduit with ¼" clearance. Therefore, look in the left column under straight-run conduit and go down the column until the 3" row is reached. Moving to the right in this row, it can be seen that the spacing between bends is 15⅝" on center, and bends No. 1 and No. 2 will be 15°, while the third bend is 30°.

Using the information found in the bending table, mark the conduit accordingly. Insert the conduit in the bender and make bends No. 1 and

INSIDE TRACK

Offset Bending

Offsets in small conduit (e.g., ½" or ¾" EMT or ½" rigid or IMC) may be easier to bend with the bender head in the air. However, it may be easier to avoid dog legs if the second bend is made on the floor whenever possible.

Straight Offsets

Use the seams on EMT as a guide for making straight offsets. The best bend angles are:

- 10° for 1" depths
- 22½° for 2" depths
- 30° for 3" and 4" depths
- 45° for 5" and greater depths

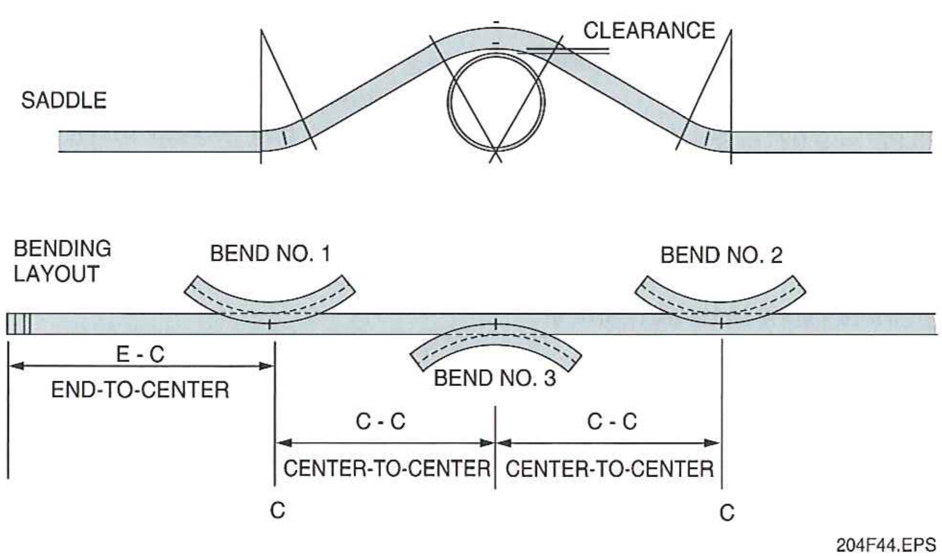

Figure 44 ◆ Principles of saddle bending.

Table 6 Saddle Table

Straight-Run Conduit	Minimum Length	Bend Spacing	Bend Degrees	Bend Degrees	Bend Degrees
—	E-C	C-C	No. 1	No. 2	No. 3
1"	20"	16"	6	6	12
1¼"	20"	16"	7	7	14
1½"	20"	16"	8	8	16
2"	20"	15⅞"	10	10	20
2½"	20"	15¾"	12½	12½	25
3"	20"	15⅝"	15	15	30
3½"	20"	15½"	18	18	36
4"	20"	15½"	20	20	40

No. 2 first, both at 15°. Back off the pump pressure, reverse the conduit in the bender, and then make the third bend at 30°. Release the pump pressure, remove the conduit from the bender, and check the saddle for accuracy.

For another example, suppose a saddle is to be built to go over an I-beam that is 36" in height (*Figure 45*). The distance from the end of the conduit to the center of the I-beam is 5'.

The task is to determine the distance between bend points when a 45° bend is being used. Determine the exact length of conduit needed so threading can be completed before bending. The conduit is to clear the top of the I-beam by 1". Determine the centerline layout of the saddle (*Figure 46*).

The 16" between bend points in this problem is an arbitrary measurement. It is determined by the person doing the bending. Enough conduit should be used to extend past the outside dimensions of the 12" I-beam so the radius of each bend does not run into the I-beam.

The distance between bend points on the hypotenuse of the imaginary triangle is calculated by multiplying the total height of the I-beam (36" + 1" clearance = 37") by the cosecant of the 45° angle of the bend or 1.41 × 37":

$$1.41 \times 37" = 52\tfrac{17}{100}" \text{ or } 52.17"$$

The centerline layout mark for the saddle would be 5' if the conduit were to be installed on a straight line from the end of the existing conduit run to the center of the I-beam. However, the conduit is not being installed on a straight line. Therefore, the measurement in question is the amount of additional conduit needed because of the 45° angle of deviation (*Figure 47*). The amount of additional conduit is equal to the side adjacent subtracted from the hypotenuse.

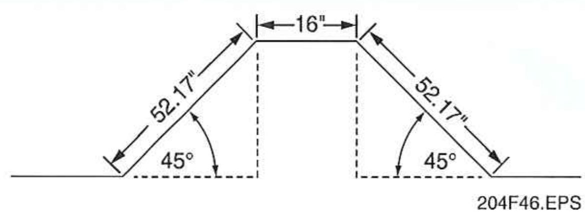

Figure 46 ◆ Saddle.

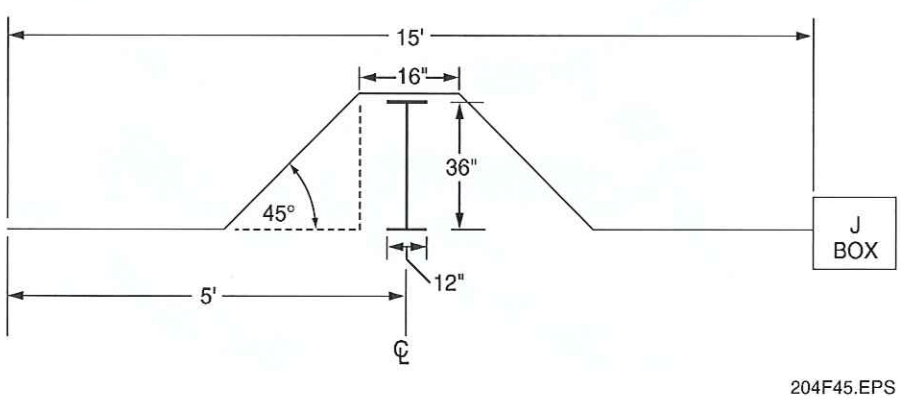

Figure 45 ◆ 36" saddle.

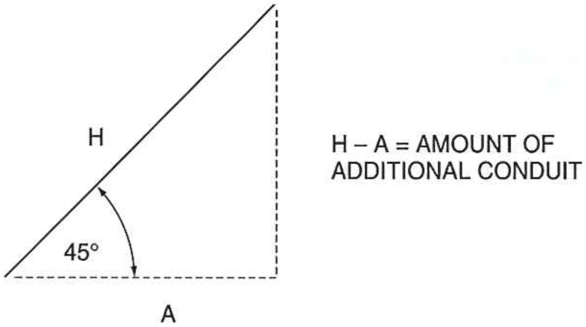

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Figure 47 ◆ Cosine function.

The side adjacent (A) first needs to be calculated, then that measurement can be subtracted from the hypotenuse (52.17"). To calculate the side adjacent, use the cosine formula (C = A ÷ H). Because we are looking for A, convert the formula to A = C × H, or:

$$A = 0.707 \times 52.17"$$

$$A = 36.88"$$

Subtract 36.88 from 57.17, or:

$$52.17" - 36.88" = 15.29"$$

That is how much extra conduit is needed to get the center of the saddle to the center of the I-beam. Therefore, the layout mark for the saddle is:

$$5' + 15.29" = 6'\text{-}3.29"$$

The layout of the conduit is shown in *Figure 48*.

To find the total amount of conduit to be used from the end of the existing conduit to the J box, simply take the straight line distance of 15' and add the difference between the hypotenuse and side adjacent to 15' two times, or:

$$15' + 15.29" + 15.29" = 15' + 30.58" = 17'\text{-}6.58"$$

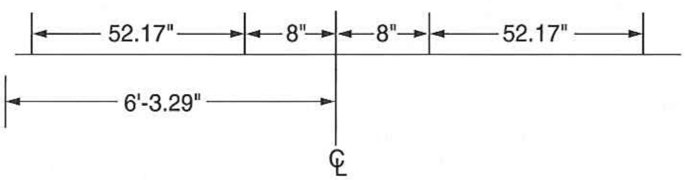

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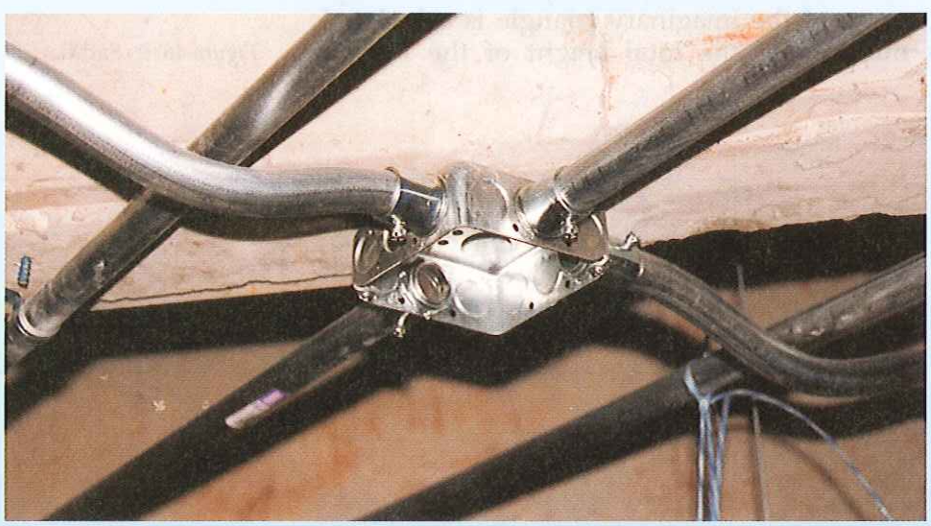
Figure 48 ◆ Conduit layout.

INSIDE TRACK

Saddle Bends

Whenever possible, a three-bend saddle should not be sharper than 30°. If the object you are trying to saddle is more than 6" in diameter, use a four-bend saddle rather than a three-bend saddle. In this installation, two three-bend saddles were required.



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The final measurements should be as follows:

Distance between bend points on the top portion of the saddle = 16"

Distance between bend points that form each hypotenuse = 52 17/100" or 52.17"

Distance from the end of the conduit to the centerline layout mark of the saddle = 6'-3.29" or 6'-3 29/100"

Overall length of the conduit required to reach the J box = 17'-6 58/100" or 17'-6.58"

10.0.0 ◆ TRICKS OF THE TRADE

There are many tricks of the trade that you will learn during your career as an electrician. Some of these will be handed down to you by experienced workers; others will be learned through experience. Most professionals are constantly seeking new methods to improve their efficiency and to make the work go smoother and faster without sacrificing workmanship.

One of the handiest personal tools for bending conduit is the small, magnetic torpedo level with a 35° and 45° bubble. This tool should be in the tool pouch of every electrician. In many cases, it can make the difference between a good job and a poor job, that is, obtaining level and plumb conduit runs or not.

Workers have also designed their own custom tools to help in conduit installations. One tip is to take a pair of vice grips and weld a small, flat piece of iron on the top of the jaws for use with the magnetic level. During multiple bends, the vice grips are positioned at the desired point on the end of a piece of conduit, locked in place, and then the magnetic level is placed on the flat plate so the bubble may be watched during the bend. There are also some new commercial tools that are designed for leveling conduit bends; keep up with these developments by reading trade journals.

10.1.0 Eliminating Dog Legs

One of the problems that exists when bending an offset or saddle is the creation of a dog leg. A dog leg occurs when the centerline that runs the length of the conduit is not maintained for both bends of an offset and for the four bends of a saddle. Dog legs can be eliminated using an anti-dog device, as discussed earlier, or by following the procedure described here.

See *Figure 49*. When the conduit is snugged up by the bender, take a piece of Unistrut® and clamp it to the end of the conduit farthest from the bending shoe. Before tightening the conduit strap, level the Unistrut®. Once this is done, make your first bend. Release the conduit from the bending shoe and move the conduit forward to the next bending mark. Roll the conduit 180° and re-level

INSIDE TRACK

Magnetic Level

A magnetic torpedo level can be attached directly to the conduit. It will remain where you put it, even if the conduit is turned over.

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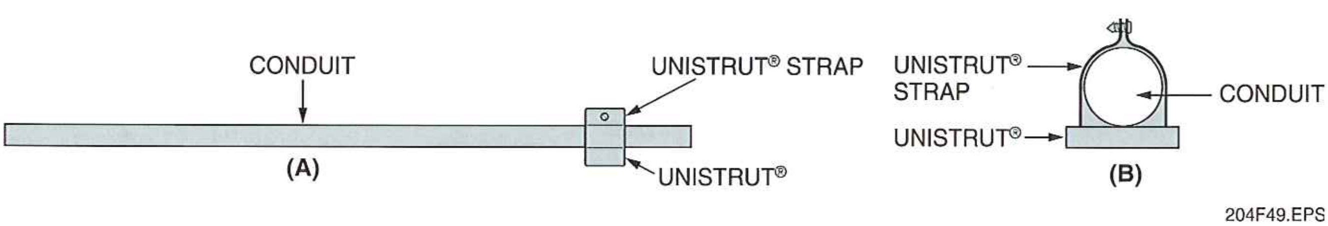

Figure 49 ◆ Dog leg elimination.

the Unistrut®. Tighten the conduit in the bender and again make sure that the Unistrut® is level. Bend the second bend and you will have an offset with no dog leg.

10.2.0 Using a Table Corner or Plywood Sheet for Calculating Added Length

The task is to use a table corner or the corner of a sheet of plywood and demonstrate how to come up with the amount of additional conduit needed to go from one point to another once a bend has been made. The distance between points is 8'. The amount of offset to be made is 25" (*Figure 50*). The degree of bend is 30°.

See *Figure 51*. Measure 25" up one side of the sheet of plywood or the corner of a table. The hypotenuse of the triangle will be 2 × 25" or 50" (2 is the cosecant for 30°). Measure from the 25" mark to the surface that is tangent to the side that is 25" long, until the 50" mark on the tape measure crosses the tangent side. Mark this 50" point. Then, place the end of the ruler on the 50" mark and let the 50" point on the ruler extend beyond the end of the plywood or table. The amount of tape that extends beyond the plywood or table edge is the amount of extra conduit that is needed to accomplish this bend. This is 6⅝" more conduit than if going on a straight line for 8' or 8'-6⅝" of conduit required to accomplish the task.

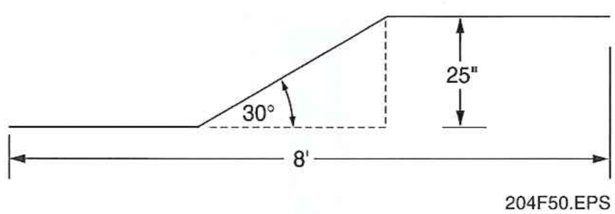

Figure 50 ◆ 25" offset.

11.0.0 ◆ PVC CONDUIT INSTALLATIONS

Rigid nonmetallic conduit and fittings (PVC electric conduit) may be used where the potential is 600V or less in direct earth burial; in walls, floors, and ceilings of buildings; in cinder fill; and in damp and dry locations. Its use is prohibited by the *NEC®* in certain hazardous locations, for support of fixtures or other equipment, where subject to physical damage, and under certain other conditions. See *NEC Article 352.*

PVC conduit can be cut easily at the job site without special tools, although PVC cutters help in cutting square ends. Sizes from ½" through 1½" can be cut with a fine-tooth saw. For sizes 2" through 6", a miter box or similar saw guide should be used to keep the conduit steady and ensure a square cut. To ensure satisfactory joining, care should be taken not to distort the end of the conduit when cutting.

After cutting, deburr the pipe ends and wipe clean of dust, dirt, and plastic shavings. Deburring is accomplished easily using a pocket knife or file.

One of the important advantages of PVC conduit, in comparison with other rigid conduit materials, is the ease and speed with which solvent-cemented joints can be made. The following steps are required for a proper joint:

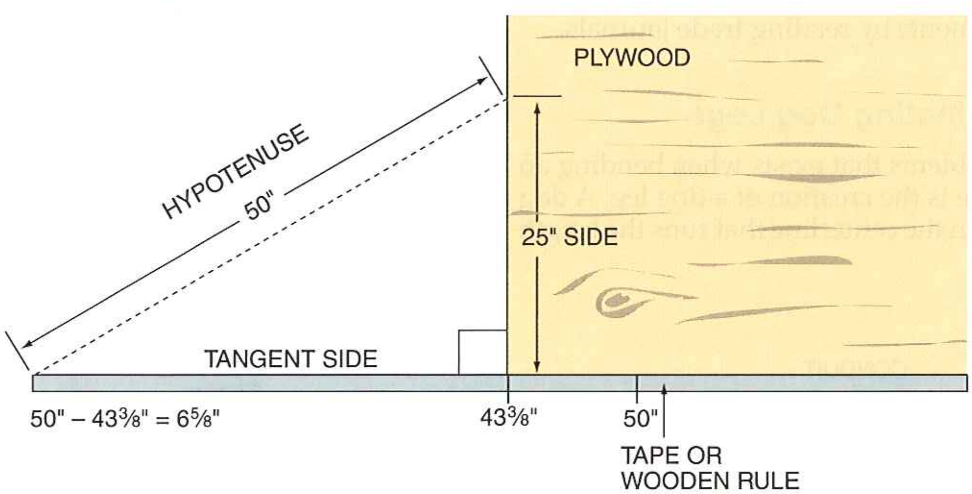

Figure 51 ◆ Extra conduit.

Step 1 The conduit should be wiped clean and dry.

WARNING!
The cement used with PVC can be hazardous. Provide adequate ventilation, avoid skin contact, and always follow the manufacturer's usage and safety instructions.

Step 2 Apply a full, even coat of PVC cement to the end of the conduit and the fitting. The cement should cover the area that will be inserted in the socket.

Step 3 Push the conduit and fitting firmly together with a slight twisting action until it bottoms and then rotate the conduit in the fitting (about a half turn) to distribute the cement evenly. Avoid cement buildup inside the conduit. The cementing and joining operation should not exceed more than 20 seconds.

Step 4 When the proper amount of cement has been applied, a bead of cement will form at the joint. Wipe the joint with a brush to remove any excess cement. The joint should not be disturbed for 10 minutes.

12.0.0 ◆ BENDING PVC CONDUIT

Most manufacturers of PVC conduit offer various radius bends in a number of segments. Where special bends are required, PVC conduit is easy to bend on the job. Stub-ups, saddles, concentric bends, offsets, and kicks are all possible with PVC conduit, just as with metallic conduit.

PVC conduit is bent with the aid of a heating unit. The PVC must be heated evenly over the entire length of the curve. Heating units are available from various sources that are designed specifically for the purpose in sizes to accommodate all conduit diameters (*Figure 52*). While some heaters use gas for the heat source, most employ infrared heat energy, which is more quickly absorbed in the conduit. Small sizes are ready to bend after a few seconds in the hotbox. Larger diameters require two or three minutes, depending on the conditions. Other methods of heating PVC conduit for bending include heating blankets and hot air blowers. The use of torches or other flame-type devices is not recommended. PVC conduit exposed to excessively high temperatures may take on a brownish color. Sections showing evidence of such scorching should be discarded.

WARNING!
Always wear gloves when working with heat.

If a number of identical bends are required, a jig can be helpful (*Figure 53*). A simple jig can be made by sawing a sheet of plywood to match the

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Figure 52 ◆ PVC heating units.

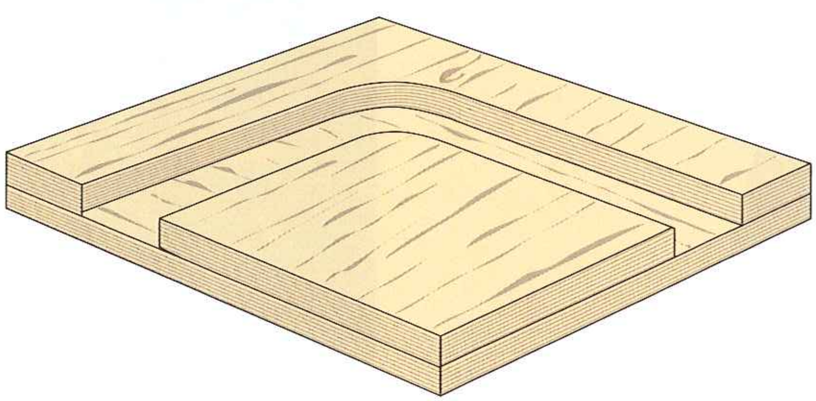

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Figure 53 ◆ Plywood jig.

desired bend. Nail to a second sheet of plywood. The heated conduit section is placed in the jig, sponged with water to cool, and is then ready to install. Care should be taken to fully maintain the ID of the conduit when bending.

If only a few bends are needed, scribe a chalk line on the floor or workbench. Then, match the heated conduit to the chalk line and cool. The conduit must be held in the desired position until it is relatively cool since the PVC material will tend to revert to its original shape. Templates are also available for many bends.

Another method is to take the heated conduit section to the point of installation and form it to fit the actual installation (*Figure 54*). This method is especially effective for making blind bends or compound bends using smaller sizes of PVC. After bending, wipe a wet rag over the bend (*Figure 55*) to cool it.

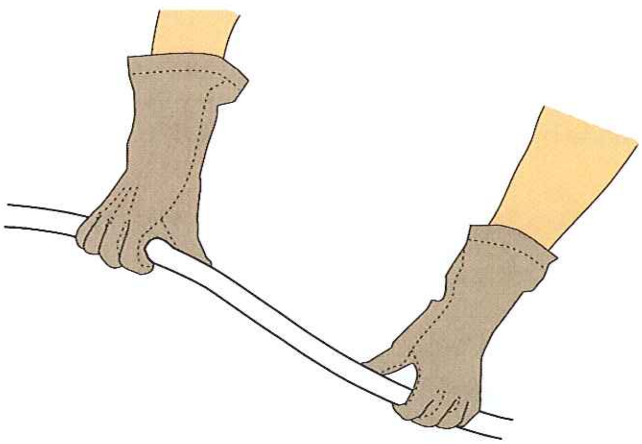
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Figure 54 ◆ Some PVC bends may be formed by hand.

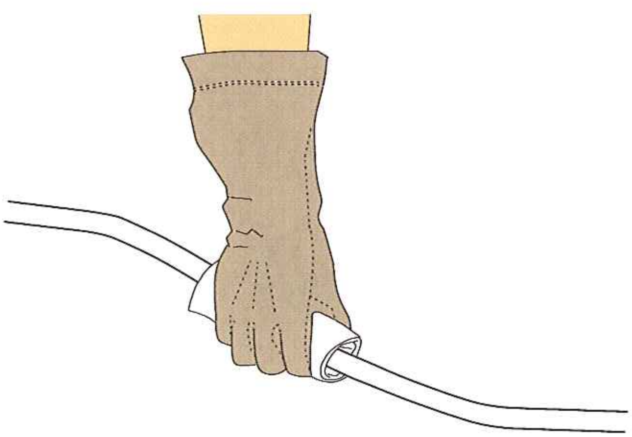
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Figure 55 ◆ After the bend is formed, wipe a wet rag over the bend to cool it.

Bends in small-diameter PVC conduit (½" to 1½") require no filling for code-approved radii. When bending PVC of 2" or larger diameter, there is a risk of wrinkling or flattening the bend. To help eliminate this problem, a plug set is used. A plug is inserted in each end of the piece of PVC being bent, and then a hand pump is used to pressurize the conduit before bending it. The pressure is about three to five pounds per square inch.

Place airtight plugs (*Figure 56*) in each end of the conduit section before heating. The retained air will expand during the heating process and hold the conduit open during bending. Do not remove the plugs until the conduit has cooled.

In applications where the conduit installation is subject to constantly changing temperatures and the runs are long, precautions should be taken to allow for expansion and contraction of PVC conduit. When expansion and contraction are factors, an O-ring expansion coupling should be installed near the fixed end of the run, or fixture, to take up any expansion or contraction that may occur. Confirm the expansion and contraction lengths available in these fittings as they may vary by manufacturer. Charts are available that indicate what expansion can be expected at various temperature levels. The coefficient of linear expansion of PVC conduit is 0.0034" per 10' per °F. *Table 7* lists the expansion rates for various temperatures.

Expansion couplings are seldom required in underground or slab applications. Expansion and contraction may generally be controlled by bowing the conduit slightly or burying the conduit immediately. After the conduit is buried, expansion and contraction cease to be factors. Care should be taken, however, in constructing a buried installation. If the conduit should be left exposed for an


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Figure 56 ◆ Typical plug set.

Table 7 PVC Expansion Rates

Temperature Change in °F	Length Change in Inches per 100 Ft of PVC Conduit	Temperature Change in °F	Length Change in Inches per 100 Ft of PVC Conduit
5	0.2	105	4.2
10	0.4	110	4.5
15	0.6	115	4.7
20	0.8	120	4.9
25	1.0	125	5.1
30	1.2	130	5.3
35	1.4	135	5.5
40	1.6	140	5.7
45	1.8	145	5.9
50	2.0	150	6.1
55	2.2	155	6.3
60	2.4	160	6.5
65	2.6	165	6.7
70	2.8	170	6.9
75	3.0	175	7.1
80	3.2	180	7.3
85	3.4	185	7.5
90	3.6	190	7.7
95	3.8	195	7.9
100	4.1	200	8.1

extended period of time during widely-variable temperature conditions, an allowance should be made for expansion and contraction.

In above-ground installations, care should be taken to provide proper support of PVC conduit because of its semi-rigidity. This is particularly important at high temperatures. The distance between supports should be based on temperatures encountered at the specific installation. Charts are available that clearly outline at what intervals support is required for PVC conduit at various temperature levels.

INSIDE TRACK

PVC Conduit Bending

PVC conduit has a memory. As soon as you have finished bending the PVC, cool it down with cold, wet towels or hose it down with cold water. Otherwise, it will begin to return to its original position.

THINK ABOUT IT

Putting It All Together

Examine the visible conduit bends in your home or workplace. Are they neat and professionally made? If not, what might you have done differently to improve the installation?

Review Questions

1. The minimum radius of a 90° bend in rigid conduit is _____ times the internal diameter of the conduit.
   a. four
   b. five
   c. six
   d. seven

2. The minimum bending radius for 1" rigid conduit without a lead sheath is _____.
   a. 4"
   b. 6"
   c. 8"
   d. 10"

3. The maximum number of 90° bends allowed between pull points in a conduit system is _____.
   a. one
   b. two
   c. three
   d. four

4. A saddle bend is counted as two ¼ bends or _____.
   a. 90°
   b. 160°
   c. 270°
   d. 180°

5. When referring to the two bends required to make an offset in a length of conduit, which of the following is always true?
   a. The degree of bend for each must be exactly 45°.
   b. The degree of bend for each must be exactly 30°.
   c. The degree of bend for each must be equal.
   d. The degree of bend for each must be unequal.

6. The reason for making a saddle bend in a run of conduit is to _____.
   a. change direction in the height of a conduit run
   b. make a 90° bend
   c. cross a small obstacle
   d. make a conduit termination in an outlet box

7. The equation used to calculate the circumference of a circle is _____.
   a. $C = \pi D$
   b. $C = 1\pi R$
   c. $C = \pi R^2$
   d. $C = \pi^2$

8. The fractional equivalent of the decimal 0.015625 is _____.
   a. $\frac{1}{64}$
   b. $\frac{1}{32}$
   c. $\frac{3}{64}$
   d. $\frac{1}{16}$

9. The rise in a conduit bend is best described as the _____.
   a. horizontal distance that runs from the point of bend and parallel with the deck
   b. leg length
   c. radius
   d. height of the stub-up

10. The best type of bending shoe for making concentric bends is the _____ shoe.
    a. concentric
    b. one-shot
    c. segmented
    d. long

11. Aluminum conduit is available in standard sizes from _____.
    a. ½" to 4"
    b. ½" to 6"
    c. ¾" to 6"
    d. ¾" to 4"

12. Two or more parallel bends that are bent in the same direction are known as _____.
    a. stubs
    b. perpendicular bends
    c. concentric bends
    d. axial bends

13. Which of the following formulas should be used to find the side adjacent?
    a. $S = O \times H$
    b. $S = O \div H$
    c. $C = A \div H$
    d. $C = A \times H$

Review Questions

14. An important safety precaution to use when working with PVC conduit is to _____.
    a. provide proper ventilation to carry off fumes from the joint cement
    b. use lengths of PVC of not more than 8'
    c. use inside diameters of 4" or less
    d. never wear gloves that may adhere to the joint cement

15. When bending larger diameter PVC pipe, _____ is/are used to prevent flattening.
    a. plugs and air pressure
    b. sand fill
    c. water fill
    d. higher temperature

Summary

Many conduit installations are visible; that is, they run exposed. Consequently, electricians must take special care to ensure that all exposed conduit runs are parallel, level, and plumb. Nothing else will do. This is one phase of the electrical construction industry where electricians have an opportunity to show off. In fact, an expert installation of a conduit system is similar to a work of art.

Learn the basics of conduit bending and installations, put your knowledge to practical use, and take pride in your abilities to perform a professional conduit installation. Make your work second to none. Of course, contractors and clients want speed, but if you have a good basic knowledge of conduit bending and then put this knowledge to use, your craftsmanship will let you bend conduit smarter and faster, giving a good-looking installation along with speed to satisfy your employer, the building owners, and all concerned.

Notes

Trade Terms Introduced in This Module

Approximate ram travel: The distance the ram of a hydraulic bender travels to make a bend. To simplify and speed bending operations, many benders are equipped with a scale that shows ram travel. Using a simple table (supplied with many benders), the degree of bend can easily be converted to inches of ram travel. This measurement, however, can only be approximated because of the variation in springback of the conduit being bent.

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

Bending protractor: Made for use with benders mounted on a bending table and used to measure degrees; also has a scale for 18, 20, 21, and 22 shots when using it to make a large sweep bend.

Bending shot: The number of shots needed to produce a specific bend.

Concentric bending: The process of making 90° bends in parallel runs of conduit. This requires increasing the radius of each conduit from the inside of the bend toward the outside.

Conduit: Piping designed especially for pulling electrical conductors. Types include rigid, IMC, EMT, PVC, aluminum, and other materials.

Degree indicator: An instrument designed to indicate the exact degree of bend while it is being made.

Developed length: The amount of straight pipe needed to bend a given radius. Also, the actual length of the conduit that will be bent.

Elbow: A 90° bend.

Gain: The amount of pipe saved by bending on a radius as opposed to right angles. Because conduit bends in a radius and not at right angles, the length of conduit needed for a bend will not equal the total determined length. Gain is the difference between the right angle distances A and B and the shorter distance C—the length of conduit actually needed for the bend.

Inside diameter (ID): The inside diameter of conduit. All electrical conduit is measured in this manner. The outside dimensions, however, will vary with the type of conduit used.

Kicks: Bends in a piece of conduit, usually less than 90°, made to change the direction of the conduit.

Leg length: The distance from the end of the straight section of conduit to the bend, measured to the centerline or to the inside or outside of the bend or rise.

Ninety-degree bend: A bend in a piece of conduit that changes its direction by 90°.

Offsets: Two equal bends made to avoid an obstruction blocking the run of the conduit.

One-shot shoe: A large bending shoe that is designed to make 90° bends in conduit.

Outside diameter (OD): The size of any piece of conduit measured on the outside diameter.

Radius: The relative size of the bent portion of a pipe.

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

Segment bend: Any bend formed by a series of bends of a few degrees each, rather than a single one-shot bend.

Segmented bending shoe: A smaller type of shoe designed for bending segmented bends only (always less than 15°).

Springback: The amount, measured in degrees, that a bent conduit tends to straighten after pressure is released on the bender ram. For example, a 90° bend, after pressure is released, will pull back about 2° to 88°.

Stub-up: Another name for the rise in a section of conduit.

Sweep bend: A 90° bend with a radius larger than that produced by a standard one-shot shoe.

Take-up (comeback): The amount that must be subtracted from the desired stub length to make the bend come out correctly using a point of reference on the bender or bending shoe.

Additional Resources

This module is intended to present thorough resources for task training. The following reference works are suggested for further study. These are optional materials for continued education rather than for task training.

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

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

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