THE CIRCLE

Definition: A closed curve in a plane having every point an equal distance from a fixed point called the center.

Circumference:	The distance around a circle
Diameter:	The distance across a circle through the center
Radius:	The distance from the center to the edge of a circle
ARC:	A part of the circumference
Chord:	A straight line connecting the ends of an arc
Segment:	An area bounded by an arc and a chord
Sector:	A part of a circle enclosed by two radii and the arc that they cut off (like a slice of pie)

Circumference of a Circle = 3.1416 x 2 x radius

Area of a Circle = 3.1416 x radius^2

ARC Length = Degrees in arc x radius x 0.01745

Radius Length = One-half length of diameter

Sector Area = One-half length of arc x radius

Chord Length = 2 $\sqrt{A \times B}$

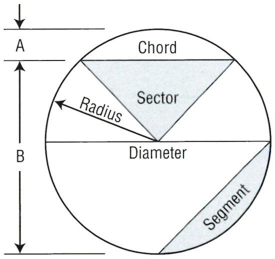
Segment Area = Sector area minus triangle area

Note:

3.1416 x 2 x R = 360°,
or 0.0087266 x 2 x R = 1°, or
0.01745 x R = 1°

This gives us the arc formula.

Degrees x Radius x 0.01745 = Developed Length



Example:

For a 90° conduit bend, having a radius of 17.25":

90 x 17.25" x 0.01745 = Developed Length

27.09" = Developed Length

FRACTIONS

Definitions

A. A fraction is a quantity less than a unit.

B. A numerator is the term of a fraction indicating how many of the parts of a unit are to be taken. In a common fraction, it appears above or to the left of the line.

C. A denominator is the term of a fraction indicating the number of equal parts into which the unit is divided. In a common fraction, it appears below or to the right of the line.

D. ***Examples:***

(1.) $\dfrac{\mathbf{1} \longrightarrow}{\mathbf{2} \longrightarrow} = \dfrac{\text{Numerator}}{\text{Denominator}} = \text{Fraction}$

(2.) Numerator $\longrightarrow$ **$^{1}/_{2}$** $\longleftarrow$ Denominator

To Add or Subtract

To solve: $^{1}/_{2} - {}^{2}/_{3} + {}^{3}/_{4} - {}^{5}/_{6} + {}^{7}/_{12} = ?$

A. Determine the lowest common denominator that each of the denominators 2, 3, 4, 6, and 12 will divide into an even number of times.

The lowest common denominator is 12.

B. Work one fraction at a time using the formula:

$$\frac{\textbf{Common Denominator}}{\textbf{Denominator of Fraction}} \quad \mathbf{x} \quad \textbf{Numerator of Fraction}$$

(1.) $^{12}/_{2}$ x 1 = 6 x 1 = 6	$^{1}/_{2}$ becomes $^{6}/_{12}$
(2.) $^{12}/_{3}$ x 2 = 4 x 2 = 8	$^{2}/_{3}$ becomes $^{8}/_{12}$
(3.) $^{12}/_{4}$ x 3 = 3 x 3 = 9	$^{3}/_{4}$ becomes $^{9}/_{12}$
(4.) $^{12}/_{6}$ x 5 = 2 x 5 = 10	$^{5}/_{6}$ becomes $^{10}/_{12}$
(5.) $^{7}/_{12}$ remains $^{7}/_{12}$	

FRACTIONS

To Add or Subtract (*continued*)

C. We can now convert the problem from its original form to its new form using 12 as the common denominator.

$1/2 - 2/3 + 3/4 - 5/6 + 7/12$ = Original form

$\frac{6 - 8 + 9 - 10 + 7}{12}$ = Present form

$\frac{4}{12} = \frac{1}{3}$ Reduced to lowest form

D. To convert fractions to decimal form, simply divide the numerator of the fraction by the denominator of the fraction.

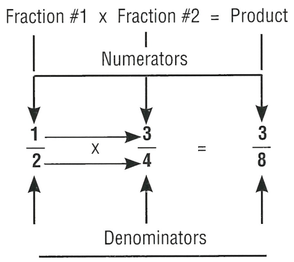
Example: $\frac{1}{3}$ = 1 Divided by 3 = 0.333

To Multiply

A. The numerator of fraction #1 times the numerator of fraction #2 is equal to the numerator of the product.

B. The denominator of fraction #1 times the denominator of fraction #2 is equal to the denominator of the product.

C. ***Example:***



Note: To change 3/8 to decimal form, divide 3 by 8 = 0.375

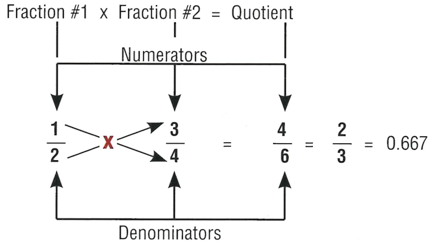
FRACTIONS

To Divide

A. The numerator of fraction #1 times the denominator of fraction #2 is equal to the numerator of the quotient.

B. The denominator of fraction #1 times the numerator of fraction #2 is equal to the denominator of the quotient.

C. ***Example:*** $\frac{1}{2} \div \frac{3}{4}$



D. An alternate method for dividing by a fraction is to multiply by the reciprocal of the divisor (the second fraction in a division problem).

E. ***Example:*** $\frac{1}{2} \div \frac{3}{4}$

The reciprocal of $\frac{3}{4}$ is $\frac{4}{3}$

so, $\frac{1}{2} \div \frac{3}{4} = \frac{1}{2} \times \frac{4}{3} = \frac{4}{6} = \frac{2}{3} = 0.667$

EQUATIONS

The word "Equation" means equal or the same as.

Example: $2 \times 10 = 4 \times 5$

$20 = 20$

Rules

A. The same number may be added to both sides of an equation without changing its values.

Example: $(2 \times 10) + 3 = (4 \times 5) + 3$

$23 = 23$

B. The same number may be subtracted from both sides of an equation without changing its values.

Example: $(2 \times 10) - 3 = (4 \times 5) - 3$

$17 = 17$

C. Both sides of an equation may be divided by the same number without changing its values.

Example: $$\frac{2 \times 10}{20} = \frac{4 \times 5}{20}$$

$1 = 1$

D. Both sides of an equation may be multiplied by the same number without changing its values.

Example: $3 \times (2 \times 10) = 3 \times (4 \times 5)$

$60 = 60$

E. Transposition:

The process of moving a quantity from one side of an equation to the other side of an equation by changing its sign of operation.

1. A term may be transposed if its sign is changed from plus (+) to minus (–), or from minus (–) to plus (+).

Example: $X + 5 = 25$

$X + 5 - 5 = 25 - 5$

$X = 20$

EQUATIONS

E. **Transposition *(continued)*:**

2. **A multiplier may be removed from one side of an equation by making it a divisor on the other side; or a divisor may be removed from one side of an equation by making it a multiplier on the other side.**

Example: Multiplier from one side of equation (4) becomes divisor on other side.

$$4X = 40 \text{ becomes } X = \frac{40}{4} = 10$$

Example: Divisor from one side of equation becomes multiplier on other side.

$$\frac{X}{4} = 10 \text{ becomes } X = 10 \times 4$$

Signs

A. **Addition** of numbers with *different* signs:

1. **Rule: Use the sign of the larger and subtract.**

Example:

$$\begin{array}{r} +3 \\ + -2 \\ \hline +1 \end{array} \qquad \begin{array}{r} -2 \\ + +3 \\ \hline +1 \end{array}$$

B. **Addition** of numbers with the *same* signs:

2. **Rule: Use the common sign and add.**

Example:

$$\begin{array}{r} +3 \\ + +2 \\ \hline +5 \end{array} \qquad \begin{array}{r} -3 \\ + -2 \\ \hline -5 \end{array}$$

C. **Subtraction** of numbers with *different* signs:

3. **Rule: Change the sign of the subtrahend (the second number in a subtraction problem) and proceed as in addition.**

Example:

$$\begin{array}{r} +3 \\ - -2 \\ \hline \end{array} = \begin{array}{r} +3 \\ + +2 \\ \hline +5 \end{array} \qquad \begin{array}{r} -2 \\ - +3 \\ \hline \end{array} = \begin{array}{r} -2 \\ + -3 \\ \hline -5 \end{array}$$

EQUATIONS

Signs *(continued)*

D. **Subtraction** of numbers with the *same* signs:

4. **Rule: Change the sign of the subtrahend (the second number in a subtraction problem) and proceed as in addition.**

Example:

$$\begin{array}{r} +3 \\ -\ +2 \\ \hline \end{array} = \begin{array}{r} +3 \\ +\ -2 \\ \hline +1 \end{array} \qquad \begin{array}{r} -3 \\ -\ -2 \\ \hline \end{array} = \begin{array}{r} -3 \\ +\ +2 \\ \hline -1 \end{array}$$

E. **Multiplication:**

5. **Rule: The product of any two numbers having like signs is positive. The product of any two numbers having unlike signs is negative.**

Example:

$(+3) \times (-2) = -6$

$(-3) \times (+2) = -6$

$(+3) \times (+2) = +6$

$(-3) \times (-2) = +6$

F. **Division:**

6. **Rule: If the divisor and the dividend have like signs, the sign of the quotient is positive. If the divisor and dividend have unlike signs, the sign of the quotient is negative.**

Example:

$\frac{+6}{-2} = -3$ $\qquad\qquad$ $\frac{+6}{+2} = +3$

$\frac{-6}{+2} = -3$ $\qquad\qquad$ $\frac{-6}{-2} = +3$

NATURAL TRIGONOMETRIC FUNCTIONS

Angle	Sine	Cosine	Tangent	Cotangent	Secant	Cosecant	
0	.0000	1.0000	.0000		1.0000		90
1	.0175	.9998	.0175	57.2900	1.0002	57.2987	89
2	.0349	.9994	.0349	28.6363	1.0006	28.6537	88
3	.0523	.9986	.0524	19.0811	1.0014	19.1073	87
4	.0698	.9976	.0699	14.3007	1.0024	14.3356	86
5	.0872	.9962	.0875	11.4301	1.0038	11.4737	85
6	.1045	.9945	.1051	9.5144	1.0055	9.5668	84
7	.1219	.9925	.1228	8.1443	1.0075	8.2055	83
8	.1392	.9903	.1405	7.1154	1.0098	7.1853	82
9	.1564	.9877	.1584	6.3138	1.0125	6.3925	81
10	.1736	.9848	.1763	5.6713	1.0154	5.7588	80
11	.1908	.9816	.1944	5.1446	1.0187	5.2408	79
12	.2079	.9781	.2126	4.7046	1.0223	4.8097	78
13	.2250	.9744	.2309	4.3315	1.0263	4.4454	77
14	.2419	.9703	.2493	4.0108	1.0306	4.1336	76
15	.2588	.9659	.2679	3.7321	1.0353	3.8637	75
16	.2756	.9613	.2867	3.4874	1.0403	3.6280	74
17	.2924	.9563	.3057	3.2709	1.0457	3.4203	73
18	.3090	.9511	.3249	3.0777	1.0515	3.2361	72
19	.3256	.9455	.3443	2.9042	1.0576	3.0716	71
20	.3420	.9397	.3640	2.7475	1.0642	2.9238	70
21	.3584	.9336	.3839	2.6051	1.0711	2.7904	69
22	.3746	.9272	.4040	2.4751	1.0785	2.6695	68
23	.3907	.9205	.4245	2.3559	1.0864	2.5593	67
24	.4067	.9135	.4452	2.2460	1.0946	2.4586	66
25	.4226	.9063	.4663	2.1445	1.1034	2.3662	65
26	.4384	.8988	.4877	2.0503	1.1126	2.2812	64
27	.4540	.8910	.5095	1.9626	1.1223	2.2027	63
	Cosine	**Sine**	**Cotangt.**	**Tangent**	**Cosecant**	**Secant**	**Angle**

(*continued on next page*)

NATURAL TRIGONOMETRIC FUNCTIONS

Angle	Sine	Cosine	Tangent	Cotangent	Secant	Cosecant	
28	.4695	.8829	.5317	1.8807	1.1326	2.1301	62
29	.4848	.8746	.5543	1.8040	1.1434	2.0627	61
30	.5000	.8660	.5774	1.7321	1.1547	2.0000	60
31	.5150	.8572	.6009	1.6643	1.1666	1.9416	59
32	.5299	.8480	.6249	1.6003	1.1792	1.8871	58
33	.5446	.8387	.6494	1.5399	1.1924	1.8361	57
34	.5592	.8290	.6745	1.4826	1.2062	1.7883	56
35	.5736	.8192	.7002	1.4281	1.2208	1.7434	55
36	.5878	.8090	.7265	1.3764	1.2361	1.7013	54
37	.6018	.7986	.7536	1.3270	1.2521	1.6616	53
38	.6157	.7880	.7813	1.2799	1.2690	1.6243	52
39	.6293	.7771	.8098	1.2349	1.2868	1.5890	51
40	.6428	.7660	.8391	1.1918	1.3054	1.5557	50
41	.6561	.7547	.8693	1.1504	1.3250	1.5243	49
42	.6691	.7431	.9004	1.1106	1.3456	1.4945	48
43	.6820	.7314	.9325	1.0724	1.3673	1.4663	47
44	.6947	.7193	.9657	1.0355	1.3902	1.4396	46
45	.7071	.7071	1.0000	1.0000	1.4142	1.4142	45
	Cosine	**Sine**	**Cotangt.**	**Tangent**	**Cosecant**	**Secant**	**Angle**

Note: For angles 0–45, use top row and left column.

For angles 45–90, use bottom row and right column.

TRIGONOMETRY

Trigonometry is the mathematics dealing with the relations of sides and angles of triangles.

A **triangle** is a figure enclosed by three straight sides. The sum of the three angles is 180°. All triangles have six parts: three angles and three sides opposite the angles.

Right triangles are triangles that have one angle of 90° and two angles of less than 90°.

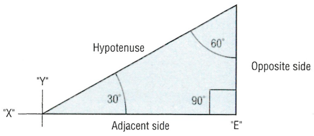
To help you remember the six trigonometric functions, memorize:

"Oh Hell Another Hour of Andy"

$$\text{Sine}\quad \Theta = \frac{\overset{(\text{Oh})}{\text{Opposite side}}}{\underset{(\text{Hell})}{\text{Hypotenuse}}}$$

$$\text{Cosine}\quad \Theta = \frac{\overset{(\text{Another})}{\text{Adjacent side}}}{\underset{(\text{Hour})}{\text{Hypotenuse}}}$$

$$\text{Tangent}\quad \Theta = \frac{\overset{(\text{Of})}{\text{Opposite side}}}{\underset{(\text{Andy})}{\text{Adjacent side}}}$$



Now, use backward: **"Andy of Hour Another Hell Oh"**

$$\text{Cotangent}\quad \theta = \frac{\overset{(\text{Andy})}{\text{Adjacent side}}}{\underset{(\text{Of})}{\text{Opposite side}}}$$

Always place the angle to be solved at the vertex (where "X" and "Y" cross).

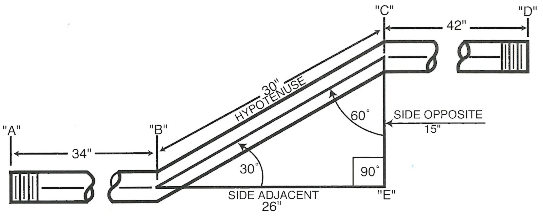
$$\text{Secant}\quad \theta = \frac{\overset{(\text{Hour})}{\text{Hypotenuse}}}{\underset{(\text{Another})}{\text{Adjacent side}}}$$

$$\text{Cosecant}\quad \theta = \frac{\overset{(\text{Hell})}{\text{Hypotenuse}}}{\underset{(\text{Oh})}{\text{Opposite side}}}$$

Note:

θ = Theta = Any Angle

BENDING OFFSETS WITH TRIGONOMETRY



The Cosecant of the Angle Times the Offset Desired Is Equal to the Distance Between the Centers of the Bends.

Example

To make a fifteen inch (15") offset, using thirty (30) degree bends:

1. Use Trig. Table (pages 158–159) to find the Cosecant of a thirty (30) degree angle. We find it to be two (2).
2. Multiply two (2) times the offset desired, which is fifteen (15) inches to determine the distance between bend "B" and bend "C." The answer is thirty (30) inches.

To mark the conduit for bending:

1. Measure from end of Conduit "A" thirty-four (34) inches to center of first bend "B," and mark.
2. Measure from mark "B" thirty (30) inches to center of second bend "C" and mark.
3. Measure from mark "C" forty-two (42) inches to "D," and mark. Cut, ream, and thread conduit before bending.

Rolling Offsets

To determine how much offset is needed to make a rolling offset:

1. Measure vertical required. Use work table (any square will do) and measure from corner this amount and mark.
2. Measure horizontal required. Measure 90° from the vertical line measurement (starting in same corner) and mark.
3. The diagonal distance between these marks will be the amount of offset required.

Note: Shrink is hypotenuse minus the side adjacent.

ONE SHOT BENDS

Shrink constant for angles less than 60° = Angle/120

Example: The shrink constant for 45° is 3/8"

45/120 = 3/8"

Shrink constant for 60° to 90° angles = Angle/100

Example: The shrink constant for 45° is 3/8"

45/100 = 3/8"

Multiplier = (60/Angle) + (Angle/200) - 0.15

Example: The multiplier for 50° is 1.3.

(60/50) + (50/200) - 0.15 = 1.3

The calculation for this multiplier is an error of less than half a percent.

Bend length = (Angle x D)/60

Example: If putting a 40° bend in 3/4" conduit, the bend length is 4".

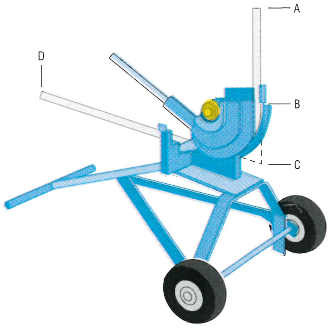
(40 x 6")/60 = 4"

"D" is the deduct for whatever size conduit is being run. This formula works for any angle between 0° and 90°.

Note: With these formulas, the entire run in pieces (straight and curved) can be seen, including exactly where each piece starts and where it ends. This allows the bender direction (hook facing east or west) to be chosen at each point in the run, and bend marks can be laid out accordingly.

CHICAGO-TYPE BENDERS: 90° BENDING

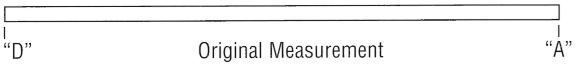
"A" to "C" = Stub-Up
"C" to "D" = Tail
"C" = Back of Stub-Up
"C" = Bottom of Conduit



Note:
There are many variations of this type bender, but most manufacturers offer two sizes.
The *small* size shoe takes 1/2," 3/4," and 1" conduit.
The *large* size shoe takes $1^1/_4$" and $1^1/_2$" conduit.

To determine the "take-up" and "shrink" of each size conduit for a particular bender to make 90° bends:

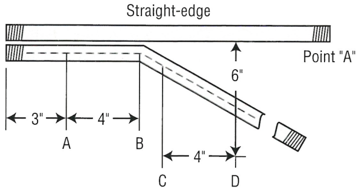
1. Use a straight piece of scrap conduit.
2. Measure exact length of scrap conduit, "A" to "D."



3. Place conduit in bender. Mark at edge of shoe, "B."
4. Level conduit. Bend ninety, and count number of pumps. Be sure to keep notes on each size conduit used.
5. After bending ninety:
   - A. Distance between "B" and "C" is the take-up.
   - B. Original measurement of the scrap piece of conduit subtracted from (distance "A" to "C" plus distance "C" to "D") is the shrink.

Note: Both time and energy will be saved if conduit can be cut, reamed, and threaded before bending. The same method can be used on hydraulic benders.

CHICAGO-TYPE BENDERS: OFFSETS




Chicago-Type Bender

Example:

To bend a 6" offset:

1. Make a mark 3" from conduit end. Place conduit in bender with mark at outside edge of jaw.
2. Make three full pumps, making sure handle goes all the way down to the stop.
3. Remove conduit from bender and place alongside straight-edge.
4. Measure 6" from straight-edge to center of conduit. Mark point "D." Use square for accuracy.
5. Mark center of conduit from both directions through bend as shown by broken line. Where lines intersect is point "B."
6. Measure from "A" to "B" to determine the distance from "D" to "C." Mark "C" and place conduit in bender with mark at the outside edge of jaw, and with the kick pointing down. Use a level to prevent dogging conduit.
7. Make three full pumps, making sure handle goes all the way down to the stop.

Note: 1. There are several methods of bending rigid conduit with a Chicago-type bender, and any method that gets the job done in a minimal amount of time with craftsmanship is acceptable.
2. Whatever method is used, quality will improve with experience.

MULTI-SHOT: 90° CONDUIT BENDING

Problem:

A. To measure, thread, cut, and ream conduit before bending.

B. To accurately bend conduit to the desired height of the stub-up (H) and to the desired length of the tail (L).

Given:

A. Size of conduit = 2"

B. Space between conduit (center to center) = 6"

C. Height of stub-up = 36"

D. Length of tail = 48"

Solution:

A. To Determine Radius (R):

Conduit #1 (inside conduit) will use the minimum radius unless otherwise specified. The minimum radius is eight times the size of the conduit. (See page 167).

Radius of Conduit #1 = 8 x 2" + 1.25" = 17.25"
Radius of Conduit #2 = RADIUS #1 + 6" = 23.25"
Radius of Conduit #3 = RADIUS #2 + 6" = 29.25"

B. To Determine Developed Length (DL):

Radius x 1.57 = DL
DL of Conduit #1 = R x 1.57 = 17.25" x 1.57 = 27"
DL of Conduit #2 = R x 1.57 = 23.25" x 1.57 = 36.5"
DL of Conduit #3 = R x 1.57 = 29.25" x 1.57 = 46"

C. To Determine Length of Nipple:

Length of Nipple, Conduit #1 = L + H + DL – 2R
= 48" + 36" + 27" – 34.5"
= 76.5"

Length of Nipple, Conduit #2 = L + H + DL – 2R
= 54" + 42" + 36.5" – 46.5"
= 86"

Length of Nipple, Conduit #3 = L + H + DL – 2R
= 60" + 48" + 46" – 58.5"
= 95.5"

Notes: 1. For 90° bends, shrink = 2R – DL
2. For offset bends, shrink = Hypotenuse – Side Adjacent

MULTI-SHOT: 90° CONDUIT BENDING

Layout and Bending:

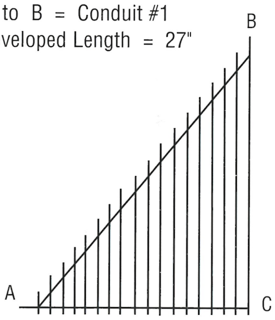
A. To locate point "B," measure from point "A," the length of the stub-up minus the radius. On all three conduit, point "B" will be 18.75" from point "A." (See page 167.)

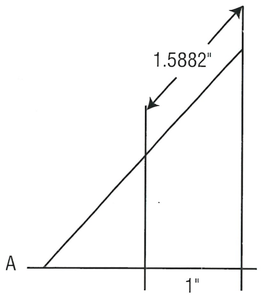
B. To locate point "C," measure from point "D," the length minus the radius, (see page 164). On all three conduit, point "C" will be 30.75" from point "D." (See page 167.)

C. Divide the developed length (point "B" to point "C") into equal spaces. Spaces should not be more than 1.75" to prevent wrinkling of the conduit. On Conduit #1, 17 spaces of 1.5882" each would give us 18 shots of 5° each. Remember there is always one less space than shot. When determining the number of shots, choose a number that will divide into 90 an even number of times.

D. If an elastic numbered tape is not available, try the method illustrated.

A to B = Conduit #1
Developed Length = 27"



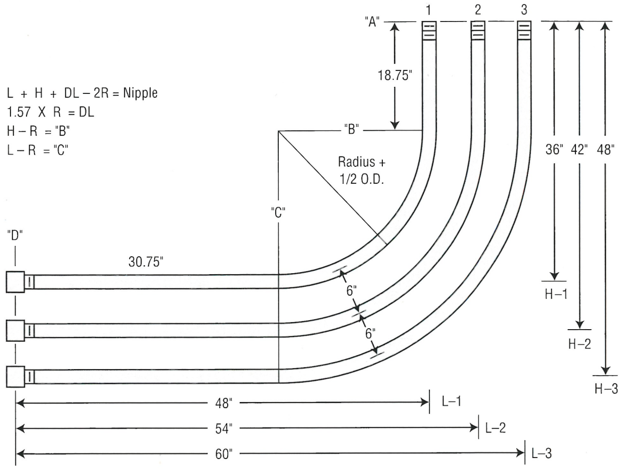


A to C = 17 1" spaces
A to B = 17 1.5882" spaces
C = table or plywood corner

Measure from Point "C" (table corner) 17 inches along table edge to Point "A" and mark. Place end of rule at Point "A." Point "B" will be located where 27" mark meets table edge B–C. Mark on board, then transfer to conduit.

MULTI-SHOT: 90° CONDUIT BENDING

L + H + DL – 2R = Nipple
1.57 X R = DL
H – R = "B"
L – R = "C"



To Locate Point "B"					To Locate Point "C"				
H#1	-	Radius #1	=	"B"	L#1	-	Radius #1	=	"C"
36"	-	17.25"	=	"B"	48"	-	17.25"	=	"C"
		18.75"	=	"B"			30.75"	=	"C"
H#2	-	Radius #2	=	"B"	L#2	-	Radius #2	=	"C"
42"	-	23.25"	=	"B"	54"	-	23.25"	=	"C"
		18.75"	=	"B"			30.75"	=	"C"
H#3	-	Radius #3	=	"B"	L#3	-	Radius #3	=	"C"
48"	-	29.25"	=	"B"	60"	-	29.25"	=	"C"
		18.75"	=	"B"			30.75"	=	"C"

Points "B" and "C" are the same distance from the end on all three conduits.

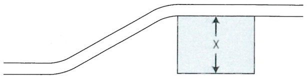
OFFSET BENDS

EMT: Using Hand Bender

An offset bend is used to change the level, or plane, of the conduit. This is usually necessitated by the presence of an obstruction in the original conduit path.

Step One:

Determine the offset depth (X).

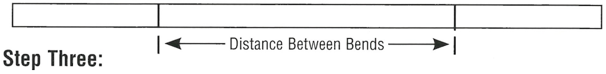


Step Two:

Multiply the offset depth X, the multiplier for the degree of bend used to determine the distance between bends.

Angle		Multiplier
10˚ x 10˚	=	6
22½˚ x 22½˚	=	2.6
30˚ x 30˚	=	2
45˚ x 45˚	=	1.4
60˚ x 60˚	=	1.2

Example: If the offset depth required (X) is 6", and you intend to use 30˚ bends, the distance between bends is 6" x 2 = 12".

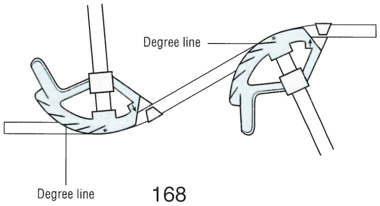


Step Three:

Mark at the appropriate points, align the arrow on the bender with the first mark, and bend to desired degree by aligning EMT with chosen degree line on bender.

Step Four:

Slide down the EMT, align the arrow with the second mark, and bend to the same degree line. Be sure to note the orientation of the bender head. Check alignment.



90° BENDS

EMT: Using Hand Bender

The stub-up is the most common bend.

Step One:

Determine the height of the stub-up required and mark on EMT.

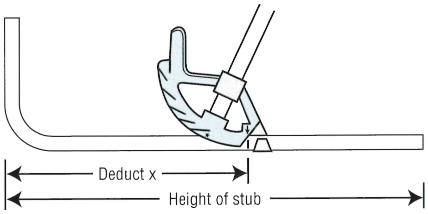
Step Two:

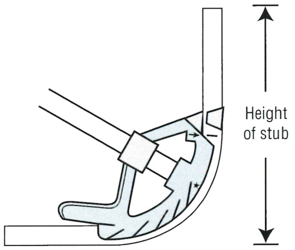
Find the "Deduct" or "Take-up" amount from the Take-Up Chart. Subtract the take-up amount from the stub height and mark the EMT that distance from the end.

Step Three:

Align the arrow on bender with the last mark made on the EMT, and bend to the 90˚ mark on the bender.

Description		Take-Up
½" EMT	=	5"
¾" EMT	=	6"
1" EMT	=	8"
1¼" EMT	=	11"





BACK-TO-BACK BENDS

EMT: Using Hand Bender

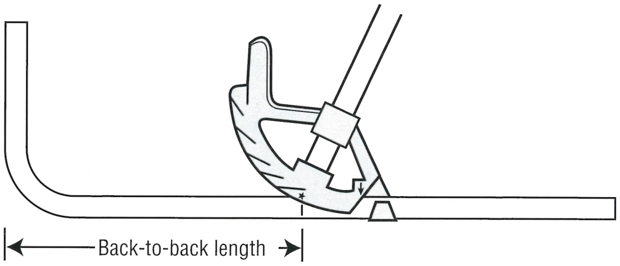
A back-to-back bend results in a "U" shape in a length of conduit. It's used for a conduit that runs along the floor or ceiling and turns up or down a wall.

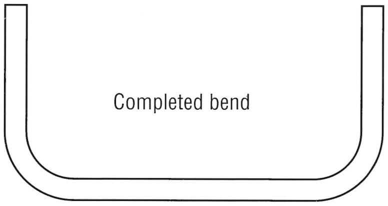
Step One:

After the first 90° bend is made, determine the back-to-back length and mark on EMT.

Step Two:

Align this back-to-back mark with the star mark on the bender, and bend to 90°.





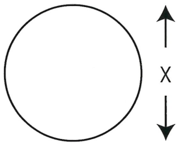
THREE-POINT SADDLE BENDS

EMT: Using Hand Bender

The 3-point saddle bend is used when encountering an obstacle (usually another pipe).

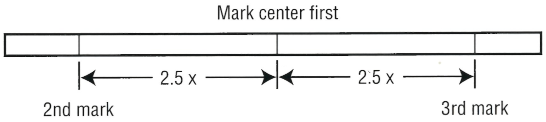
Step One:

Measure the height of the obstruction.
Mark the center point on EMT.



Step Two:

Multiply the height of the obstruction by 2.5 and mark this distance on each side of the center mark.



Step Three:

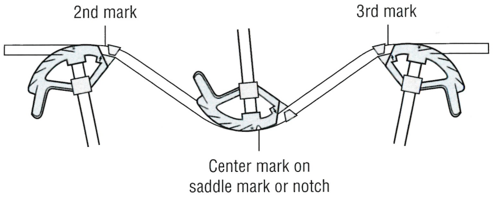
Place the center mark on the saddle mark or notch. Bend to 45°.

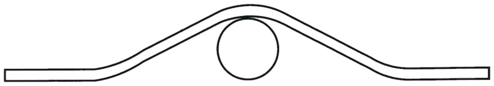
Step Four:

Bend the second mark to 22½° angle at arrow.

Step Five:

Bend the third mark to 22½° angle at arrow. Be aware of the orientation of the EMT on all bends. Check alignment.





PULLEY CALCULATIONS

The most common configuration consists of a motor with a pulley attached to its shaft, connected by a belt to a second pulley. The motor pulley is referred to as the **Driving Pulley**. The second pulley is called the **Driven Pulley**. The speed at which the Driven Pulley turns is determined by the speed at which the Driving Pulley turns as well as the diameters of both pulleys. The following formulas may be used to determine the relationships between the motor, pulley diameters, and pulley speeds.

D = Diameter of Driving Pulley
d^1 = Diameter of Driven Pulley
S = Speed of Driving Pulley (revolutions per minute)
s^1 = Speed of Driven Pulley (revolutions per minute)

- *To determine the speed of the Driven Pulley (Driven RPM):*

$$s^1 = \frac{D \times S}{d^1} \quad \text{or} \quad \text{Driven RPM} = \frac{\text{Driving Pulley Dia. x Driving RPM}}{\text{Driven Pulley Dia.}}$$

- *To determine the speed of the Driving Pulley (Driving RPM):*

$$S = \frac{d^1 \times s^1}{D} \quad \text{or} \quad \text{Driving RPM} = \frac{\text{Driven Pulley Dia. x Driven RPM}}{\text{Driving Pulley Dia.}}$$

- *To determine the diameter of the Driven Pulley (Driven Dia.):*

$$d^1 = \frac{D \times S}{s^1} \quad \text{or} \quad \text{Driven Dia.} = \frac{\text{Driving Pulley Dia. x Driving RPM}}{\text{Driven RPM}}$$

- *To determine the diameter of the Driving Pulley (Driving Dia.):*

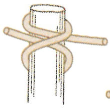
$$D = \frac{d^1 \times s^1}{S} \quad \text{or} \quad \text{Driving Dia.} = \frac{\text{Driven Pulley Dia. x Driven RPM}}{\text{Driving RPM}}$$

USEFUL KNOTS

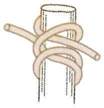

Bowline


Running bowline


Bowline on the bight

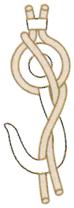

Clove hitch

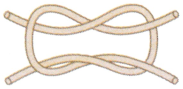

Sheep shank

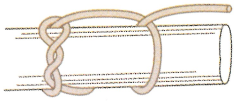

Rolling hitch

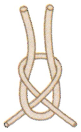

Single blackwall hitch


Catspaw


Double blackwall hitch


Square knot


Timber hitch with half hitch


Single sheet bend

HAND SIGNALS


Stop


Dog everything


Emergency stop


Travel


Travel both tracks (crawler cranes only)


Travel one track (crawlers)


Retract boom


Extend boom


Swing boom

HAND SIGNALS

Raise load

Lower load

Main hoist

Move
slowly

Raise boom
and lower load
(flex fingers)

Lower boom
and raise load
(flex fingers)

Use
whip line

Boom up

Boom
down

ELECTRICAL SAFETY DEFINITIONS

Note: Some NFPA 70E *definitions include informational notes, which are shown below. Comments shown in italics under some definitions are additional explanations that do not appear in* NFPA 70E.

Arc-Flash Hazard: A source of possible injury or damage to health associated with the possible release of energy caused by an electric arc.

Informational Note No. 1: See 110.2(B) Exception No. 1 for further information regarding normal operation. The likelihood of occurrence of an arc flash incident increases when energized electrical conductors or circuit parts are exposed or when they are within equipment in a guarded or enclosed condition, provided a person is interacting with the equipment in such a manner that could cause an electric arc. An arc flash incident is not likely to occur under normal operating conditions when enclosed energized equipment has been properly installed and maintained.

Boundary, Arc Flash: When an arc flash hazard exists, an approach limit from an arc source at which incident energy equals 1.2 cal/cm^2 (5 J/cm^2).

Boundary, Limited Approach: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which an electric shock hazard exists.

Boundary, Restricted Approach: An approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement.

De-energized: Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.

Comment: This is a key concept of NFPA 70E. *The safest way to work on electrical conductors and equipment is de-energized. See* Electrically Safe Work Condition.

Electrical Hazard: A dangerous condition such that contact or equipment failure can result in electrical shock, arc-flash burn, thermal burn, or arc-blast injury.

Electrical Safety: Identifying hazards associated with the use of electrical energy and taking precautions to reduce the risk associated with those hazards.

ELECTRICAL SAFETY DEFINITIONS

Note: Some NFPA 70E *definitions include informational notes, which are shown below. Comments shown in italics under some definitions are additional explanations that do not appear in* NFPA 70E.

Electrically Safe Work Condition: A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested for the absence of voltage, and, if necessary, temporarily grounded for personnel protection.

Comment: This is a key concept of NFPA 70E. The safest way to work on electrical conductors and equipment is de-energized. The process of turning off the electricity, verifying that it is off, and ensuring that it stays off while work is performed is called "establishing an electrically safe work condition." Many people call the process of ensuring that the current is removed "lockout/tagout"; however, lockout/tagout is only one step in the process.

Energized: Electrically connected to, or is, a source of voltage.

Incident Energy: The amount of thermal energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. Incident energy is typically expressed in calories per square centimeter (cal/cm^2).

Qualified Person: One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.

Comment: A person can be considered qualified with respect to certain equipment and methods, but still be unqualified for others. Holding a license or "having done it before" does not make a person qualified. The individual must meet the NFPA 70E definition of qualified person *for the specific task being performed.*

Working Distance: The distance between a person's face and chest area and a prospective arc source.

Informational Note: See 130.5(G) in NFPA 70E for further information. Incident energy increases as the distance from the arc source decreases.

WHO IS RESPONSIBLE FOR ELECTRICAL SAFETY?

NFPA 70E, like OSHA, states that both employers and employees are responsible for preventing injury.

- Employers shall provide safety-related work practices and shall train the employees.
- Employees shall implement the safety-related work practices established.
- Multiple employers often work together on the same construction site or in buildings and similar facilities. Some might be onsite personnel working for the host employer, while others are "outside" personnel such as electrical contractors, mechanical and plumbing contractors, painters, or cleaning crews. Outside personnel working for the host employer are employees of contract employers.
- NFPA 70E requires that when a host employer and contract employer work together within the limited approach boundary or the arc-flash boundary of exposed energized electrical conductors or circuit parts, they must coordinate their safety procedures.
- Where the host employer has knowledge of hazards covered by NFPA 70E that are related to the contract employer's work, there shall be a documented meeting between the host employer and the contract employer.
- Outside contractors often are required to follow the host employer's safety procedures.
- Multiple employers involved in the same project sometimes decide to follow the most stringent set of safety procedures.
- Whichever approach is taken, the decision should be recorded in the safety meeting documentation. In accordance with NFPA 70E, where the host employer has knowledge of hazards covered by NFPA 70E that are related to the contract employer's work, there shall be a documented meeting between the host employer and the contract employer.

LOCKOUT–TAGOUT AND ELECTRICALLY SAFE WORK CONDITION

The term lockout/tagout refers to specific practices and procedures to safeguard employees from the unexpected energization or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities. OSHA and NFPA 70E address the control of hazardous energy during service or maintenance of machines or equipment.

OSHA's standard for The Control of Hazardous Energy (Lockout/Tagout), found in Title 29 of the Code of Federal Regulations (CFR) Part 1910.147, addresses the practices and procedures necessary to disable machinery or equipment, thereby preventing the release of hazardous energy while employees perform servicing and maintenance activities. Other OSHA standards, such as 29 CFR 1910.269 and 1910.333 also contain energy control provisions.

Article 120 in NFPA 70E contains requirements for lockout/tagout as well as procedures for establishing and verifying an electrically safe work condition.

Establishing and verifying an electrically safe work condition shall include all of the following steps, which shall be performed in the order presented, if feasible:

1. Identify the power sources.
2. Disconnect power sources.
3. If possible, visually verify that power is disconnected.
4. Release stored electrical energy.
5. Block or relieve stored nonelectrical energy.
6. Apply lockout/tagout devices.
7. Test for the absence of voltage.
8. Install temporary protective grounding equipment if there is a possibility of induced voltages or stored electrical energy (where applicable).

ELECTRICAL SAFETY: SHOCK PROTECTION BOUNDARIES

130.4(E)(a) Approach Boundaries for Electric Shock Protection, Alternating-Current Systems

Phase-to-Phase Voltage	Limited Approach Boundary Movable	Limited Approach Boundary Fixed	Restricted Approach Boundary
Less than 50	Not specified	Not specified	Not specified
50–150*	10 ft	3 ft 6 in.	Avoid contact
151–750	10 ft	3 ft 6 in.	1 ft
751–5000	10 ft	3 ft 6 in.	2 ft 1 in.
5001–15000	10 ft	5 ft	2 ft 2 in.
15001–36000	10 ft	6 ft	2 ft 7 in.
36001–46000	10 ft	8 ft	2 ft 10 in.
46001–72500	10 ft	8 ft	3 ft 4 in.
72600–121000	10 ft 8 in.	8 ft	3 ft 9 in.

* This includes circuits where the exposure does not exceed 120 volts nominal.

Adapted from NFPA 70E®, *Standard for Electrical Safety in the Workplace*®, Table 130.4(E)(a) with permission from National Fire Protection Association, Quincy, MA 02169. This reprinted material is not the complete and official position of the NFPA or the referenced subject, which is represented only by the standard in its entirety.

Where approaching personnel are exposed to energized electrical conductors or circuit parts, the approach boundaries are as follows:

- **Limited Approach Boundary:** This boundary is an approach limit at a distance from an exposed energized electrical conductor or circuit part within which an electric shock hazard exists. This boundary is larger for movable conductors than for fixed circuit parts.
- **Restricted Approach Boundary:** This boundary is an approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc-over combined with inadvertent movement. It allows for the fact that a person's hand or tool might slip, or someone else might jostle the worker from behind.

INFORMATION USUALLY FOUND ON AN ARC-FLASH EQUIPMENT LABEL

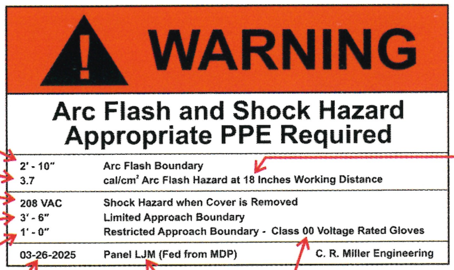
(Courtesy of Charles R. Miller)

Electrical equipment such as switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling units, and are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field marked with a label containing the information in NFPA 70E, 130.5(H).

The available incident energy at the working distance. Instead of the available incident energy and the corresponding working distance, the arc-flash PPE category could have been on this label. See NFPA 70E, 130.5(H).

When an arc flash hazard exists, this is the distance from an arc source at which incident energy equals 1.2 cal/cm^2. The onset of a second-degree burn is assumed to be when the skin receives 1.2 cal/cm^2 of incident energy.

When incident energy is on the label, it is based on a working distance so the working distance has to be on the label as well.



WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

2' - 10"	Arc Flash Boundary
3.7	cal/cm^2 Arc Flash Hazard at 18 Inches Working Distance
208 VAC	Shock Hazard when Cover is Removed
3' - 6"	Limited Approach Boundary
1' - 0"	Restricted Approach Boundary - Class 00 Voltage Rated Gloves
03-26-2025	Panel LJM (Fed from MDP) C. R. Miller Engineering

Date the incident-energy analysis (arc-flash analysis) was performed.

Class of voltage-rated glove. The maximum use voltage (ac) for a Class 00 insulated rubber glove is 500 volts.

Closest of the two shock boundaries. Shock boundaries are determined by nominal system voltage measured phase-to-phase.

Identification or name of the equipment.

Farthest of the two shock boundaries. See NFPA Table 130.4(E)(a).

Nominal system voltage at the equipment.

ELECTRICAL SAFETY: PERSONAL PROTECTION EQUIPMENT GUIDE

Required Personal Protective Equipment (PPE)

PPE Category	PPE
1	**Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm^2** (16.75 J/cm^2)[a] Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated face shield[b] or arc flash suit hood Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d] Leather footwear[e] (AN)
2	**Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm^2** (33.5 J/cm^2)[a] Arc-rated long-sleeve shirt and pants or arc-rated coverall Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Heavy-duty leather gloves, arc-rated gloves, or rubber insulating gloves with protectors (SR)[d] Leather footwear[e]
3	**Arc-Rated Clothing Selected So That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm^2** (104.7 J/cm^2)[a] Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves or rubber insulating gloves with protectors (SR)[d] Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Leather footwear[e]

(continued on next page)

ELECTRICAL SAFETY: PERSONAL PROTECTION EQUIPMENT GUIDE

PPE Category	PPE
4	**Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm^2** (167.5 J/cm^2)[a] Arc-rated long-sleeve shirt (AR) Arc-rated pants (AR) Arc-rated coverall (AR) Arc-rated arc flash suit jacket (AR) Arc-rated arc flash suit pants (AR) Arc-rated arc flash suit hood Arc-rated gloves or rubber insulating gloves with protectors (SR)[d] Arc-rated jacket, parka, high-visibility apparel, rainwear, or hard hat liner (AN)[f] **Protective Equipment** Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)[c] Leather footwear[e]

AN: as needed (optional). AR: as required. SR: selection required.

[a] *Arc rating is* defined in Article 100 of NFPA 70E.

[b] Face shields are to have wrap-around guarding to protect not only the face but also the forehead, ears, and neck, or, alternatively, an arc-rated arc flash suit hood is required to be worn.

[c] Other types of hearing protection are permitted to be used in lieu of or in addition to ear canal inserts provided they are worn under an arc-rated arc flash suit hood.

[d] Rubber insulating gloves with protectors provide arc flash protection in addition to electric shock protection. Higher class rubber insulating gloves with protectors, due to their increased material thickness, provide increased arc flash protection.

[e] Footwear other than leather or dielectric shall be permitted to be used provided it has been tested to demonstrate no ignition, melting, or dripping at the minimum arc rating for the respective arc flash PPE category.

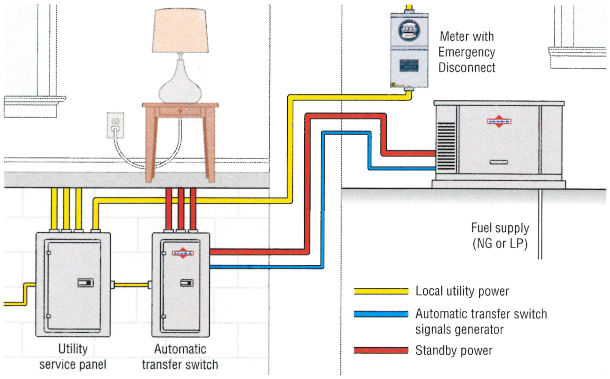
[f] The arc rating of outer layers worn over arc-rated clothing as protection from the elements or for other safety purposes, and that are not used as part of a layered system, shall not be required to be equal to or greater than the estimated incident energy exposure.

Reprinted with permission from NFPA 70E®, *Standard for Electrical Safety in the Workplace®*, Copyright © 2024, National Fire Protection Association. Table130.7(C)(15)(c) as modified. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

ALTERNATIVE ENERGY

Distributed generation systems are designed to work either independently or in parallel with the electric utility grid and have the goal of reducing utility billing, improving electrical reliability, or selling power back to the utility, and being less harmful to the environment. There are five basic types of distributed generation systems: engine-generation systems, solar photovoltaic systems, wind turbines, fuel cells, and microturbines.

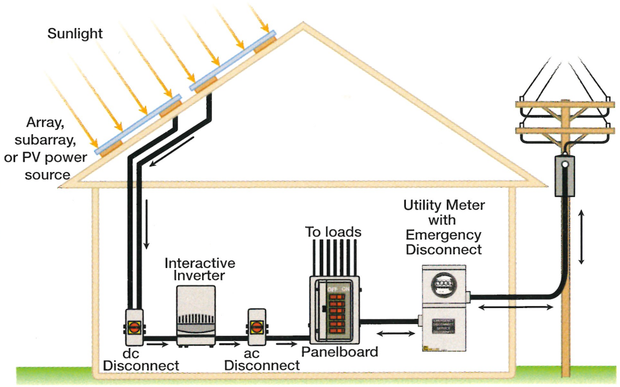
Engine-Generation Systems



Engine-generation is the most common type of distributed generation system currently available and can be used almost anywhere. Engine-generators have the following:

- An internal combustion engine that runs on a variety of fuels.
- Components that consist of the engine and either an induction generator or a synchronous generator.
- An engine that is either a standby rated or a prime rated. A standby-rated engine is rated to deliver power for the duration of a utility outage. A prime-rated engine is rated to deliver a continuous output with approximately 10% reserved for surges.

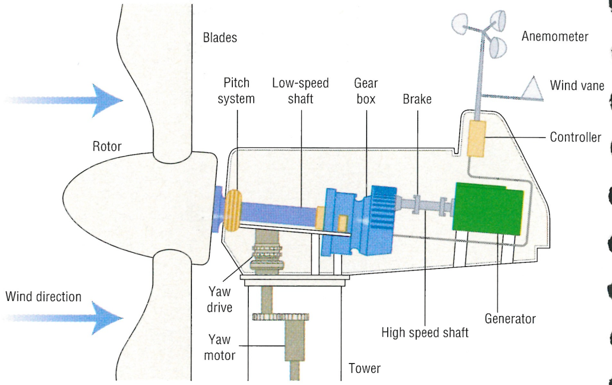
Solar Photovoltaic Systems



Solar photovoltaic power converts sunlight to dc electrical energy. Solar is limited because of its requirement of sunlight.

- The operation of a solar system is automatic.
- Components consist of foundation and supports, either fixed or tracking arrays, and one or more inverters.
- Per the *NEC* 690.4(B), equipment and all solar-associated wiring and interconnections shall be installed by qualified persons only.
- The PV system disconnecting means shall be installed at a readily accessible location.

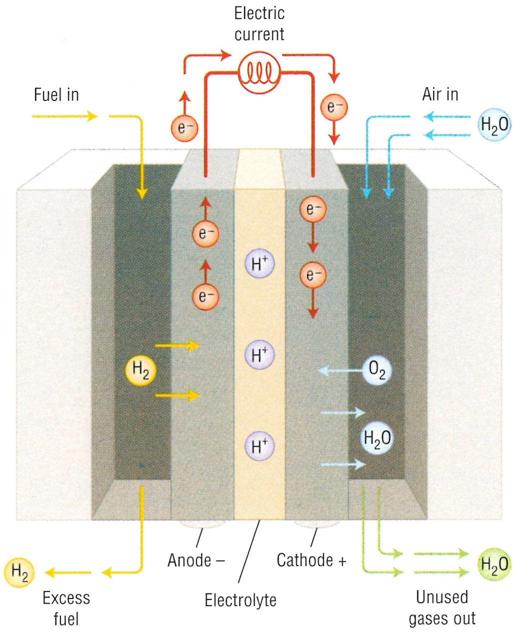
Wind Turbines



Wind power converts wind to either ac or dc electrical energy. Wind is limited because it needs to be in an area of steady reliable wind.

- Wind is useful as a supplemental power source, but not as a backup source.
- The components of wind power are self-contained wind turbines and support towers.
- The turbine generator can be either directly connected to the fan blade or by a gearbox.
- *NEC* 694.7 requires that installation and maintenance be performed by qualified persons only.
- See *NEC* Article 694 for more information regarding wind (turbine) electric systems.

Fuel Cells

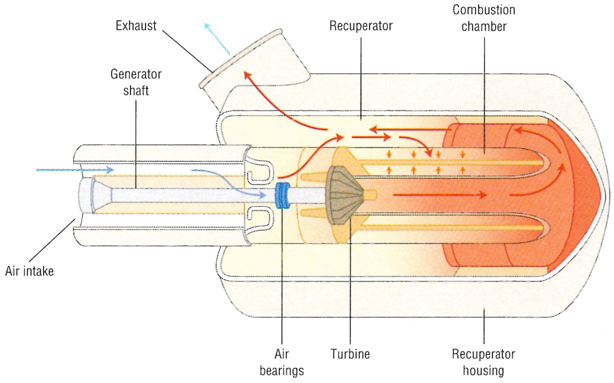


Fuel cells use an electrochemical reactor to generate dc electrical energy. Fuel cells are basically batteries that use hydrogen and oxygen as fuel instead of storing electrical energy.

- A fuel cell generator has no moving parts.
- The fuel cell is composed of a fuel processor, individual fuel cells, fuel cell stack, and power-conditioning equipment.
- *NEC* 692.4(C) requires that construction and maintenance be performed by qualified persons only.

- Fuel cells can have extremely high operating temperatures, which can limit where they can be used.
- The fuel processor converts hydrocarbon fuel into a relatively pure hydrogen gas.
- Fuel cell systems cannot be installed in a Class I hazardous location (see *NEC* Article 501) and should be installed outside where possible. See *NEC* Article 692 for more information on fuel cell systems. See *NEC* 700.12(D), 701.12(D), and 708.20(G) for additional information regarding fuel cell systems and their requirements.

Microturbines



Microturbines are small, single-staged combustion turbines. They can generate either ac or dc electrical energy. Microturbines are also limited in where they can be used due to their high operating temperatures.

- Microturbines range in size from 25 to 500 kW and are modular. They can operate on a wide variety of fuels but are only considered as a renewable energy source.
- The components of microturbines are the compressor, combustion chamber, turbine, generator, recuperator, and the power controller.

- Microturbines are capable of being a stand-alone unit, but the generator loading needs to be relatively steady due to the microturbines' inability to respond quickly.

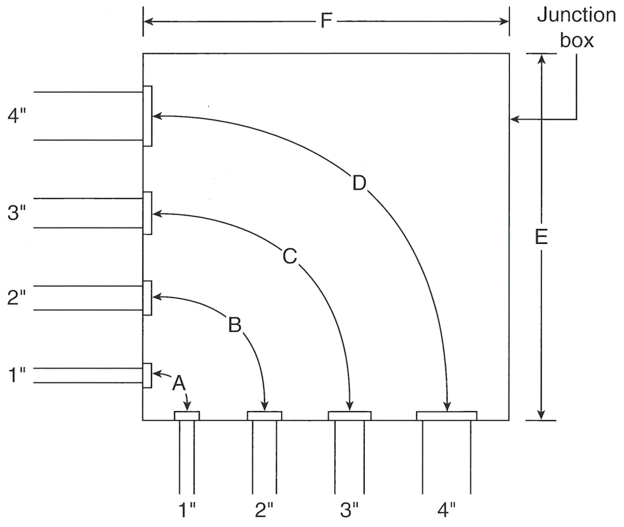
Interconnected Generation Systems

Interconnected generation systems are one of two basic types: passive or active. Passive generation technologies have no control over power production (wind and solar). Active generation technologies have control over power production and can be regulated to load demands. All grid-connected generation systems must comply with *NEC* Article 705 and with IEEE 1547, *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.*

Utility-interactive power inverters regulate the conversion of dc power into 60 Hz ac voltage waveform in parallel with another ac source (e.g., the electric grid). These systems should comply with *NEC* Articles 690–692, and 705, as required.

Distributed generation systems that are capable of being connected to the grid must have a disconnecting means capable of disconnecting from the grid to prevent the potential hazard of back-feed. See *NEC* 404.8(C).

JUNCTION BOX SIZING



A—6 times conduit size = 6" minimum
B—6 times conduit size = 12" minimum
C—6 times conduit size = 18" minimum
D—6 times conduit size = 24" minimum
E—6 times largest conduit size, plus all other conduits entering.
6 x 4 + 3 + 2 + 1 = 30" minimum
F—In this case, same as E.