

Electrical Level 2



Conduit Bending 26204-14



Objectives

When trainees have completed this lesson, they should be able to do the following:

1. Describe the process of conduit bending using power tools.
2. Identify all parts of electric and hydraulic benders.
3. Bend offsets, kicks, saddles, segmented, and parallel bends.
4. Explain the requirements of the *National Electrical Code*[®] (*NEC*[®]) for bending conduit.
5. Compute the radius, degrees in bend, developed length, and gain for conduit up to six inches.



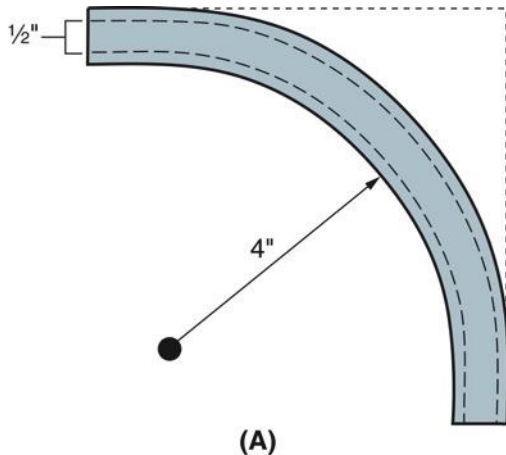
Performance Tasks

1. Use an electric or hydraulic bender to bend a 1" conduit stub-up to an exact distance of $15\frac{1}{4}$ " above the deck.
2. Make an offset in a length of conduit to miss a 10" high obstruction with a clearance between the obstruction and the conduit of not less than 1" nor more than $1\frac{1}{2}$ ".
3. Make a saddle in a length of conduit to cross an 8" pipe with 1" clearance between the pipe and the conduit.



1.0.0 – 2.1.0

Introduction; *NEC*[®] Requirements



(B)

- The *NEC*[®] specifies a minimum radius for conduit bends in order to avoid damage to both the conduit and conductors.
- In addition, the total of all bends in a conduit run must not exceed 360 degrees.

1.0.0 – 2.1.0

NEC[®] Minimum Requirements for Radius of Conduit Bends – One-Shot and Full-Shoe Benders

Per **NEC Chapter 9, Table 2**, the minimum radius to the centerline of the conduit for one-shot and full-shoe benders must be no less than that listed here.

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

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1.0.0 – 2.1.0

NEC[®] Minimum Requirements for Radius of Other Conduit Bends

Per **NEC Chapter 9, Table 2**, the minimum radius to the centerline of the conduit of other bends must be no less than that listed here.

Trade Size (Inches)	Other Bends (Inches)
1/2	4
3/4	5
1	6
1 1/4	8
1 1/2	10
2	12
2 1/2	15
3	18
3 1/2	21
4	24
5	30
6	36

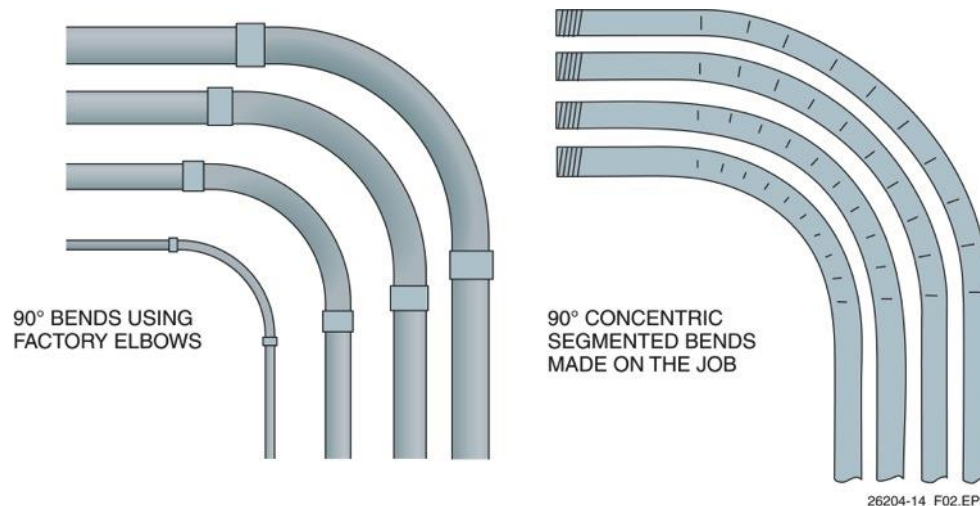
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3.0.0

Types of Bends

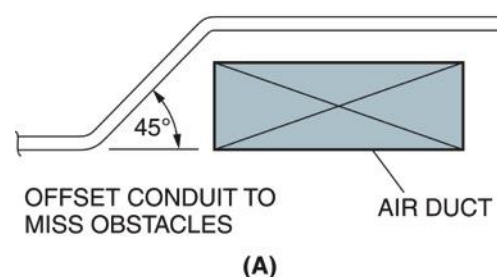
- Basic bends include elbows, offsets, saddles, and kicks.
- An elbow provides a 90-degree change in direction. Factory elbows are used to save time when installing runs of large conduit.
- Segmented bends can be used to provide concentric bends with multiple conduit runs.



3.0.0

Applications of Conduit Offsets

- Offsets consist of two equal bends and are used to route conduit around obstructions.
- Offsets are also used to route conduit to outlet boxes, cabinets, panelboards, and pull boxes.

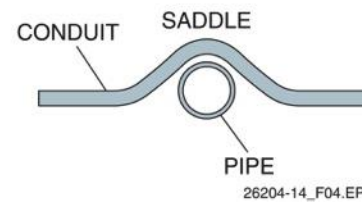
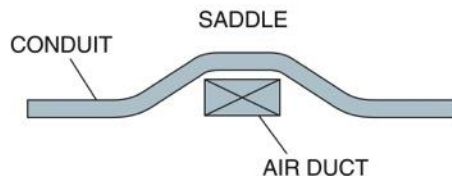
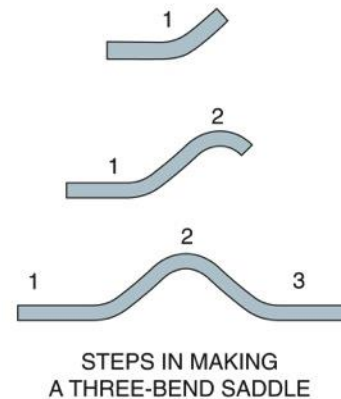
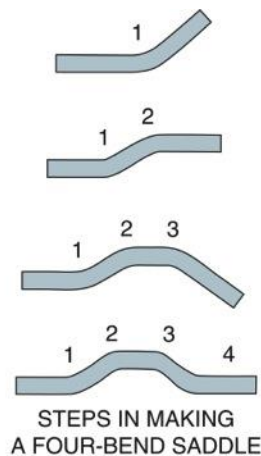


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3.0.0

Practical Application of a Saddle Bend

- Saddle bends can be used to route conduit around obstructions such as ductwork or piping.
- Both three- bend and four-bend saddles can be used.



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3.0.0

Kick

- A kick is a single change in direction.
- Kicks are often used to route conduit up through deck work.

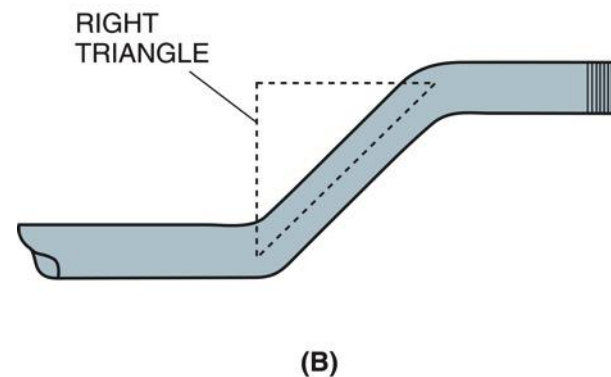
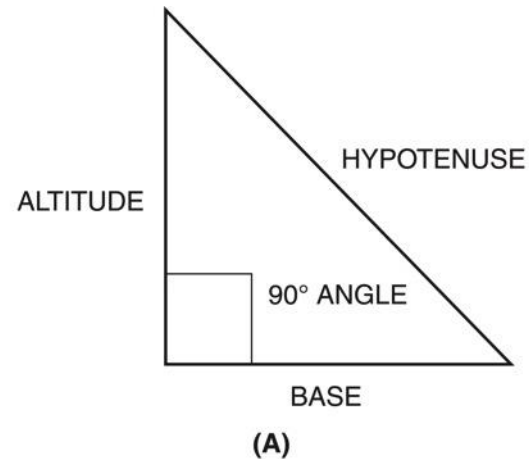


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4.0.0 – 4.1.1

The Geometry of Bending Conduit

- The offset of a conduit bend forms the hypotenuse of a right triangle.
- The mathematics of right triangles can be used to find unknown measurements.

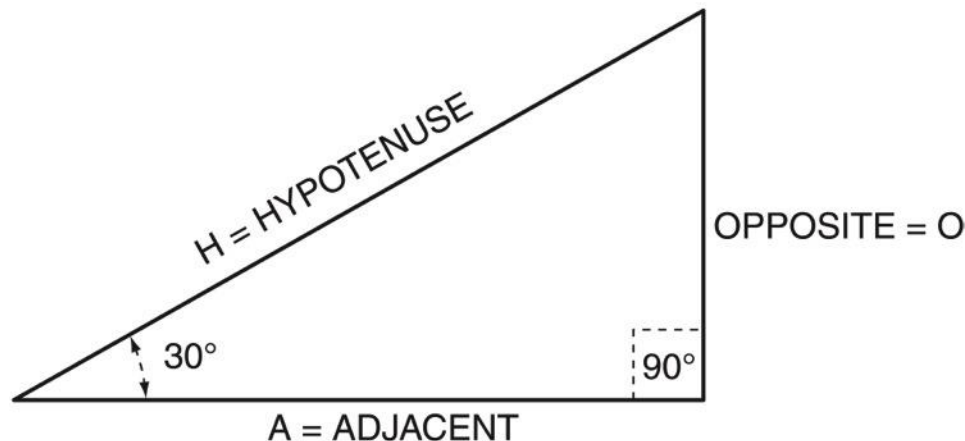


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4.0.0 – 4.1.1

Trigonometry Fundamentals of a Right Triangle

- Trigonometric equations can be used to find an unknown side or angle.
- These equations can also be applied to determine conduit measurements, such as the rise or stub-up and the distance between bends.



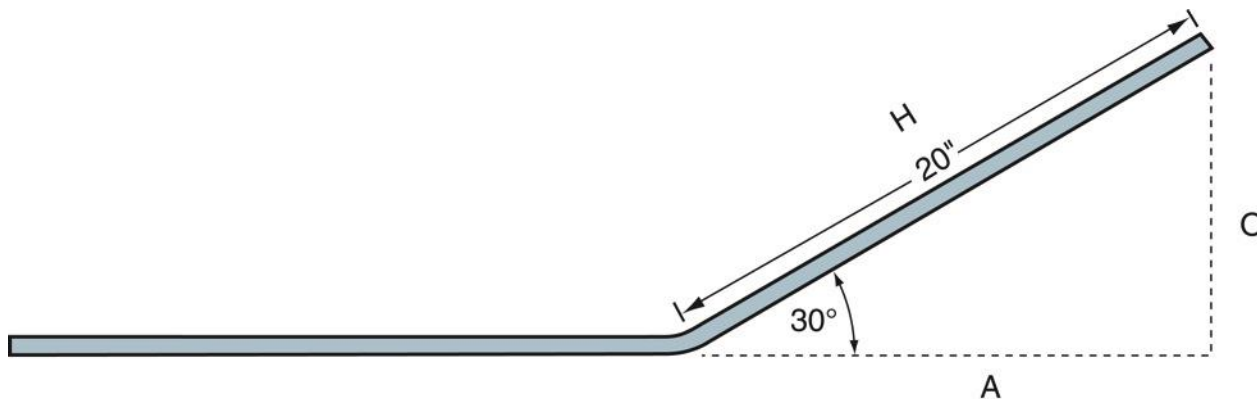
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4.0.0 – 4.1.1

Kick Example

- The length of the side opposite (O) can be found by rearranging the cosecant equation to solve for O (opposite = hypotenuse/cosecant).
- To determine the height of this kick, the length of the hypotenuse (20") is divided by the cosecant of the angle of 30 degrees (2) to arrive at a height of 10".



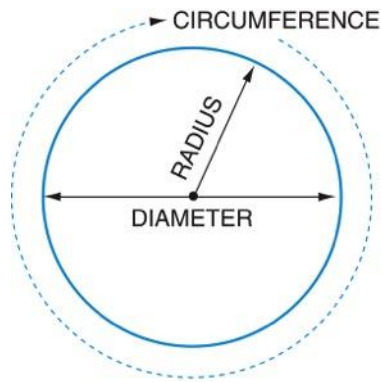
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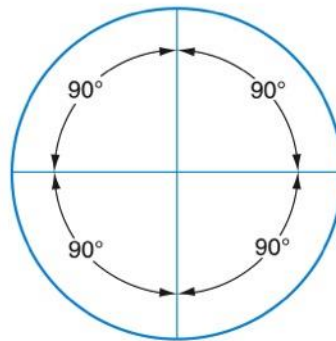
4.2.0 – 4.2.1

Circle

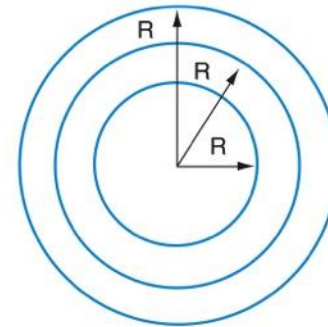
- A circle is a closed, curved line with all points equidistant from the center.
- The distance from the center point to the edge is the radius and the distance through the center to the other side is the diameter.
- Concentric circles have a common center but different radii.



(A)



(B)



(C)

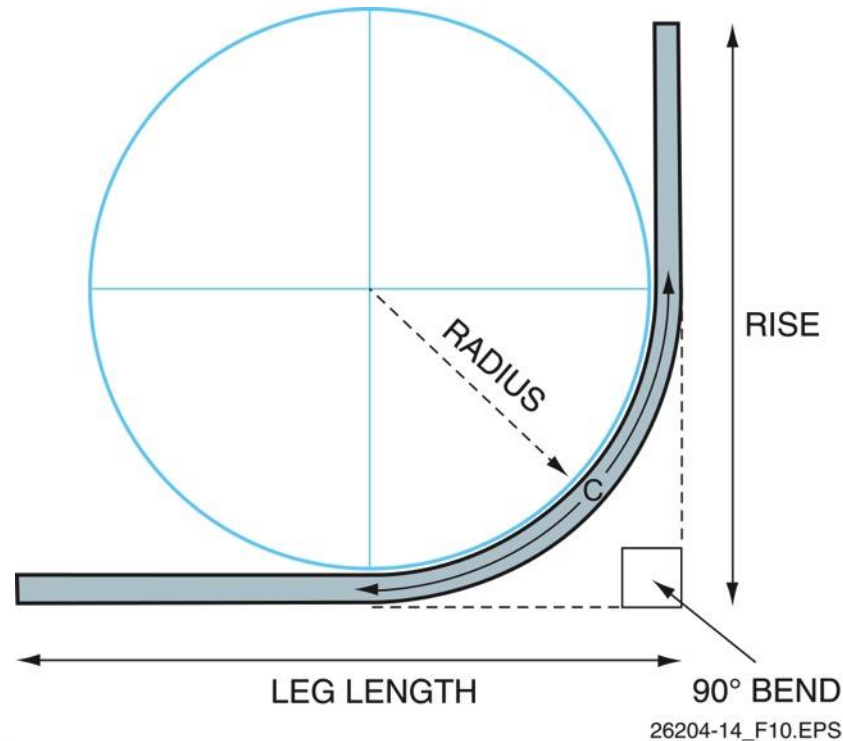
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4.2.0 – 4.2.1

Parts of a Circle Related to Conduit Bending

A 90-degree bend in conduit represents a quarter of a circle.



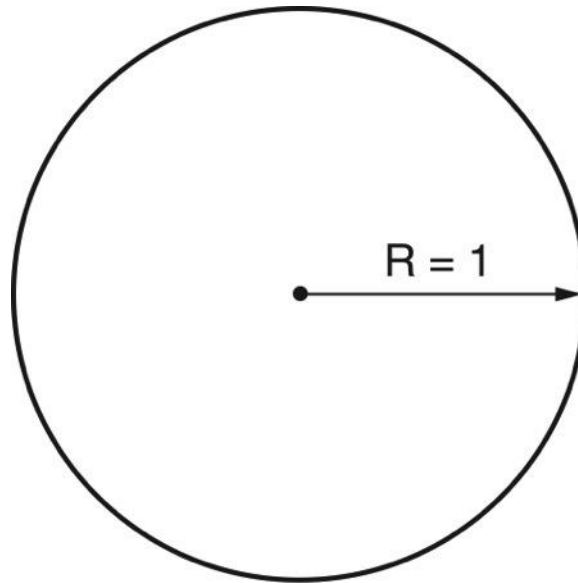
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4.2.0 – 4.2.1

Unit Circle

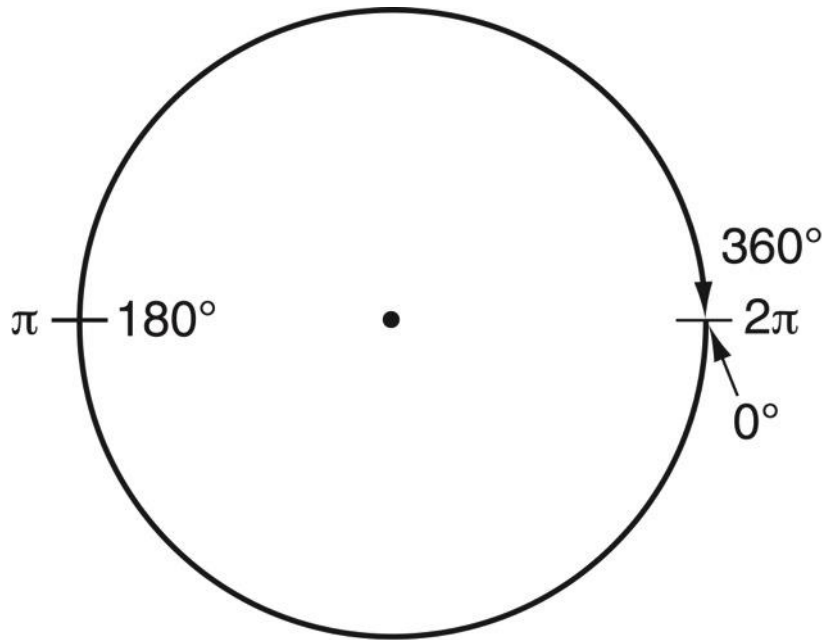
- A unit circle has a given radius of one.
- To find the circumference of a circle, multiple 2 times the value of pi (3.14) times the radius ($C = 2\pi R$).



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4.2.0 – 4.2.1

π and 2π



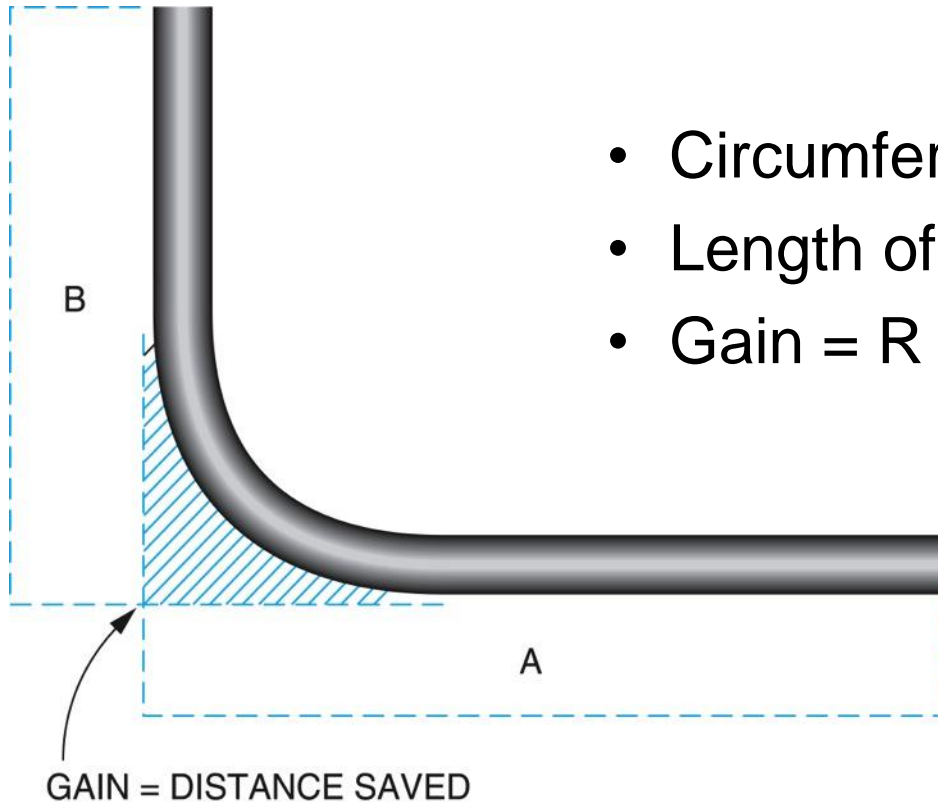
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- Using a unit circle with a radius of one, the circumference is equal to 2π .
- Half of the circle equals $2\pi/2$ or simply π , and a 90° bend equals $\pi/2$ or 1.57.
- Multiplying 1.57 times the radius provides the distance from 0° to 90° . This is known as the developed length.

4.3.0 – 4.3.1

Equations

- Circumference = π x diameter
- Length of arc = $1.57R$
- Gain = R x gain factor



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4.3.0 – 4.3.1

Gain Factors

- Find the gain factor for a given conduit size and degree of bend.
- Multiply the gain factor by the centerline radius of the bend and subtract it from the conduit length to find the gain.

	—	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	—	—	—	—	—	—	—	—	—



4.3.0 – 4.3.1

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

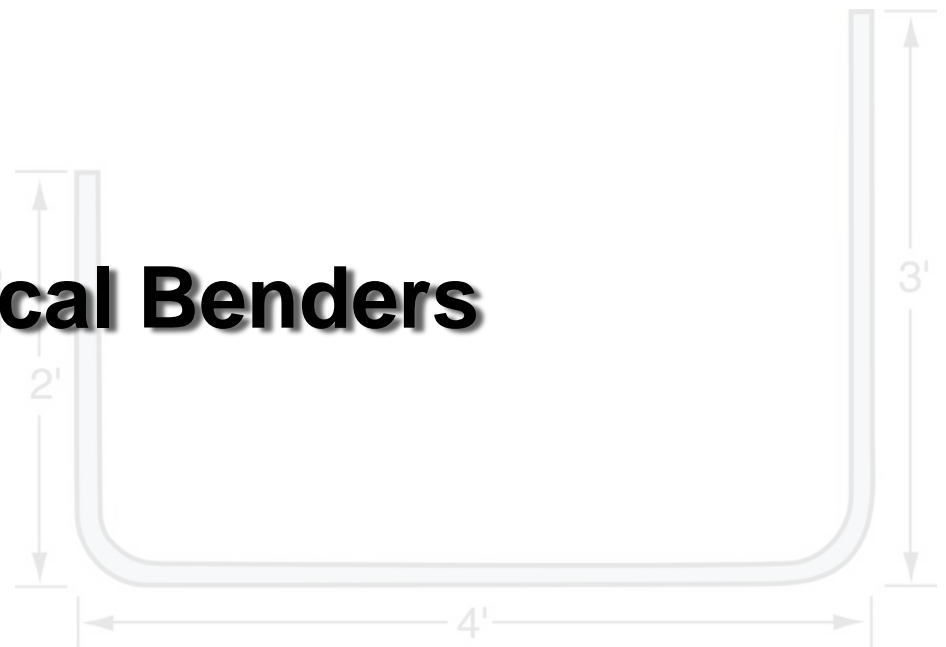


4.3.0 – 4.3.1

Next Session...to-Back 90° Bends

- When making back-to-back bends, calculate the gain by multiplying the gain factor by the centerline radius of the bend.
- Multiply the gain by two and subtract from the overall length.

Mechanical Benders

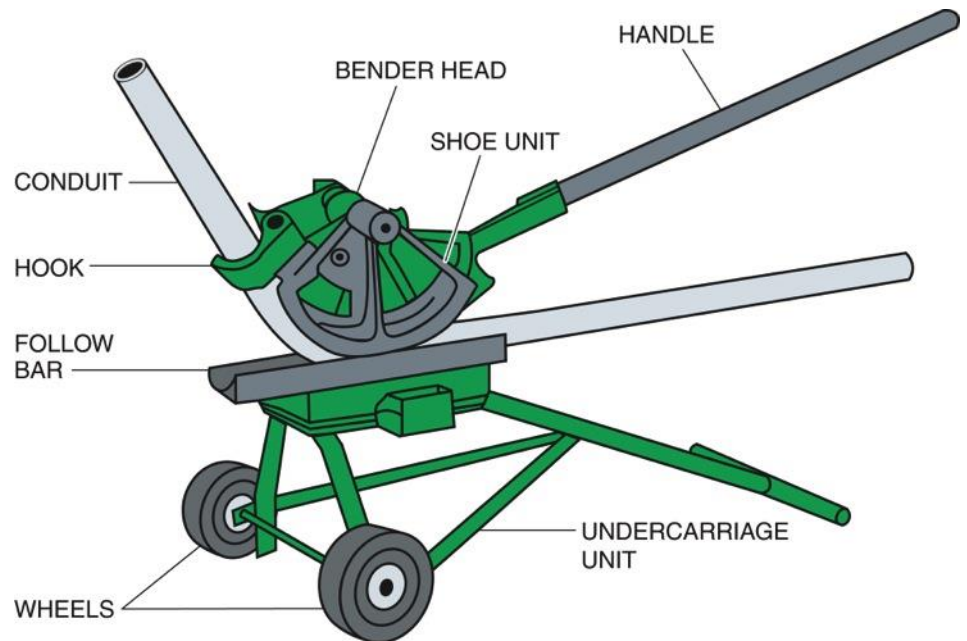


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5.0.0

Mechanical Benders

- Hickeys and EMT bending tools are used on smaller conduit and runs with few bends.
- Mechanical benders can be used to duplicate multiple bends with minimal effort. Select the correct bender shoe for the type and size of conduit in use.

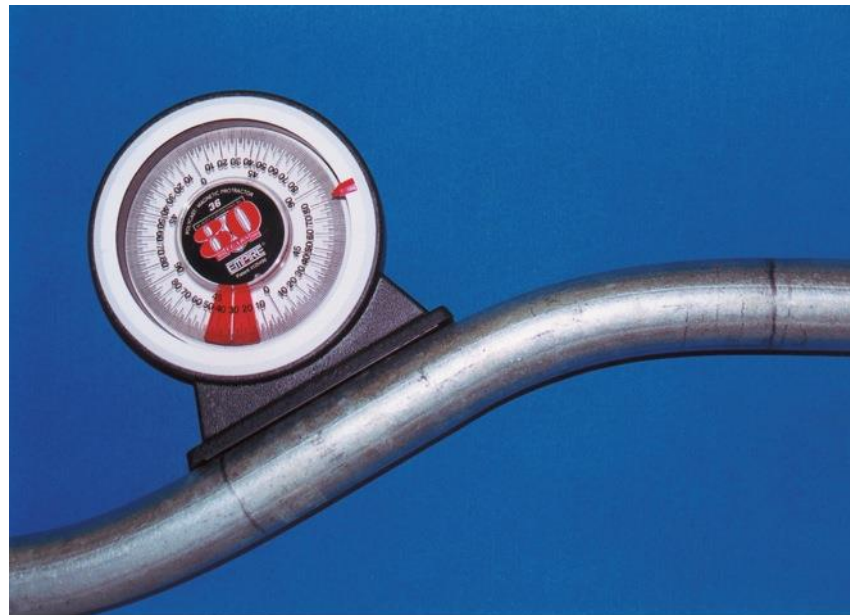


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5.0.0

Bending Protractor

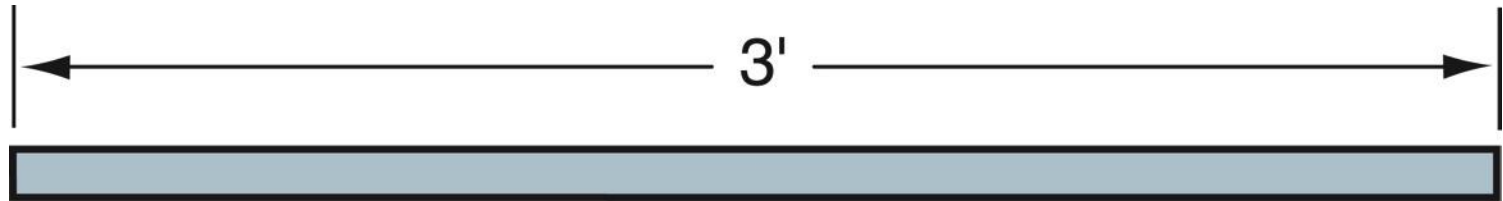
- Before making a bend, the desired angle is set using an adjustable pointer on the bender.
- Use a bending protractor to check the angle before making multiple bends.



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5.0.0

Conduit



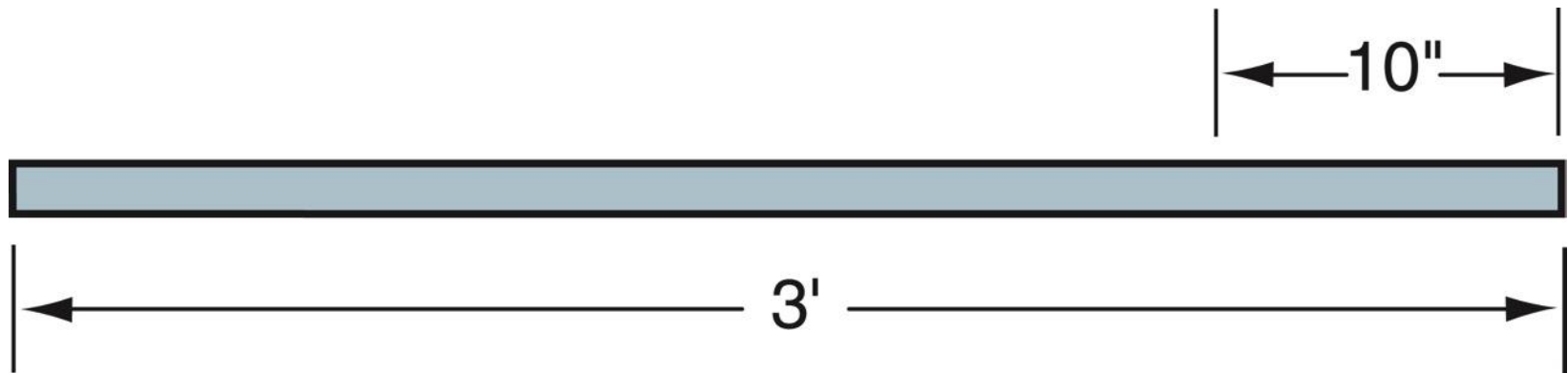
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- Benders can be charted using a scrap piece of conduit.
- This process can be used to find the minimum rise, gain, and centerline distances for various bends.

5.0.0

Conduit with 10" Mark

To begin charting a bender, place a mark at a given distance from the end of the conduit (in this case, 10").



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5.0.0

Kick of 15°



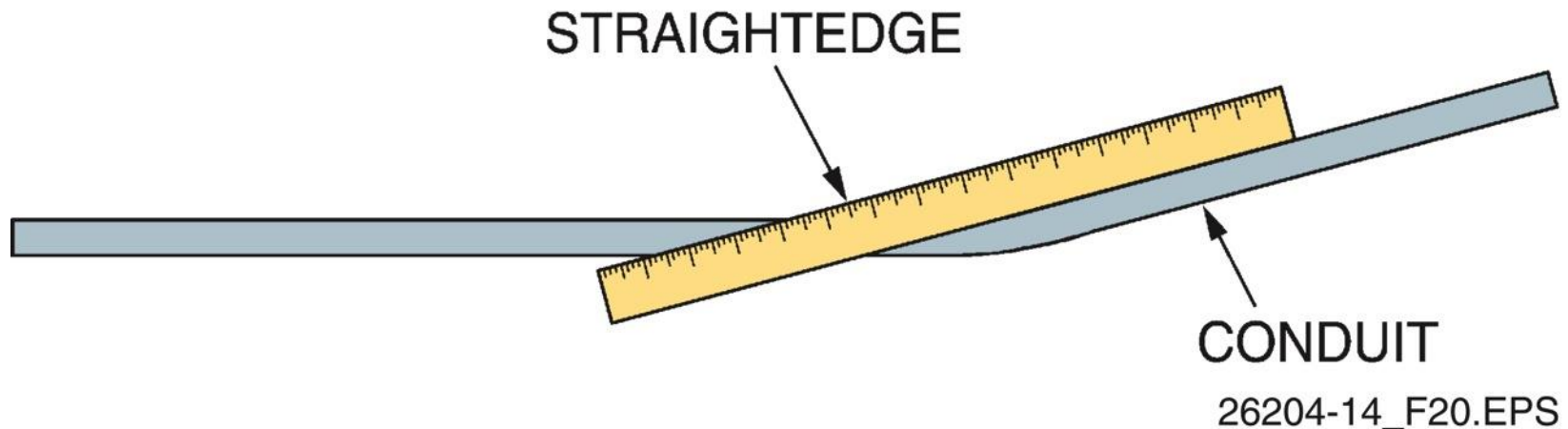
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- Place the bender arrow on the 10" mark and a bending protractor on the conduit in front of the bend.
- Bend the conduit until the protractor reads 15° .

5.0.0

Conduit and Straightedge

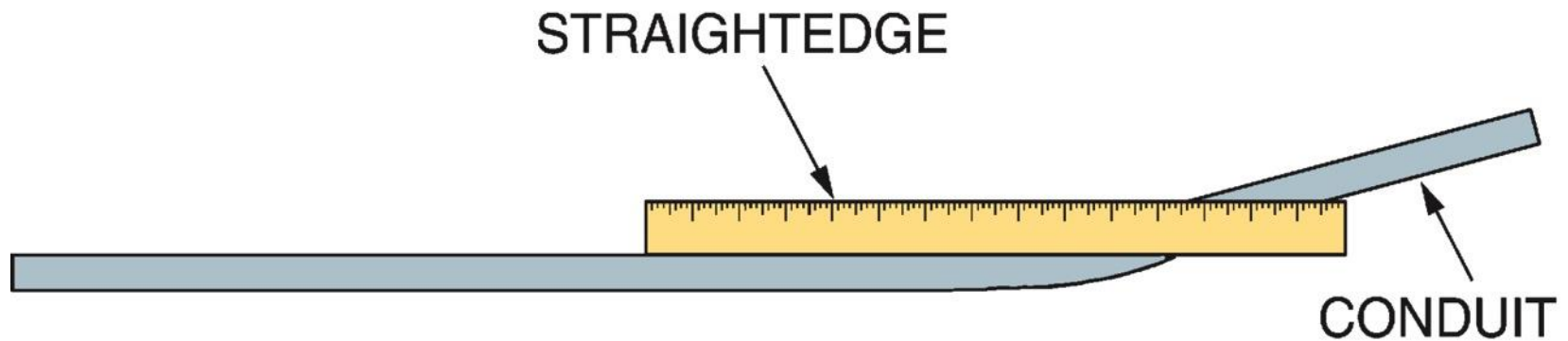
Align a straightedge with the inside of the bend and scribe a line across the bend.



5.0.0

Conduit and Horizontal Straightedge

Next, align a straightedge with the horizontal conduit and scribe another line across the bend.

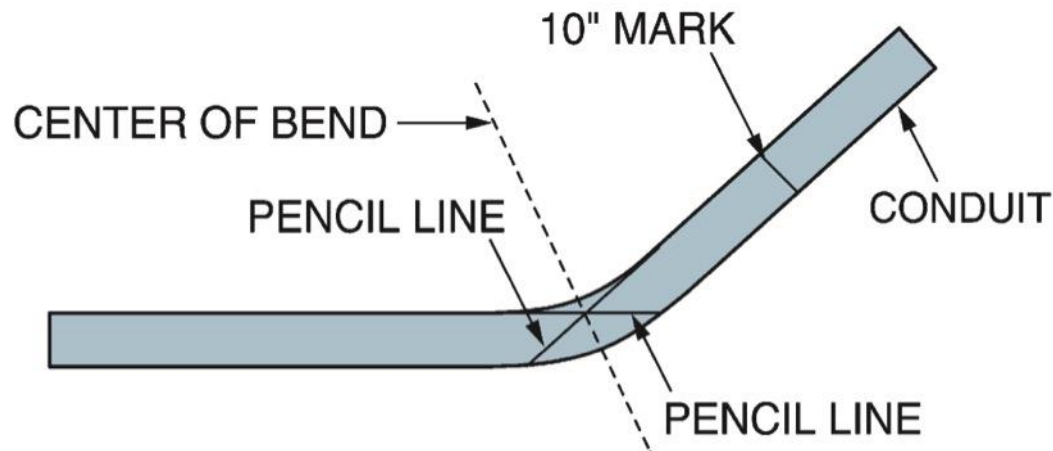


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5.0.0

Center of Bend

- The point at which the two lines cross represents the center of the bend.
- Measure from the 10" mark to the centerline of the bend and chart this measurement for 15° .
- Repeat this process for other bends.



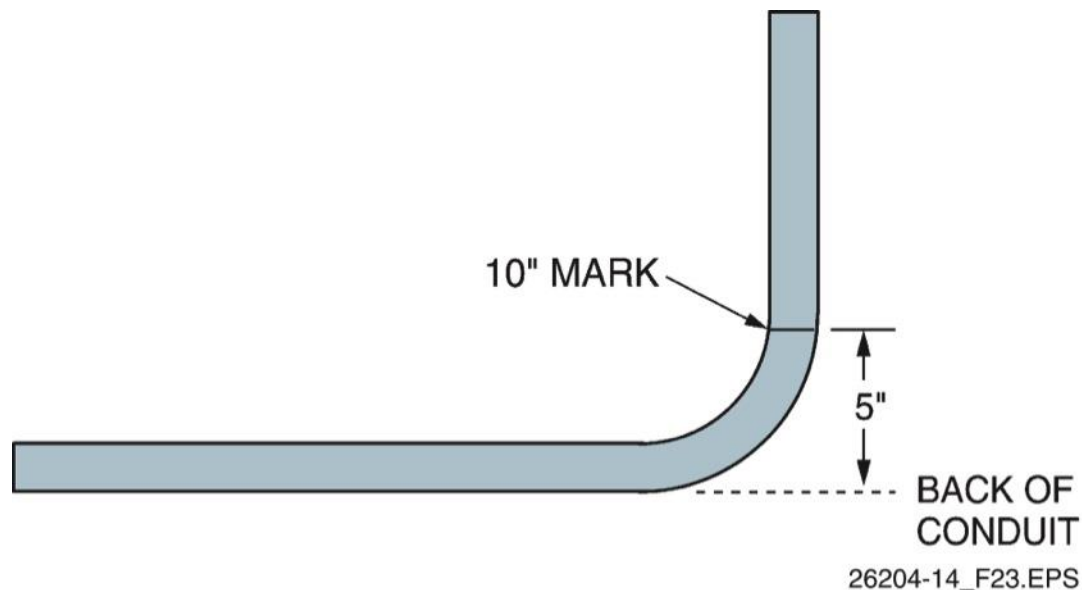
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5.0.0

90° Stub-Up

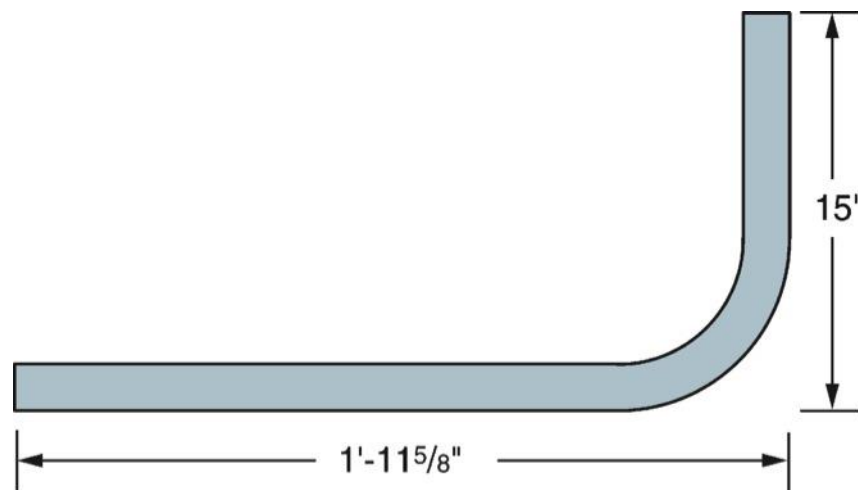
- To find the minimum rise, place the protractor on the bender and bend the conduit until it reads 90° .
- Measure from the back of the conduit to the 10" mark. This is the minimum stub-up length.



5.0.0

90° Elbow

- To determine the gain of a bender for a 90° bend, measure the length of both sides of the scrap piece of conduit.
- Add the two measured lengths and subtract the original length of the conduit. Chart this as the gain of the bender.



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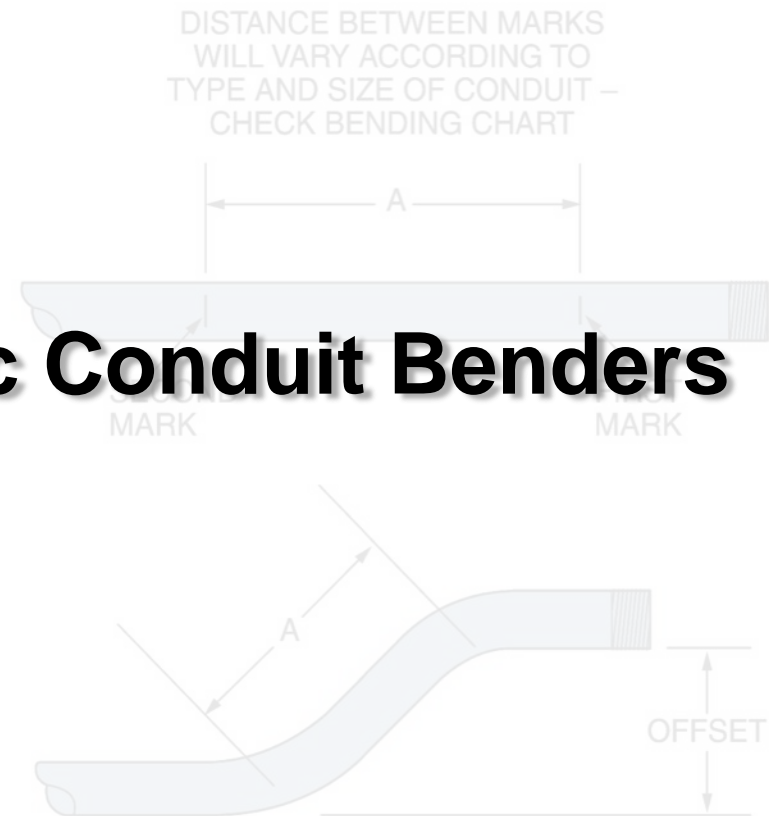


6.0.0 – 7.1.0

Next Session... Mechanical Stub-Ups; Mechanical Offsets

- The deduct chart on the bender lists information for various stub-ups and offsets.
- To bend a mechanical stub-up, subtract the chart value for the stub-up from the offset. Place the bender on this measurement and bend the conduit.
- To bend an offset, mark the distance to the first bend, then find the distance between bends on the chart for the given angle. Bend the conduit.

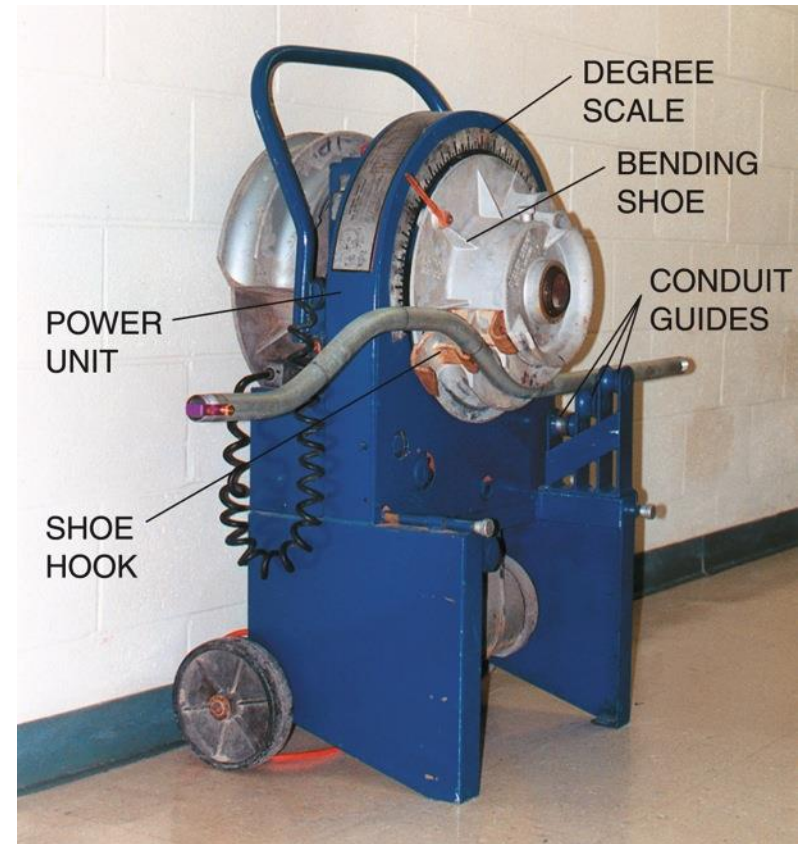
Electric and Hydraulic Conduit Benders



8.0.0 – 8.1.1

Electric and Hydraulic Conduit Benders

- Larger conduit is bent using electrical or hydraulic benders.
- Electric benders can be used to make one-shot bends in ½" through 2" EMT, IMC, or RMC.
- Bender charts include deduct and springback figures, along with offset information. Springback occurs when conduit relaxes slightly after bending.

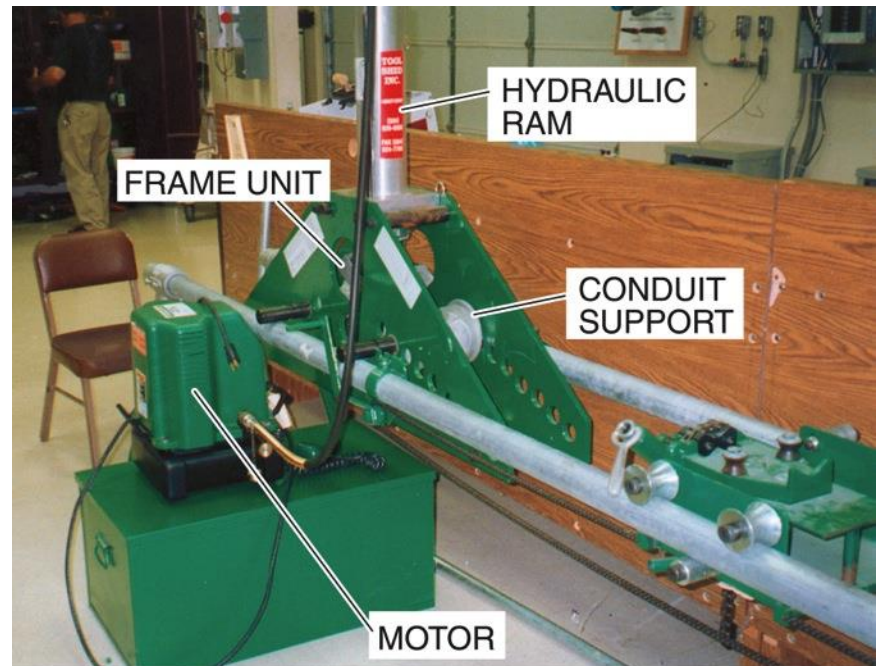


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8.2.0 – 8.2.3

Hydraulic Conduit Benders

- Hydraulic benders can be used to bend conduit up to 6" trade size.
- Hydraulic benders are available with both one-shot and segmented bending shoes.
- Aluminum conduit is prone to wrinkling and scoring and tends to produce inconsistent bends.

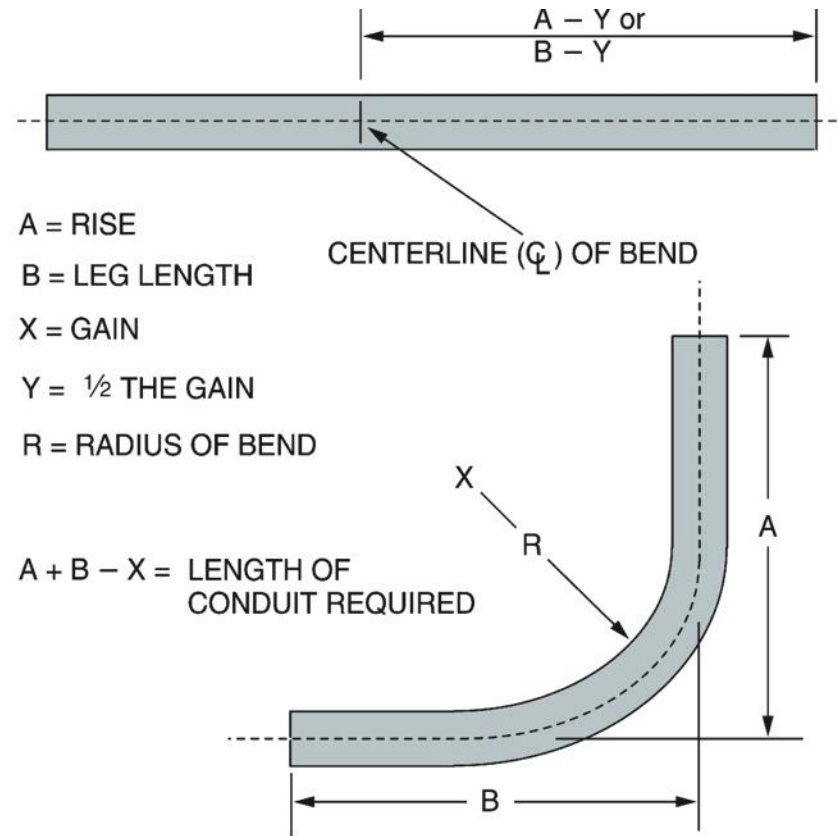


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8.2.0 – 8.2.3

Laying Out Stub-Ups

- To lay out a one-shot stub-up, add the rise and leg length, then subtract the gain.
- Subtract half of the gain from either leg length to find the center of the bend.
- Calculate the developed length and the length of conduit required.



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8.2.0 – 8.2.3

Dimensions of Stub-Ups for Various Sizes of Conduit

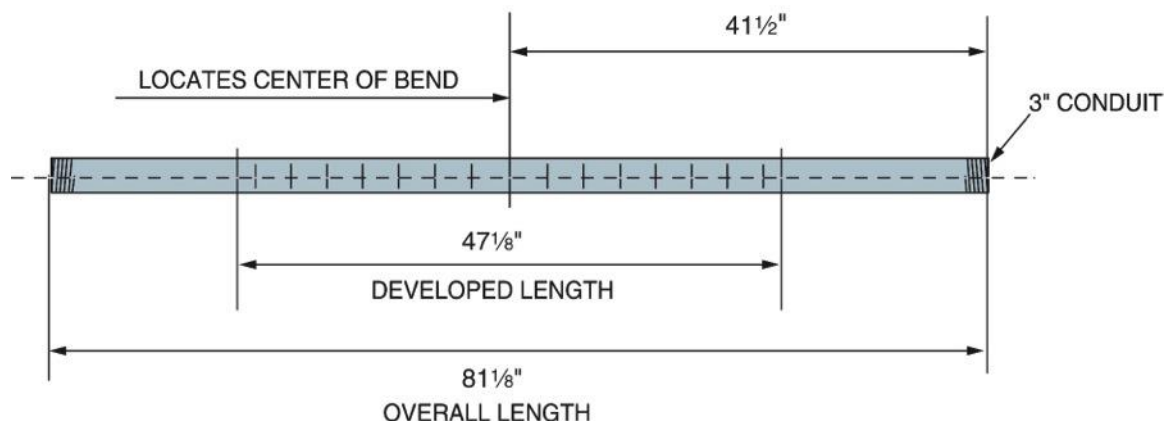
Pipe and Conduit Size	Radius of Bend R	Minimum Developed Length 90°	Gain X	1/2 Gain Y
1/2"	4"	6 ⁵ / ₁₆ "	1 ¹¹ / ₁₆ "	27/ ₃₂ "
3/4"	4 ¹ / ₂ "	7 ¹ / ₁₆ "	1 ¹⁵ / ₁₆ "	31/ ₃₂ "
1"	5 ³ / ₄ "	9"	2 ¹ / ₂ "	1 ¹ / ₄ "
1 ¹ / ₄ "	7 ¹ / ₄ "	11 ³ / ₈ "	3 ¹ / ₈ "	1 ⁹ / ₁₆ "
1 ¹ / ₂ "	8 ¹ / ₄ "	13"	3 ¹ / ₂ "	1 ³ / ₄ "
2"	9 ¹ / ₂ "	14 ¹⁵ / ₁₆ "	4 ¹ / ₁₆ "	2 ¹ / ₃₂ "



8.2.0 – 8.2.3

Laying Out Segment Bends

- To lay out a segment bend, multiply the radius by 1.57 to determine the developed length.
- Locate the center of the required bend. Once the center is found, it is easy to locate the other bend marks.
- Use an odd number of shots so there are an equal number of bends on either side of the center mark.

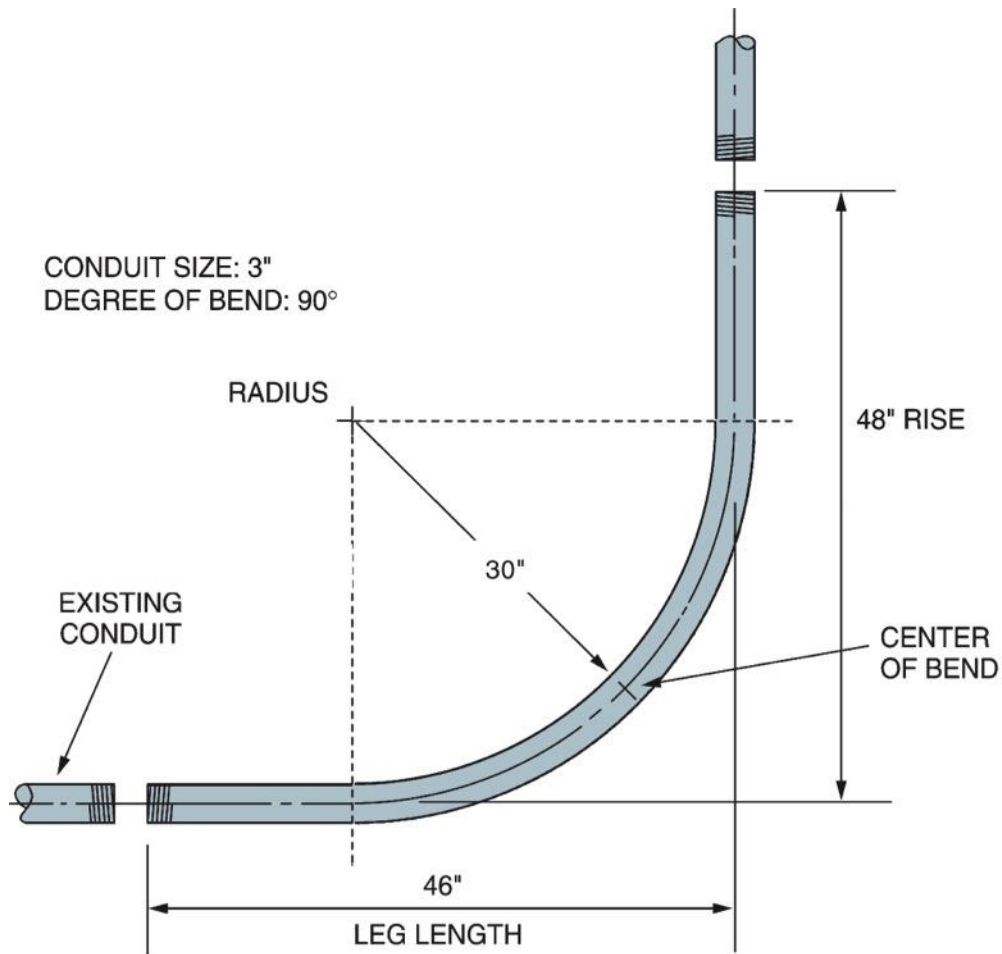


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8.2.0 – 8.2.3

Specifications for Sample Bend



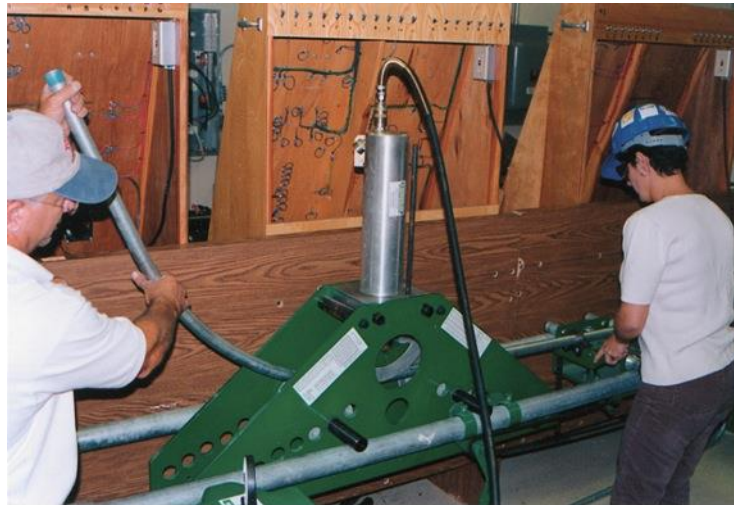
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8.2.0 – 8.2.3

Conduit Placed in Hydraulic Bender for Segment Bends

- Check the distance between the first and last bend marks before starting the first bend.
- After positioning the conduit in the bender, attach the pipe bending degree indicator in a convenient location.

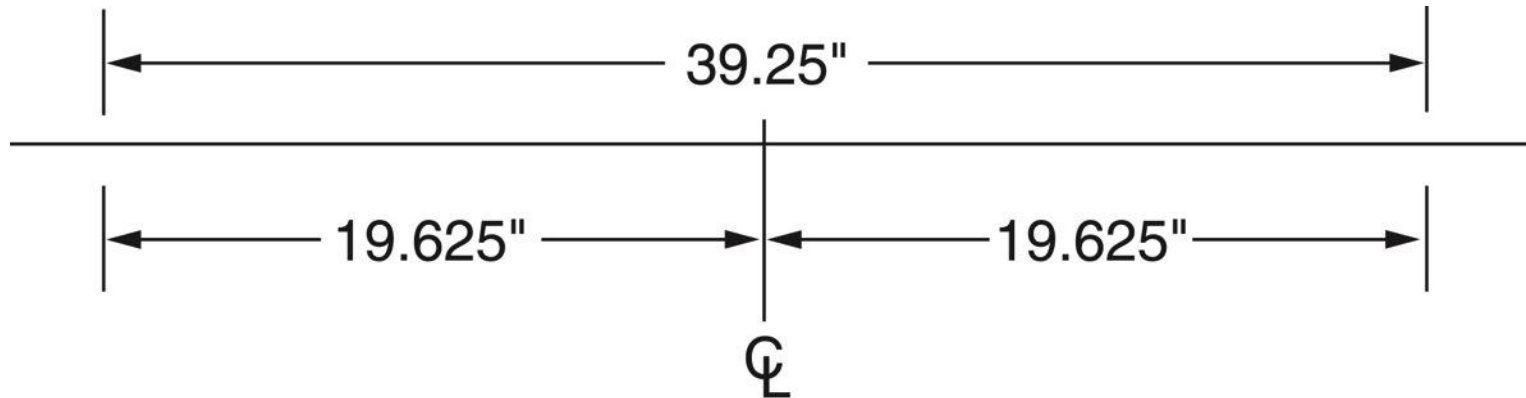


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8.2.0 – 8.2.3

Conduit Center

- To find the developed length, multiply the radius by 1.57 to find the developed length of the bend.
- The segments are laid out on either side of the centerline.



8.2.0 – 8.2.3

Next Session... Conduit Segments

- Divide the developed length by the number of shots to determine the distance between segments.
- Divide 90 degrees by the number of shots to determine the degrees per shot.



26204-14_F33.EPS

Performance Task

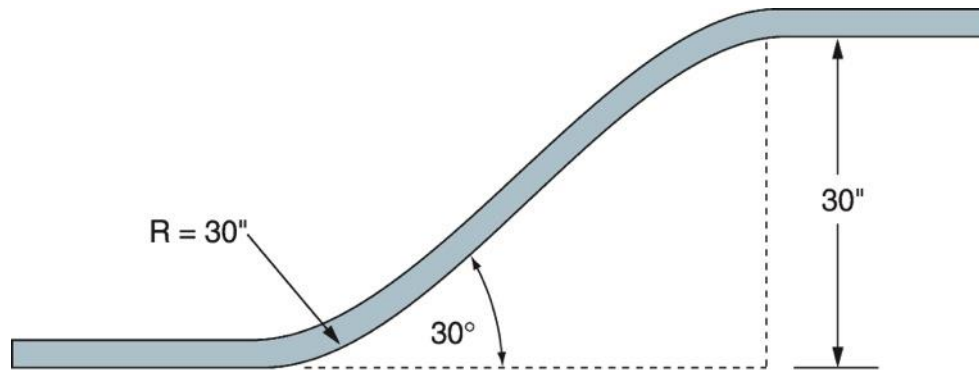
This session will conclude with trainees using an electric or hydraulic bender to bend a 1" conduit stub-up to an exact distance of $15\frac{1}{4}$ " above the deck.



9.0.0

Segment Bending Techniques

- The four methods of measuring segment bends include using a bend degree protractor, a magnetic angle finder, the amount of travel method, and the number of pumps method.
- Precise measurements are necessary—even a small segment bending error will be compounded as the bend is completed.

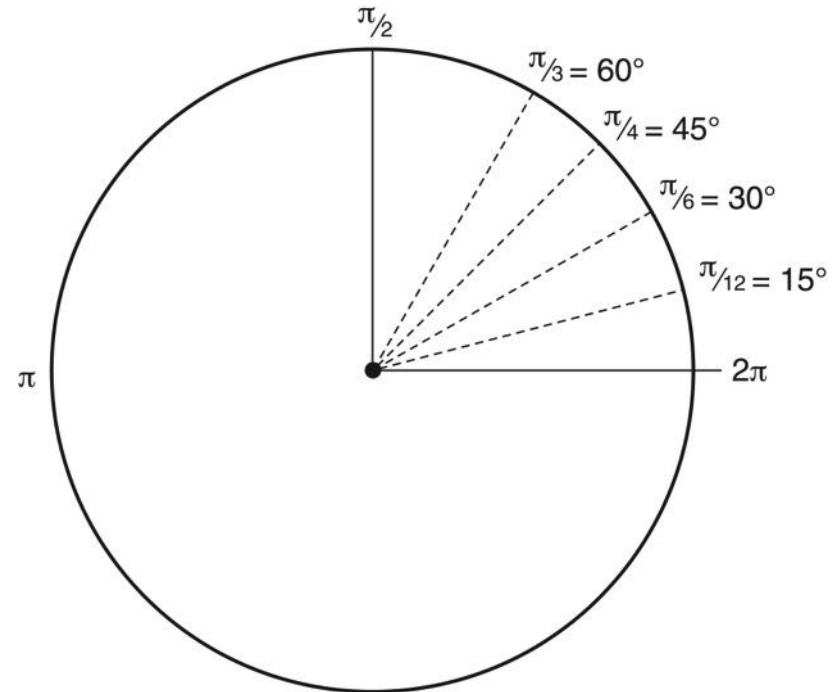


26204-14_F34.EPS

9.0.0

Radians and Degrees

- All angles in a unit circle can be calculated in relation to pi using the circumference formula.
- To find the developed length of the conduit at 30 degrees, divide the value of pi by six and multiply it by the radius of the bend.



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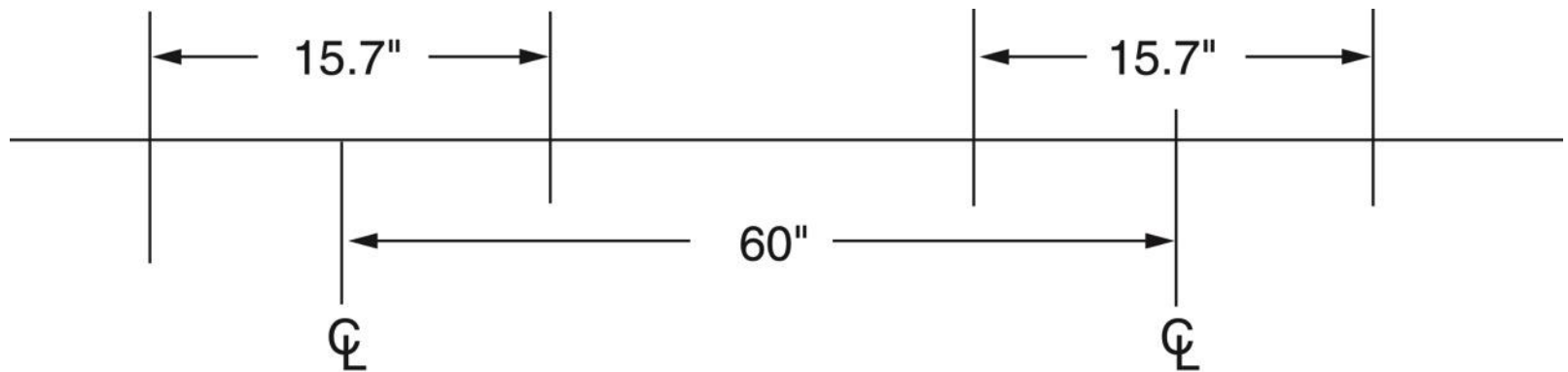
9.0.0

Bend Centerline Distance

The distance between the centerlines of each bend is found by rearranging the cosecant formula to solve for the hypotenuse:

Hypotenuse = opposite x cosecant

Hypotenuse = 30" x 2 = 60"



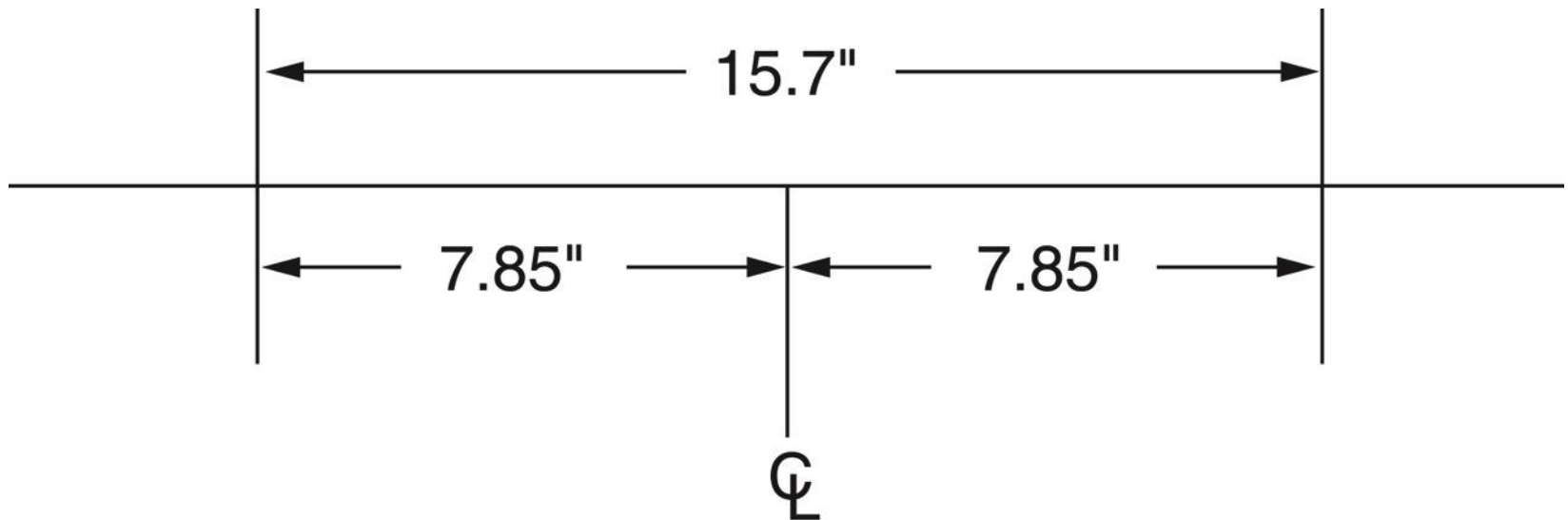
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9.0.0

Bend Centerline

The next step is to find the centerline of each bend by dividing the developed length by two.



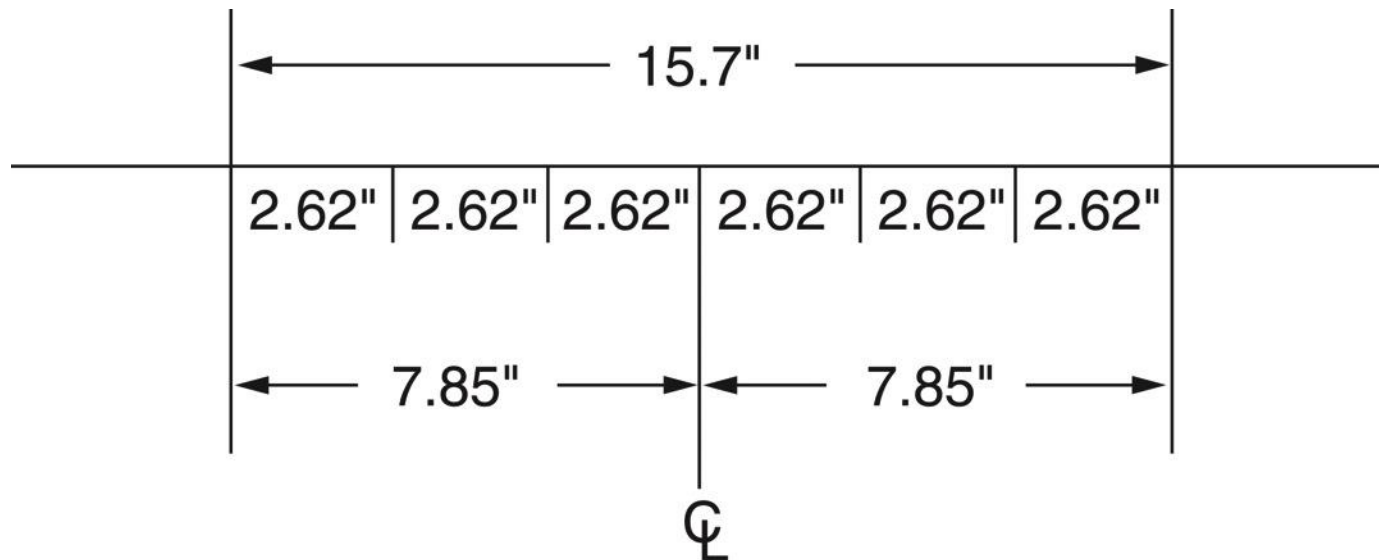
26204-14_F37.EPS



9.0.0

Bend Segments

- When building a 90-degree sweep, the rule of thumb is 21 shots or 20 segments.
- A 30-degree sweep would use seven shots or six segments.



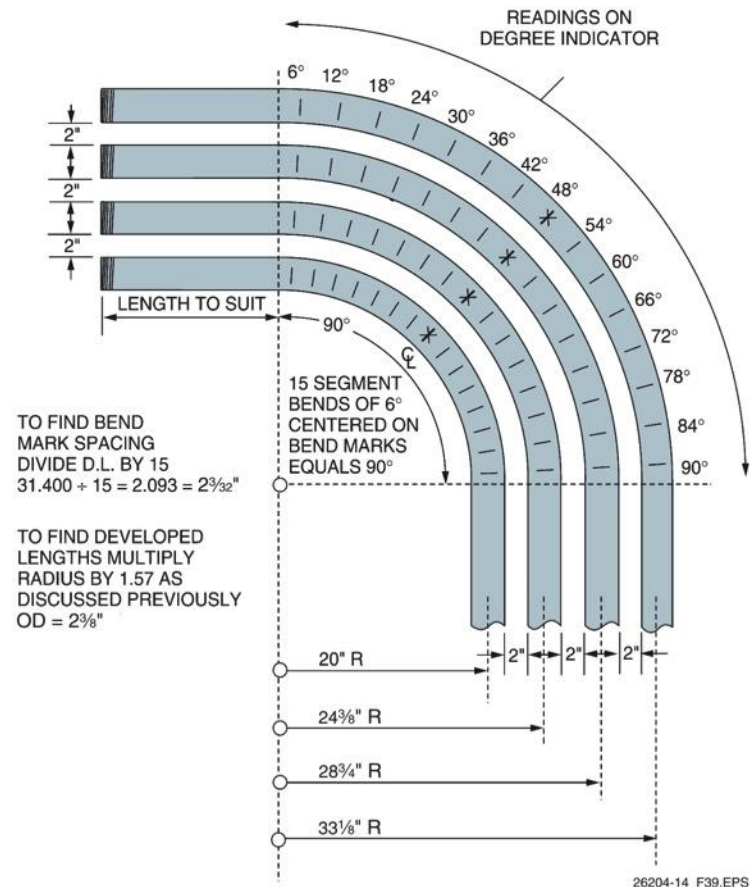
26204-14_F38.EPS



9.1.0

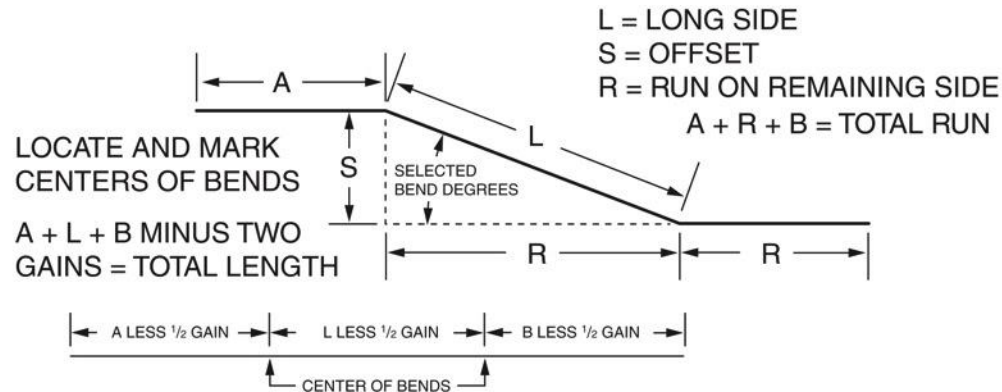
Concentric Bending

- When routing two or more parallel runs of conduit in the same direction, the best results are obtained using concentric bends.
- The bend for the innermost conduit is calculated first, then the second radius is formed by adding the outside diameter of the first conduit to the first radius and the desired spacing.



9.2.0 – 9.3.0

Offset Bends



TO FIND	KNOWN	TIMES CORRESPONDING MULTIPLIER EQUALS								UNKNOWN
		TABLE OF MULTIPLIER FOR SELECTED DEGREES OF BEND								
		5 7/8°	11 1/4°	15°	22 1/2°	30°	37 1/2°	45°	60°	
L	S	10.207	5.126	3.864	2.613	2.00	1.643	1.414	1.155	L
S	L	0.098	0.195	0.259	0.383	0.50	0.609	0.707	0.866	S
R	S	10.158	5.027	3.732	2.414	1.732	1.303	1.00	0.577	R
S	R	0.098	0.199	0.268	0.414	0.577	0.767	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	0.995	0.981	0.966	0.933	0.866	0.793	0.707	0.50	R
GAIN PER BEND	RADIUS OR SHOE	0.0002	0.0006	0.0015	0.0051	0.0124	0.0212	0.0430	0.1076	GAIN PER BEND

26204-14_F40.EPS



9.2.0 – 9.3.0

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?

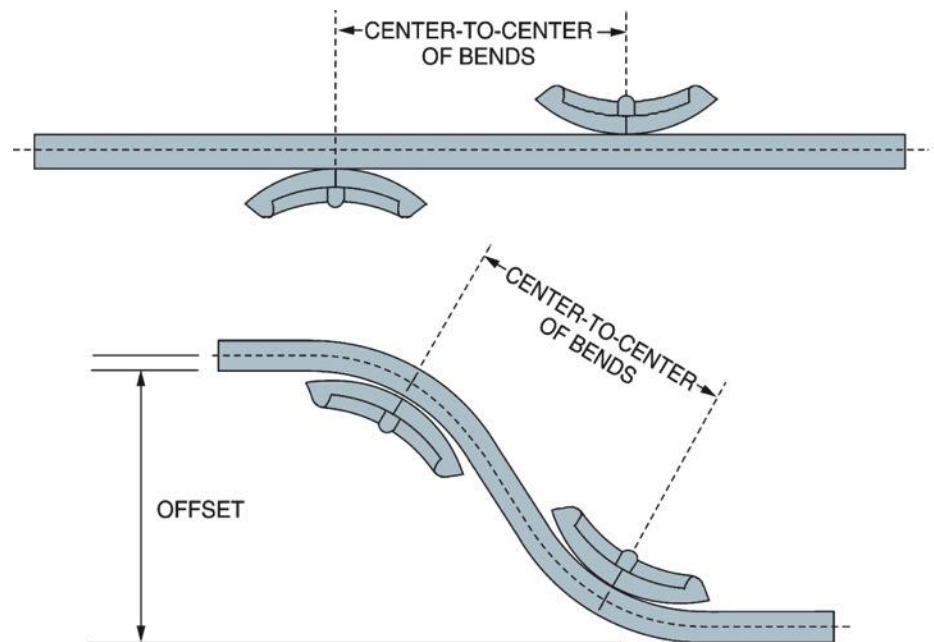


26204-14_SA04.EPS

9.2.0 – 9.3.0

Position of Conduit in Bender for Making Offsets

- To make an offset, the conduit is positioned in the bender and the shoe is used to make the first 45-degree bend.
- The conduit is reversed in the bender and the next 45-degree bend is made at the second mark.

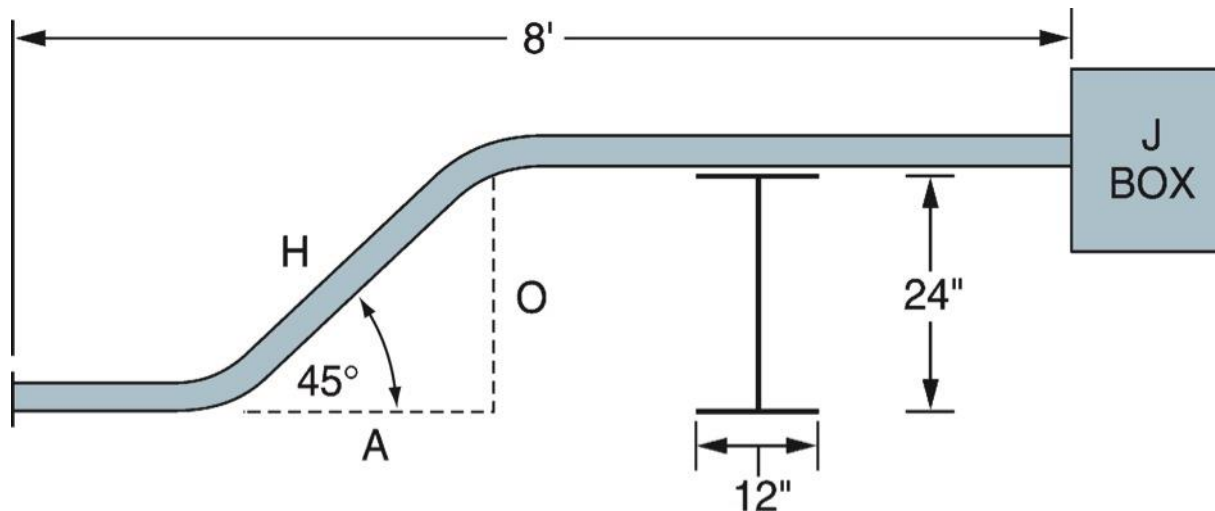


26204-14_F41.EPS

9.2.0 – 9.3.0

24" Offset

- To find the distance between bend points, multiply the offset required by the cosecant of the bending angle.
- The amount of conduit to be added to the straight distance entering the junction box is found using the cosine formula (adjacent = cosine x hypotenuse).



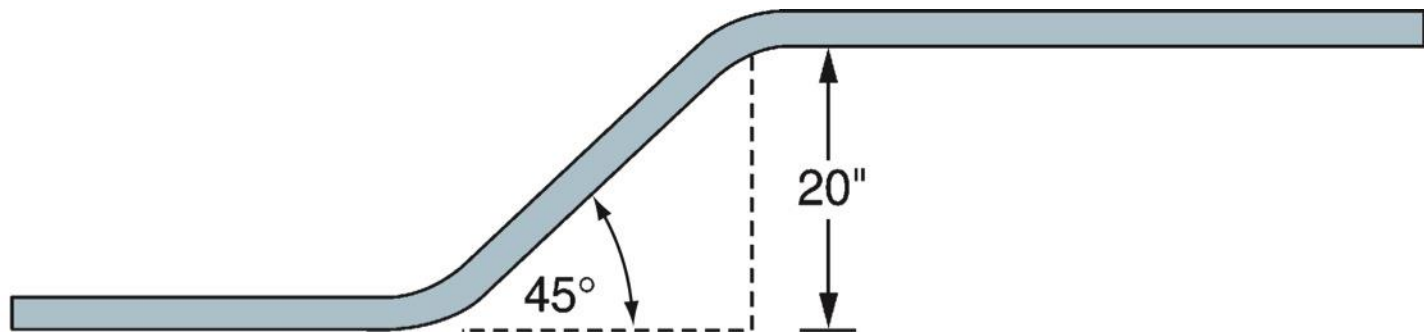
26204-14_F42.EPS



9.2.0 – 9.3.0

20" Offset

- It is better to use multiple shots when making offsets to provide a smoother bend and easier conductor installation.
- Concentric offsets are made by adding the radius of the first pipe to the outside diameter of the first pipe and the desired spacing between the runs.



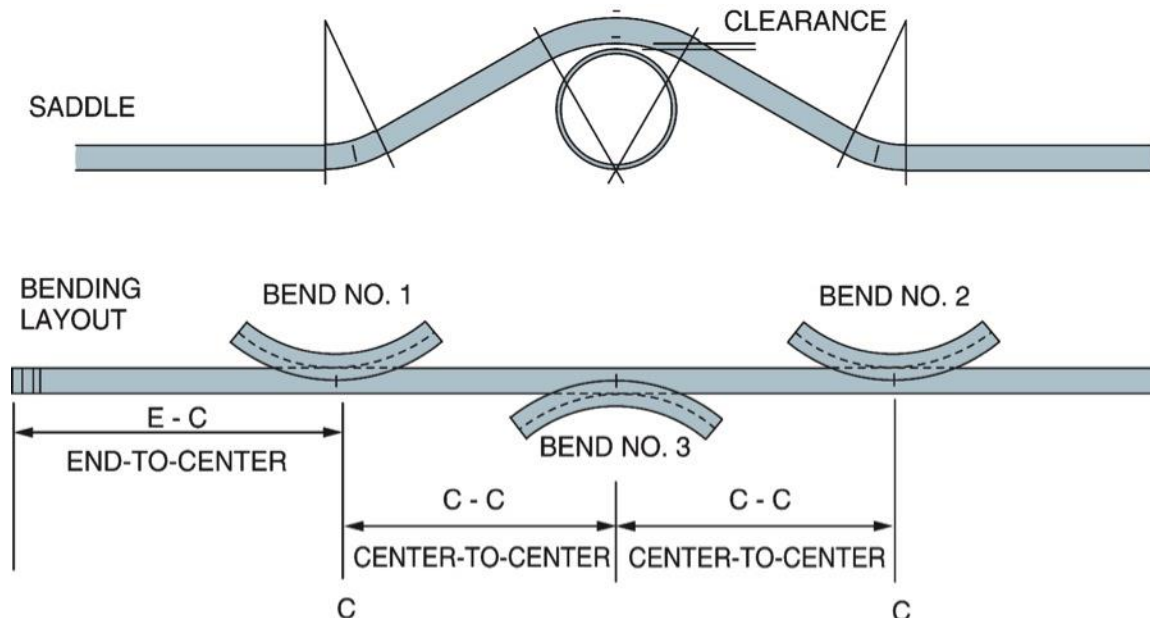
26204-14_F43.EPS



9.3.1

Saddle Bends

- To make a saddle bend, the bend is calculated using bending charts.
- Make the two smaller bends first, then make the third larger bend.



26204-14_F44.EPS



9.3.1

Saddle Table

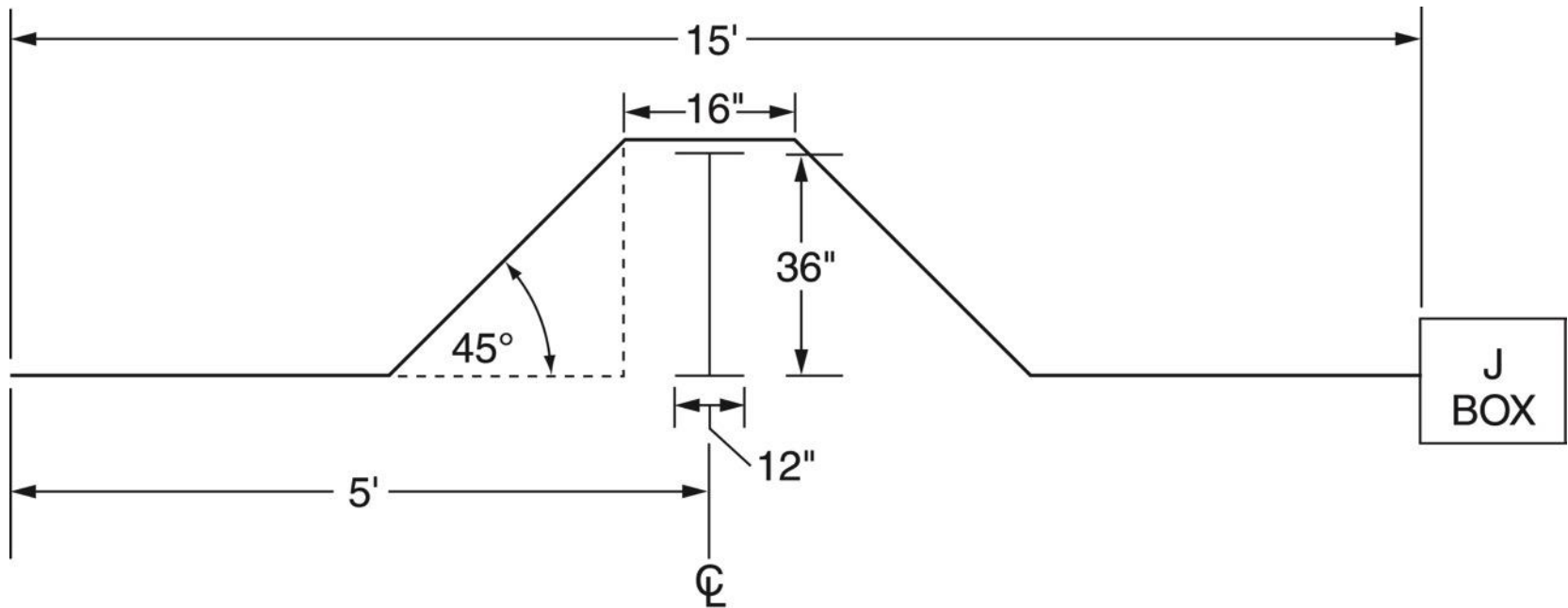
- Hydraulic benders can be used to make saddle bends in conduit up to four inches inside diameter (ID).
- Bending charts are used to find the spacing between bends for various angles and sizes of conduit.

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



9.3.1

36" Saddle

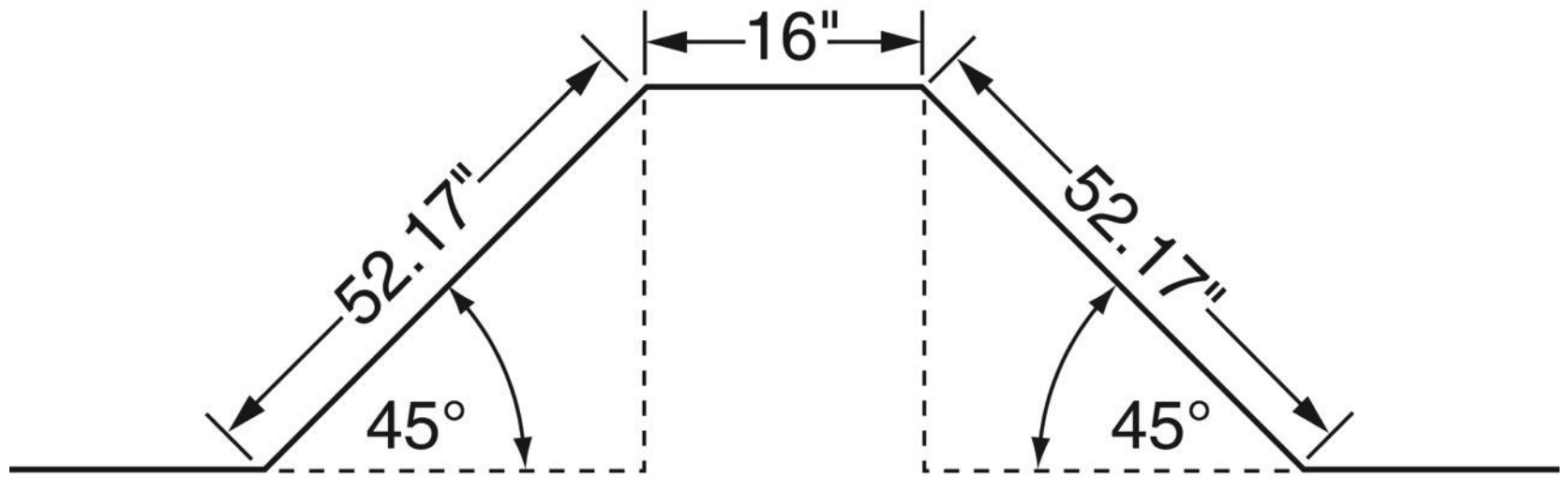


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9.3.1

Saddle

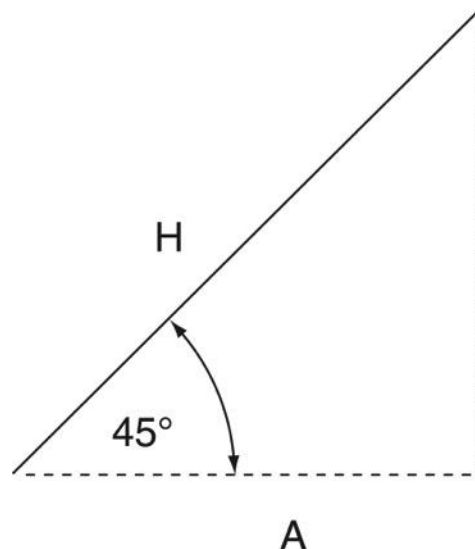


26204-14_F46.EPS

9.3.1

Cosine Function

- Subtract the length of the adjacent side from the hypotenuse measurement to find the amount of additional conduit required to make the bend.
- To calculate the length of the adjacent side, use the cosine formula (adjacent = cosine x hypotenuse).



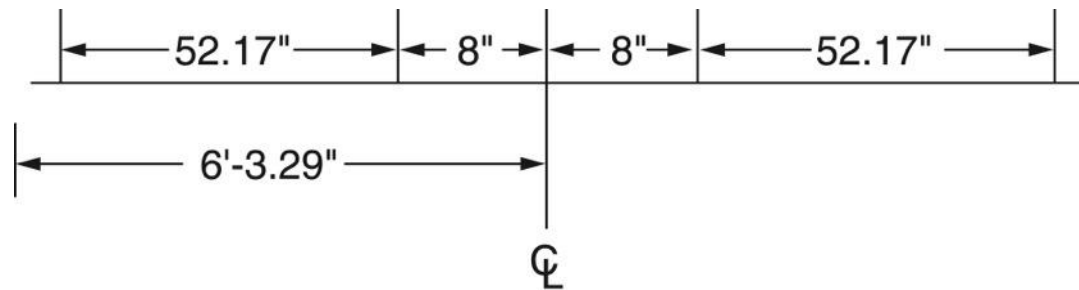
$H - A = \text{AMOUNT OF ADDITIONAL CONDUIT}$

9.3.1

Conduit Layout

To find the total amount of conduit required from the end of the existing conduit to the junction box, add the straight line distance of 15' to the difference between the hypotenuse and side adjacent two times:

$$15' + 15.29'' + 15.29'' = 17'6.58''$$



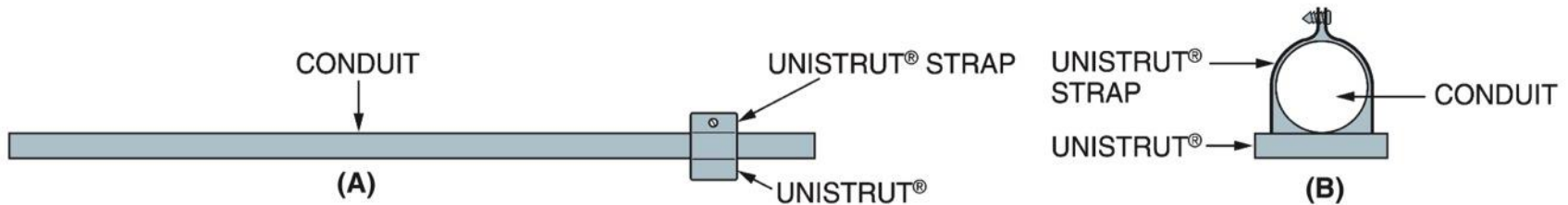
26204-14_F48.EPS

Performance Tasks

This session will conclude with trainees making offsets and saddle bends using a hydraulic bender.



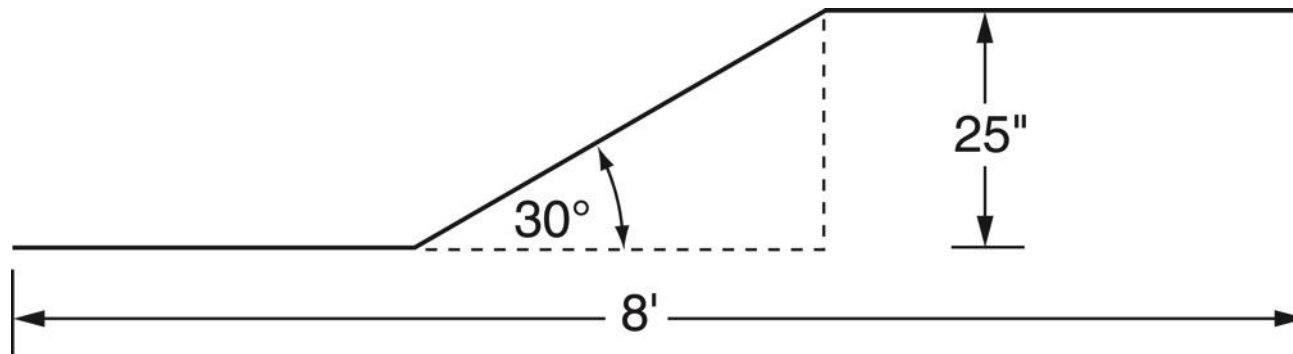
Tricks of the Trade



26204-14_F49.EPS

- A dog leg occurs when the conduit centerline is not maintained for both bends of an offset or for the four bends of a saddle.
- Doglegs can be avoided using an anti-dog device, which is a small setscrew clamp with a built-in level. A piece of Unistrut® can also be used to keep the conduit aligned properly during bending.

25" Offset

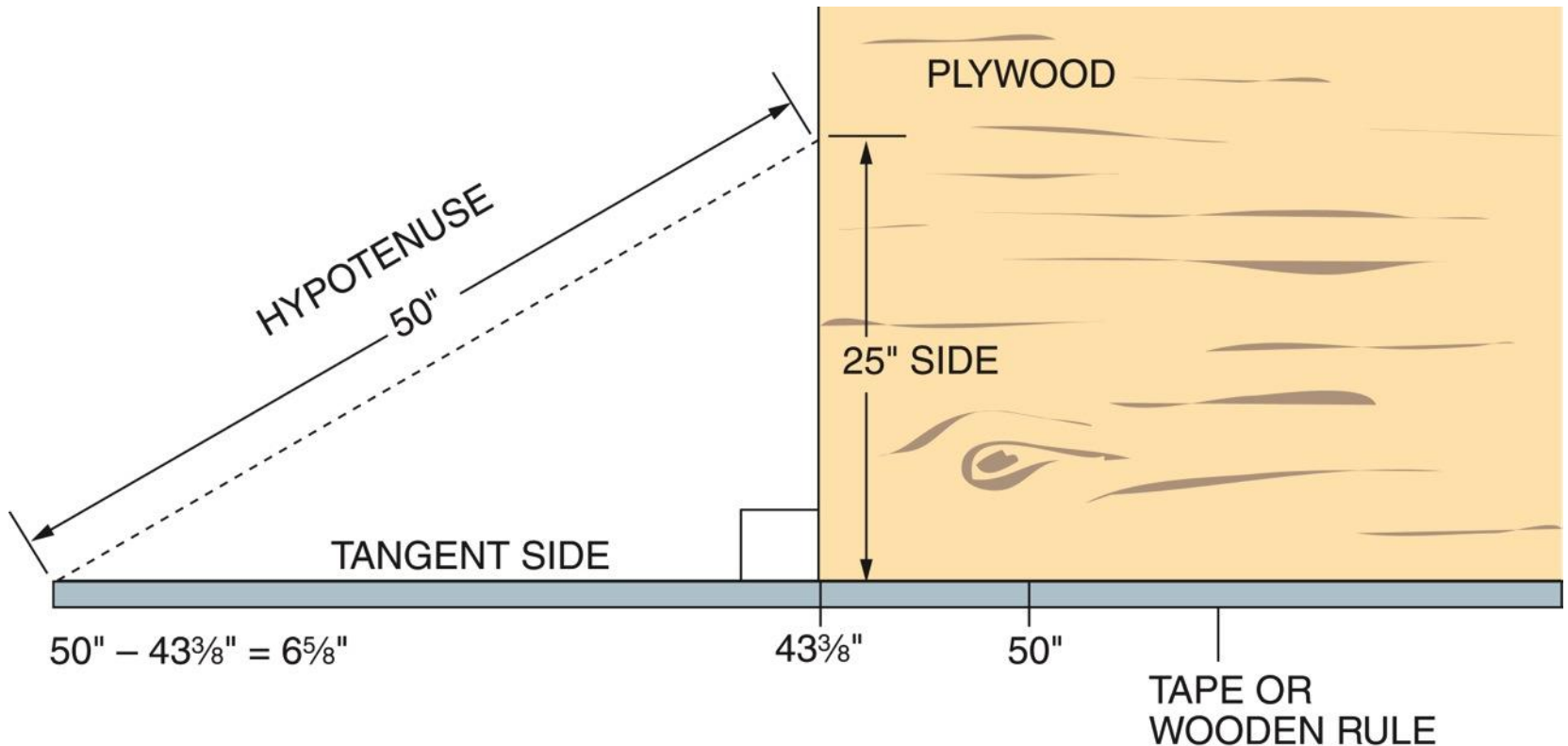


26204-14_F50.EPS

- A table corner or the corner of a sheet of plywood can be used to determine the amount of additional conduit needed to travel from one point to another after a bend has been made.
- Use the corner of the table/plywood to establish a right triangle, then use the cosecant formula to find the hypotenuse.

10.0.0 – 10.2.0

Extra Conduit



26204-14_F51.EPS



11.0.0 – 12.0.0

PVC Conduit Installations; Bending PVC Conduit

- PVC conduit is easily cut and joined in the field using a hacksaw or PVC cutters and solvent-cement.
- PVC heating units are used to make various bends in PVC conduit.

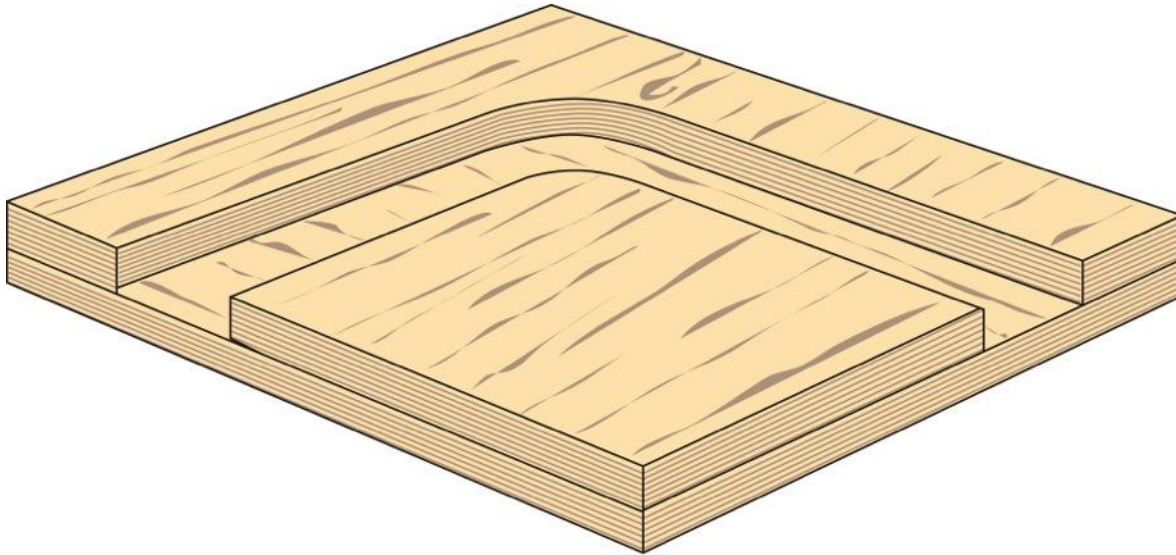


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Plywood Template

- If several identical bends are required, a plywood template can be fabricated.
- The heated conduit section is placed in the template and bent to the desired angle.

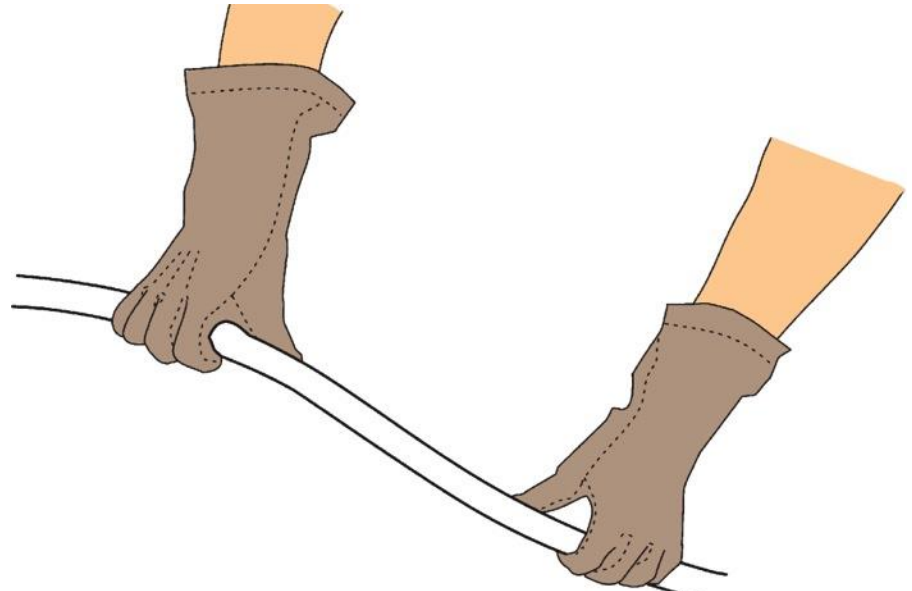


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11.0.0 – 12.0.0

Some PVC Bends May be Formed by Hand

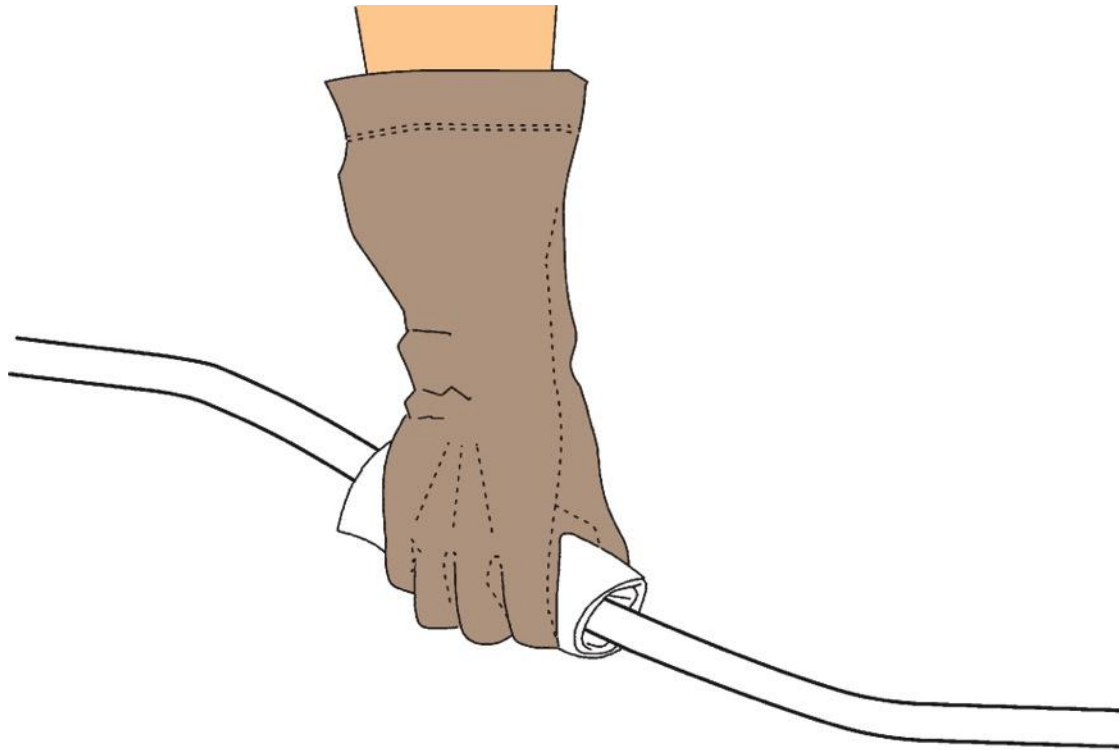
- Smaller PVC conduit can be heated and bent by hand to fit the installation.
- This method is useful for making blind bends or compound bends using smaller sizes of PVC.



26204-14_F54.EPS

11.0.0 – 12.0.0

After the Bend is Formed, Wipe a Wet Rag Over the Bend to Cool It



26204-14_F55.EPS

11.0.0 – 12.0.0

Typical Plug Set

- Place airtight plugs in each end of the conduit section before heating.
- Plugs prevent the conduit from flattening when making the bend.



26204-14_F56.EPS

11.0.0 – 12.0.0

Next Session... 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

Wrap Up



Wrap Up

3-2-1

- 3 – Write 3 important things learned during class
- 2 – Write 2 questions you have about the material
- 1 – Write 1 thought you had about the material



Next Session...

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.

