

UGLY'S™

ELECTRICAL REFERENCES

Charles R. Miller | Daniel Sandefur



2026
EDITION





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LEARNING

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OHM'S LAW

Ohm's Law is the relationship between voltage (E), current (I), and resistance (R). The rate of the current flow is equal to electromotive force divided by resistance.

I = Intensity of Current = Amperes

E = Electromotive Force = Volts

R = Resistance = Ohms

P = Power = Watts

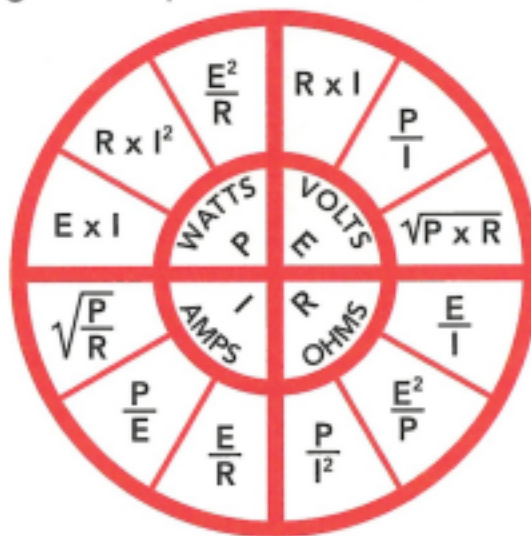
The three basic Ohm's Law formulas are:

$$I = \frac{E}{R}$$

$$R = \frac{E}{I}$$

$$E = I \times R$$

Below is a chart containing the formulas related to Ohm's Law. To use the chart, start in the center circle and select the value you need to find, I (Amps), R (Ohms), E (Volts), or P (Watts). Then select the formula containing the values you know from the corresponding chart quadrant.



Example:

An electrical appliance is rated at 1200 watts and is connected to 120 volts. How much current will it draw?

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts}} \quad I = \frac{P}{E} \quad I = \frac{1200}{120} = 10 \text{ Amps}$$

What is the resistance of the same appliance?

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}} \quad R = \frac{E}{I} \quad R = \frac{120}{10} = 12 \text{ Ohms}$$



OHM'S LAW

In the preceding example, we know the following values:

$$I = \text{Amps} = 10 \text{ Amps} \quad R = \text{Ohms} = 12 \text{ Ohms}$$

$$E = \text{Volts} = 120 \text{ Volts} \quad P = \text{Watts} = 1200 \text{ Watts}$$

We can now see how the 12 formulas in the Ohm's Law chart can be applied.

$$\text{Amps} = \sqrt{\frac{\text{Watts}}{\text{Ohms}}} \quad I = \sqrt{\frac{P}{R}} = \sqrt{\frac{1200}{12}} = \sqrt{100} = 10 \text{ Amps}$$

$$\text{Amps} = \frac{\text{Watts}}{\text{Volts}} \quad I = \frac{P}{E} = \frac{1200}{120} = 10 \text{ Amps}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}} \quad I = \frac{E}{R} = \frac{120}{12} = 10 \text{ Amps}$$

$$\text{Watts} = \frac{\text{Volts}^2}{\text{Ohms}} \quad P = \frac{E^2}{R} = \frac{120^2}{12} = \frac{14400}{12} = 1200 \text{ Watts}$$

$$\text{Watts} = \text{Volts} \times \text{Amps} \quad P = E \times I = 120 \times 10 = 1200 \text{ Watts}$$

$$\text{Watts} = \text{Amps}^2 \times \text{Ohms} \quad P = I^2 \times R = 10^2 \times 12 = 1200 \text{ Watts}$$

$$\text{Volts} = \sqrt{\text{Watts} \times \text{Ohms}} \quad E = \sqrt{P \times R} = \sqrt{1200 \times 12} = \sqrt{14400} = 120 \text{ Volts}$$

$$\text{Volts} = \text{Amps} \times \text{Ohms} \quad E = I \times R = 10 \times 12 = 120 \text{ Volts}$$

$$\text{Volts} = \frac{\text{Watts}}{\text{Amps}} \quad E = \frac{P}{I} = \frac{1200}{10} = 120 \text{ Volts}$$

$$\text{Ohms} = \frac{\text{Volts}^2}{\text{Watts}} \quad R = \frac{E^2}{P} = \frac{120^2}{1200} = \frac{14400}{1200} = 12 \text{ Ohms}$$

$$\text{Ohms} = \frac{\text{Watts}}{\text{Amps}^2} \quad R = \frac{P}{I^2} = \frac{1200}{10^2} = 12 \text{ Ohms}$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amps}} \quad R = \frac{E}{I} = \frac{120}{10} = 12 \text{ Ohms}$$

SERIES CIRCUITS

A series circuit is a circuit that has only one path through which the electrons may flow.

Rule 1: The total current in a series circuit is equal to the current in any other part of the circuit.

$$\text{Total Current } I_T = I_1 = I_2 = I_3, \text{ etc.}$$

Rule 2: The total voltage in a series circuit is equal to the sum of the voltages across all parts of the circuit.

$$\text{Total Voltage } E_T = E_1 + E_2 + E_3, \text{ etc.}$$

Rule 3: The total resistance of a series circuit is equal to the sum of the resistances of all the parts of the circuit.

$$\text{Total Resistance } R_T = R_1 + R_2 + R_3, \text{ etc.}$$

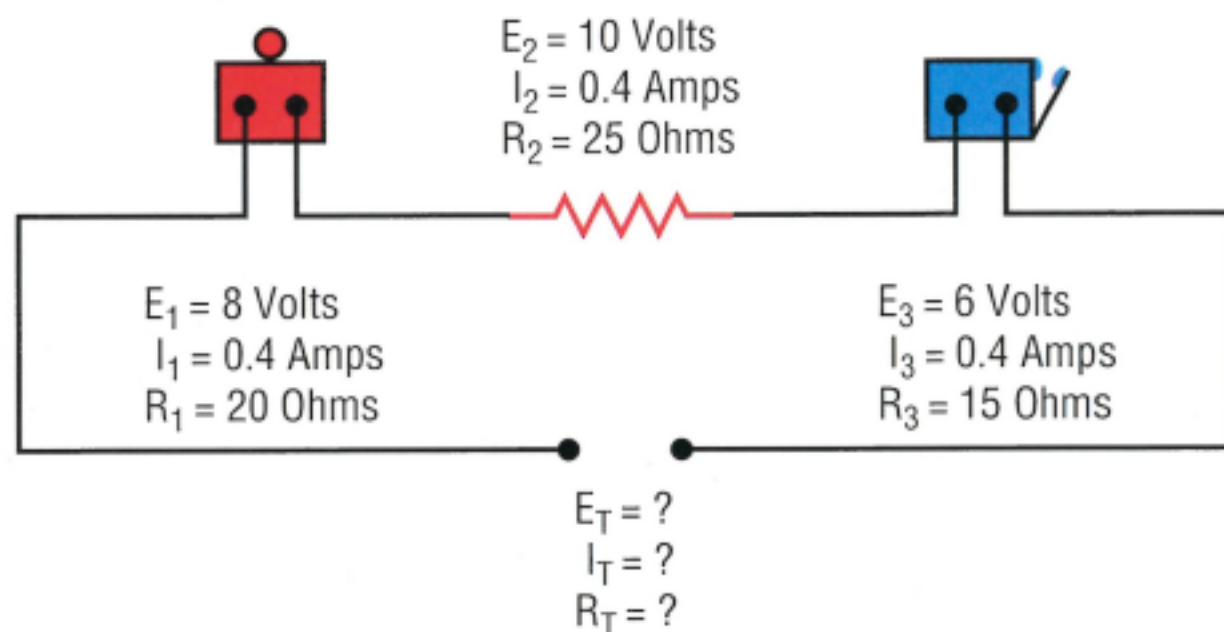
Formulas from Ohm's Law

$$\text{Amperes} = \frac{\text{Volts}}{\text{Resistance}} \quad \text{or} \quad I = \frac{E}{R}$$

$$\text{Resistance} = \frac{\text{Volts}}{\text{Amperes}} \quad \text{or} \quad R = \frac{E}{I}$$

$$\text{Volts} = \text{Amperes} \times \text{Resistance} \quad \text{or} \quad E = I \times R$$

Example 1: Find the total voltage, total current, and total resistance of the following series circuit.





SERIES CIRCUITS

$$\begin{aligned}
 E_T &= E_1 + E_2 + E_3 \\
 &= 8 + 10 + 6 \\
 E_T &= 24 \text{ Volts}
 \end{aligned}$$

$$\begin{aligned}
 I_T &= I_1 = I_2 = I_3 \\
 &= 0.4 = 0.4 = 0.4 \\
 I_T &= 0.4 \text{ Amps}
 \end{aligned}$$

$$\begin{aligned}
 R_T &= R_1 + R_2 + R_3 \\
 &= 20 + 25 + 15 \\
 R_T &= 60 \text{ Ohms}
 \end{aligned}$$

Example 2: Find E_T , E_1 , E_3 , I_T , I_1 , I_2 , I_4 , R_T , R_2 , and R_4 .

Remember that the total current in a series circuit is equal to the current in any other part of the circuit.

$$E_1 = ?$$

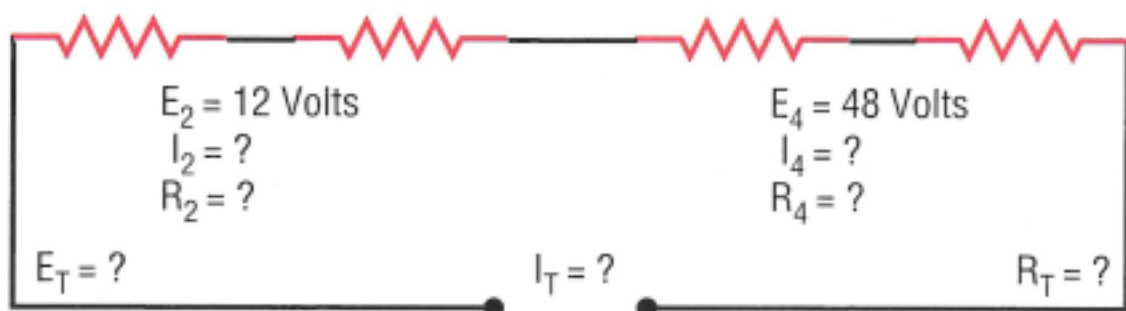
$$E_3 = ?$$

$$I_1 = ?$$

$$I_3 = 0.5 \text{ Amps}$$

$$R_1 = 72 \text{ Ohms}$$

$$R_3 = 48 \text{ Ohms}$$



$$I_T = I_1 = I_2 = I_3 = I_4$$

$$I_T = I_1 = I_2 = 0.5 = I_4$$

$$0.5 = 0.5 = 0.5 = 0.5 = 0.5$$

$$I_T = 0.5 \text{ Amps} \quad I_2 = 0.5 \text{ Amps}$$

$$I_1 = 0.5 \text{ Amps} \quad I_4 = 0.5 \text{ Amps}$$

$$\begin{aligned}
 E_T &= E_1 + E_2 + E_3 + E_4 \\
 &= 36 + 12 + 24 + 48
 \end{aligned}$$

$$E_T = 120 \text{ Volts}$$

$$\begin{aligned}
 R_T &= R_1 + R_2 + R_3 + R_4 \\
 &= 72 + 24 + 48 + 96
 \end{aligned}$$

$$R_T = 240 \text{ Ohms}$$

$$R_2 = \frac{E_2}{I_2} = \frac{12}{0.5}$$

$$R_2 = 24 \text{ Ohms}$$

$$E_1 = I_1 \times R_1$$

$$= 0.5 \times 72$$

$$E_1 = 36 \text{ Volts}$$

$$E_3 = I_3 \times R_3$$

$$= 0.5 \times 48$$

$$E_3 = 24 \text{ Volts}$$

$$R_4 = \frac{E_4}{I_4} = \frac{48}{0.5}$$

$$R_4 = 96 \text{ Ohms}$$



PARALLEL CIRCUITS

A parallel circuit is a circuit that has more than one path through which the electrons may flow.

Rule 1: The total current in a parallel circuit is equal to the sum of the currents in all the branches of the circuit.

$$\text{Total Current } I_T = I_1 + I_2 + I_3, \text{ etc.}$$

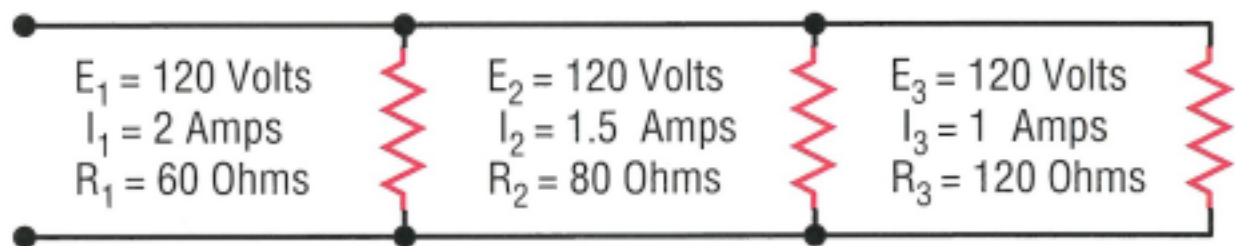
Rule 2: The total voltage across any branch in parallel is equal to the voltage across any other branch and is also equal to the total voltage.

$$\text{Total Voltage } E_T = E_1 = E_2 = E_3, \text{ etc.}$$

Rule 3: The total resistance of a parallel circuit is found by applying Ohm's Law to the total values of the circuit.

$$\text{Total Resistance} = \frac{\text{Total Voltage}}{\text{Total Amperes}} \text{ or } R_T = \frac{E_T}{I_T}$$

Example 1: Find the total current, total voltage, and total resistance of the following parallel circuit.



$$\begin{aligned}
 I_T &= I_1 + I_2 + I_3 \\
 &= 2 + 1.5 + 1 \\
 I_T &= 4.5 \text{ Amps}
 \end{aligned}$$

$$\begin{aligned}
 E_T &= E_1 = E_2 = E_3 \\
 &= 120 = 120 = 120 \\
 E_T &= 120 \text{ Volts}
 \end{aligned}$$

$$R_T = \frac{E_T}{I_T} = \frac{120 \text{ Volts}}{4.5 \text{ Amps}} = 26.66 \text{ Ohms Resistance}$$

Note: In a parallel circuit, the total resistance is always less than the resistance of any branch. If the branches of a parallel circuit have the same resistance, then each will draw the same current. If the branches of a parallel circuit have different resistances, then each will draw a different current. In either series or parallel circuits, the larger the resistance, the smaller the current drawn.

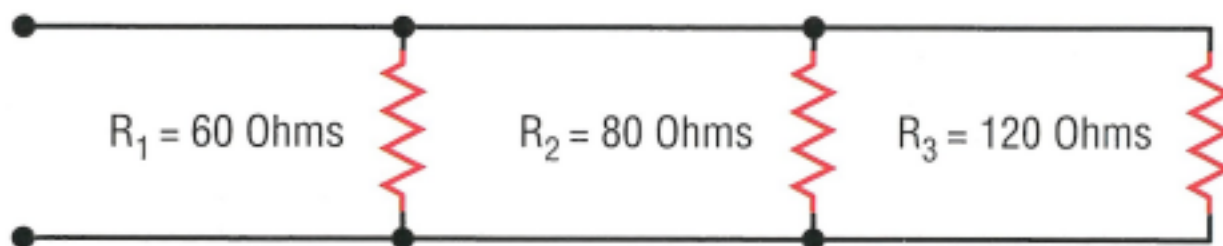


PARALLEL CIRCUITS

To determine the total resistance in a parallel circuit when the total current and total voltage are unknown:

$$\frac{1}{\text{Total Resistance}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \text{ etc.}$$

Example 2: Find the total resistance.



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_T} = \frac{1}{60} + \frac{1}{80} + \frac{1}{120}$$

$$\frac{1}{R_T} = \frac{4 + 3 + 2}{240} = \frac{9}{240} \quad \text{Use lowest common denominator (240).}$$

$$\frac{1}{R_T} = \frac{9}{240} \quad \text{Cross multiply.}$$

For a review of Adding Fractions and Common Denominators, see Ugly's pages 152–154.

$$9 \times R_T = 1 \times 240 \quad \text{or} \quad 9R_T = 240$$

Divide both sides of the equation by 9.

$$R_T = 26.66 \text{ Ohms Resistance}$$

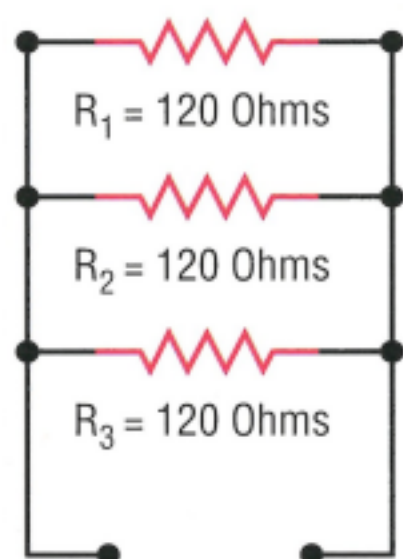
Note: The total resistance of a number of equal resistors in parallel is equal to the resistance of one resistor divided by the number of resistors.

$$\text{Total Resistance} = \frac{\text{Resistance of One Resistor}}{\text{Number of Resistors in Circuit}}$$

PARALLEL CIRCUITS

Formula: $R_T = \frac{R}{N}$

Example 3: Find the total resistance.



There are three resistors in parallel. Each has a value of 120 Ohms resistance. According to the formula, if we divide the resistance of any one of the resistors by three, we will obtain the total resistance of the circuit.

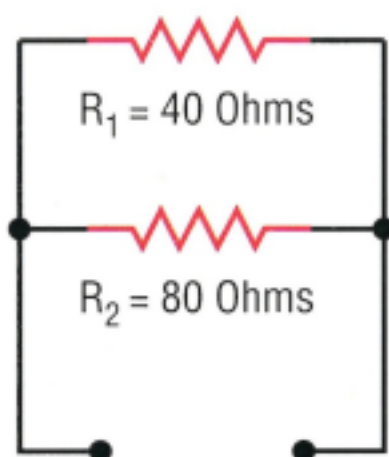
$$R_T = \frac{R}{N} \quad \text{or} \quad R_T = \frac{120}{3}$$

$$\text{Total Resistance} = 40 \text{ Ohms}$$

Note: To find the total resistance of only two resistors in parallel, multiply the resistances, and then divide the product by the sum of the resistors.

Formula: $\text{Total Resistance} = \frac{R_1 \times R_2}{R_1 + R_2}$

Example 4: Find the total resistance.



$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$= \frac{40 \times 80}{40 + 80}$$

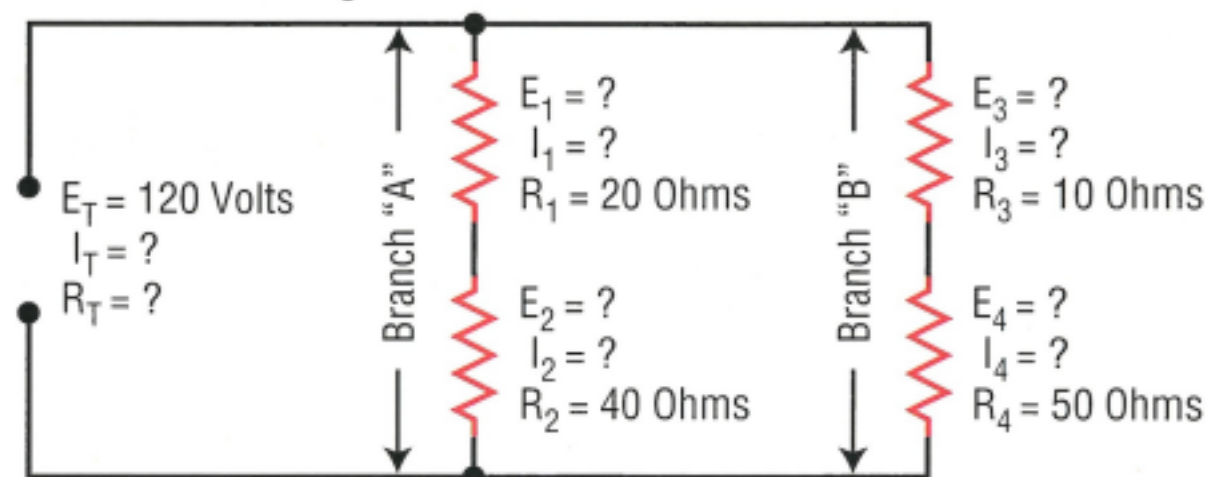
$$R_T = \frac{3200}{120} = 26.66 \text{ Ohms}$$

COMBINATION CIRCUITS

In combination circuits, we combine series circuits with parallel circuits. Combination circuits make it possible to obtain the different voltages of series circuits and the different currents of parallel circuits.

Example 1: Parallel-Series Circuit.

Solve for all missing values.



To solve:

- Find the total resistance of each branch. Both branches are simple series circuits, so:

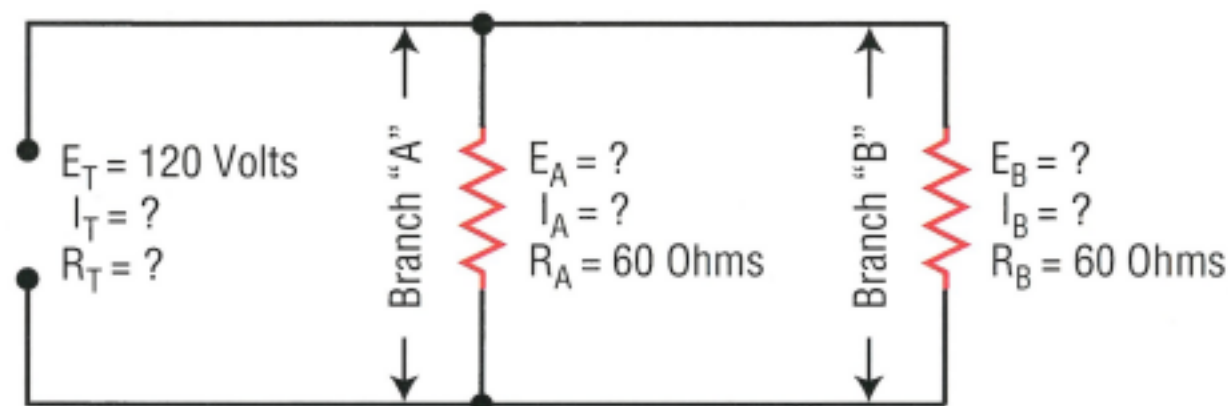
$$R_1 + R_2 = R_A$$

$$20 + 40 = 60 \text{ Ohms total resistance of branch "A"}$$

$$R_3 + R_4 = R_B$$

$$10 + 50 = 60 \text{ Ohms total resistance of branch "B"}$$

- Redraw the circuit, combining resistors ($R_1 + R_2$) and ($R_3 + R_4$) so that each branch will have only one resistor.





COMBINATION CIRCUITS

Note: We now have a simple parallel circuit, so:

$$E_T = E_A = E_B$$

$$120 \text{ Volts} = 120 \text{ Volts} = 120 \text{ Volts}$$

We now have a parallel circuit with only two resistors, and they are of equal value. We have a choice of three different formulas that can be used to find the total resistance of the circuit.

$$(1) \quad R_T = \frac{R_A \times R_B}{R_A + R_B} = \frac{60 \times 60}{60 + 60} = \frac{3600}{120} = 30 \text{ Ohms}$$

(2) When the resistors of a parallel circuit are of equal value,

$$R_T = \frac{R}{N} = \frac{60}{2} = 30 \text{ Ohms} \quad \text{or}$$

$$(3) \quad \frac{1}{R_T} = \frac{1}{R_A} + \frac{1}{R_B} = \frac{1}{60} + \frac{1}{60} = \frac{2}{60} = \frac{1}{30}$$

$$\frac{1}{R_T} \begin{matrix} \diagup \\ \diagdown \end{matrix} = \begin{matrix} \diagdown \\ \diagup \end{matrix} \frac{1}{30} \quad \text{or} \quad 1 \times R_T = 1 \times 30 \quad \text{or} \quad R_T = 30 \text{ Ohms}$$

3. We know the values of E_T , R_T , E_A , R_A , E_B , R_B , R_1 , R_2 , R_3 , and R_4 . Next we will find the values of I_T , I_A , I_B , I_1 , I_2 , I_3 , and I_4 .

$$I_T = \frac{E_T}{R_T} \quad \text{or} \quad \frac{120}{30} = 4 \quad I_T = 4 \text{ Amps}$$

$$I_A = \frac{E_A}{R_A} \quad \text{or} \quad \frac{120}{60} = 2 \quad I_A = 2 \text{ Amps}$$

$$I_A = I_1 = I_2 \quad \text{or} \quad 2 = 2 = 2 \quad \begin{matrix} I_1 = 2 \text{ Amps} \\ I_2 = 2 \text{ Amps} \end{matrix}$$

$$I_B = \frac{E_B}{R_B} = \quad \text{or} \quad \frac{120}{60} = 2 \quad I_B = 2 \text{ Amps}$$

$$I_B = I_3 = I_4 \quad \text{or} \quad 2 = 2 = 2 \quad \begin{matrix} I_3 = 2 \text{ Amps} \\ I_4 = 2 \text{ Amps} \end{matrix}$$



COMBINATION CIRCUITS

4. We know that resistors #1 and #2 of branch "A" are in series. We also know that resistors #3 and #4 of branch "B" are in series. We have determined that the total current of branch "A" is 2 amps, and the total current of branch "B" is 2 amps. By using the series formula, we can find the current of each branch.

Branch "A"

$$I_A = I_1 = I_2$$

$$2 = 2 = 2$$

$$I_1 = 2 \text{ Amps}$$

$$I_2 = 2 \text{ Amps}$$

Branch "B"

$$I_B = I_3 = I_4$$

$$2 = 2 = 2$$

$$I_3 = 2 \text{ Amps}$$

$$I_4 = 2 \text{ Amps}$$

5. We were given the resistance values of all resistors. $R_1 = 20 \text{ Ohms}$, $R_2 = 40 \text{ Ohms}$, $R_3 = 10 \text{ Ohms}$, and $R_4 = 50 \text{ Ohms}$. By using Ohm's Law, we can determine the voltage drop across each resistor.

$$E_1 = R_1 \times I_1$$

$$= 20 \times 2$$

$$E_1 = 40 \text{ Volts}$$

$$E_3 = R_3 \times I_3$$

$$= 10 \times 2$$

$$E_3 = 20 \text{ Volts}$$

$$E_2 = R_2 \times I_2$$

$$= 40 \times 2$$

$$E_2 = 80 \text{ Volts}$$

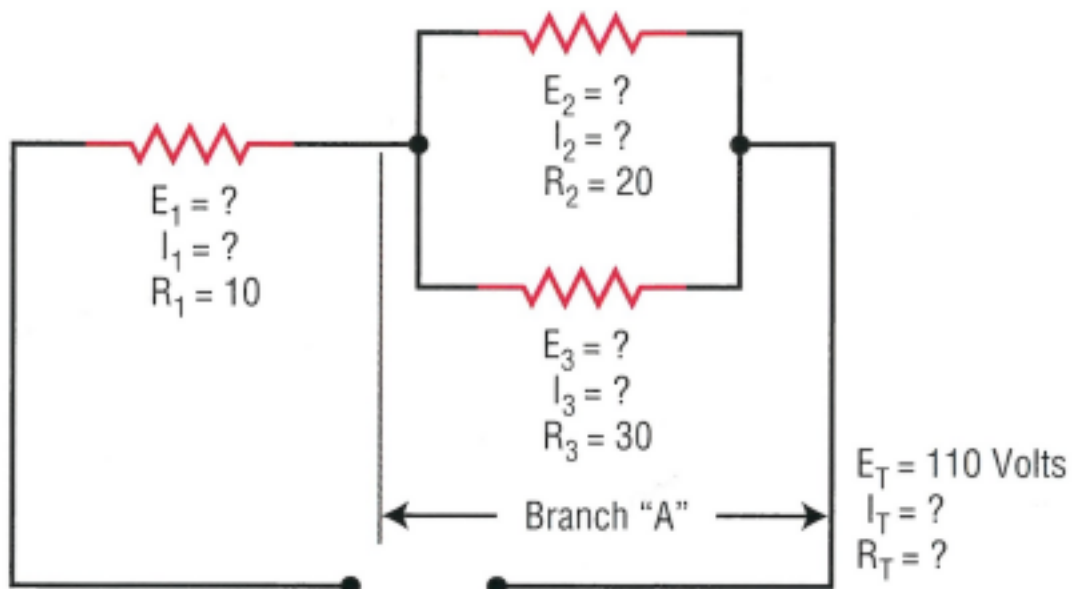
$$E_4 = R_4 \times I_4$$

$$= 50 \times 2$$

$$E_4 = 100 \text{ Volts}$$

Example 2: Series Parallel Circuit.

Solve for all missing values.





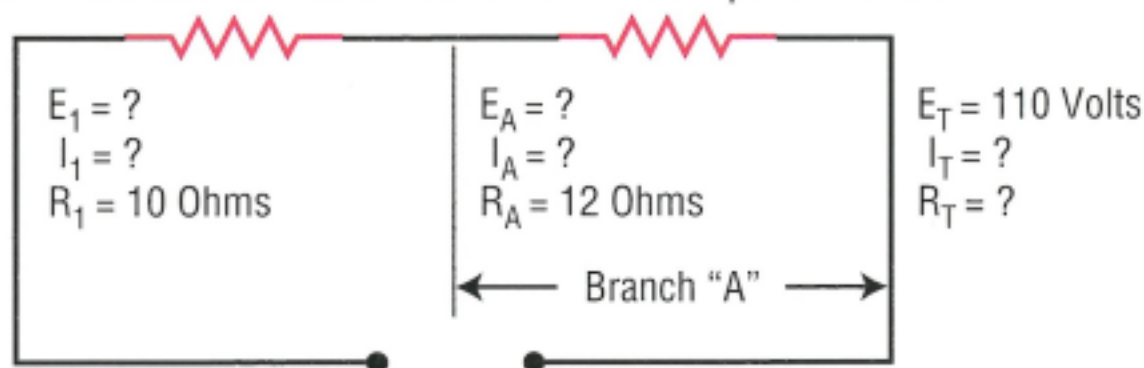
COMBINATION CIRCUITS

To solve:

- We can see that resistors #2 and #3 are in parallel, and combined they are branch "A." When there are only two resistors, we use the following formula:

$$R_A = \frac{R_2 \times R_3}{R_2 + R_3} \text{ or } \frac{20 \times 30}{20 + 30} \text{ or } \frac{600}{50} \text{ or } 12 \text{ Ohms}$$

- We can now redraw our circuit as a simple series circuit.



- In a series circuit,
 $R_T = R_1 + R_A$ or $R_T = 10 + 12$ or 22 Ohms

By using Ohm's Law,

$$I_T = \frac{E_T}{R_T} = \frac{110}{22} = 5 \text{ Amps}$$

In a series circuit,

$$I_T = I_1 = I_A \text{ or } I_T = 5 \text{ Amps, } I_1 = 5 \text{ Amps, and } I_A = 5 \text{ Amps}$$

By using Ohm's Law,

$$E_1 = I_1 \times R_1 = 5 \times 10 = 50 \text{ Volts}$$

$$E_T - E_1 = E_A \text{ or } 110 - 50 = 60 \text{ Volts} = E_A$$

In a parallel circuit,

$$E_A = E_2 = E_3 \text{ or } E_A = 60 \text{ Volts}$$

$$E_2 = 60 \text{ Volts, and } E_3 = 60 \text{ Volts}$$

By using Ohm's Law,

$$I_2 = \frac{E_2}{R_2} = \frac{60}{20} = 3 \text{ Amps}$$

$$I_3 = \frac{E_3}{R_3} = \frac{60}{30} = 2 \text{ Amps}$$



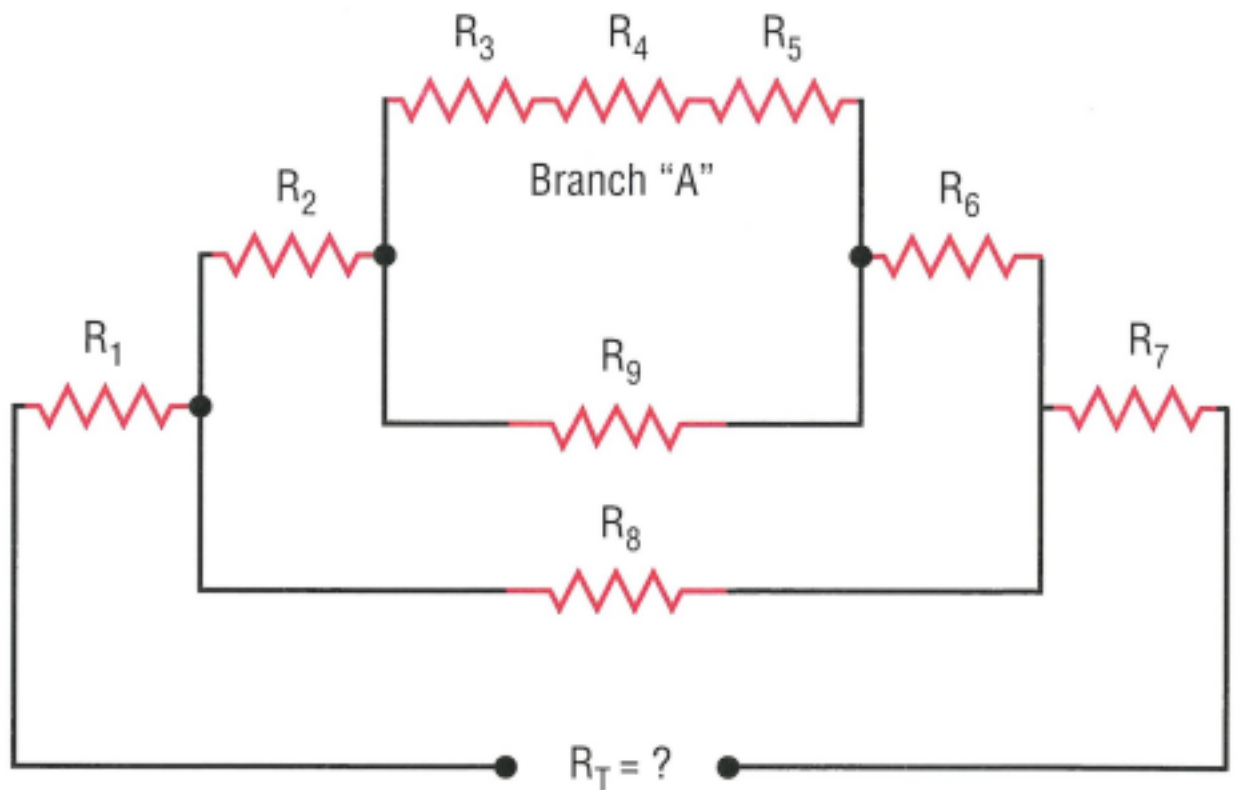
COMBINATION CIRCUITS

Problem:

Find the total resistance.

Redraw circuit as many times as necessary.

Correct answer is 100 Ohms.



Given Values:

$$R_1 = 15 \text{ Ohms}$$

$$R_2 = 35 \text{ Ohms}$$

$$R_3 = 50 \text{ Ohms}$$

$$R_4 = 40 \text{ Ohms}$$

$$R_5 = 30 \text{ Ohms}$$

$$R_6 = 25 \text{ Ohms}$$

$$R_7 = 10 \text{ Ohms}$$

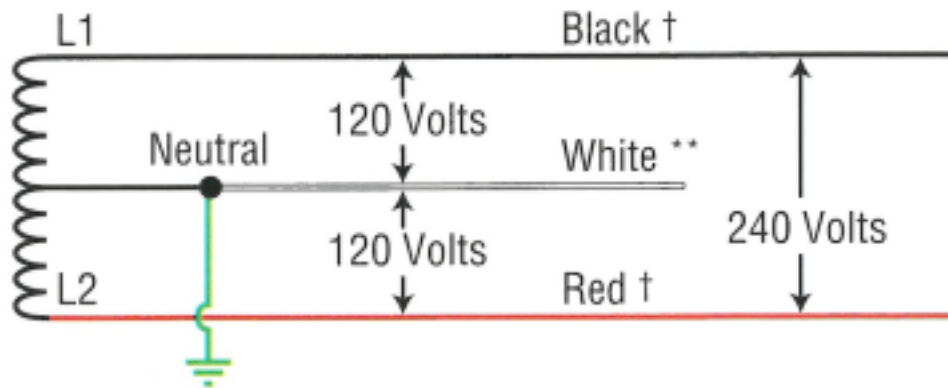
$$R_8 = 300 \text{ Ohms}$$

$$R_9 = 60 \text{ Ohms}$$



COMMON ELECTRICAL DISTRIBUTION SYSTEMS

120/240-Volt, Single-Phase, Three-Wire System

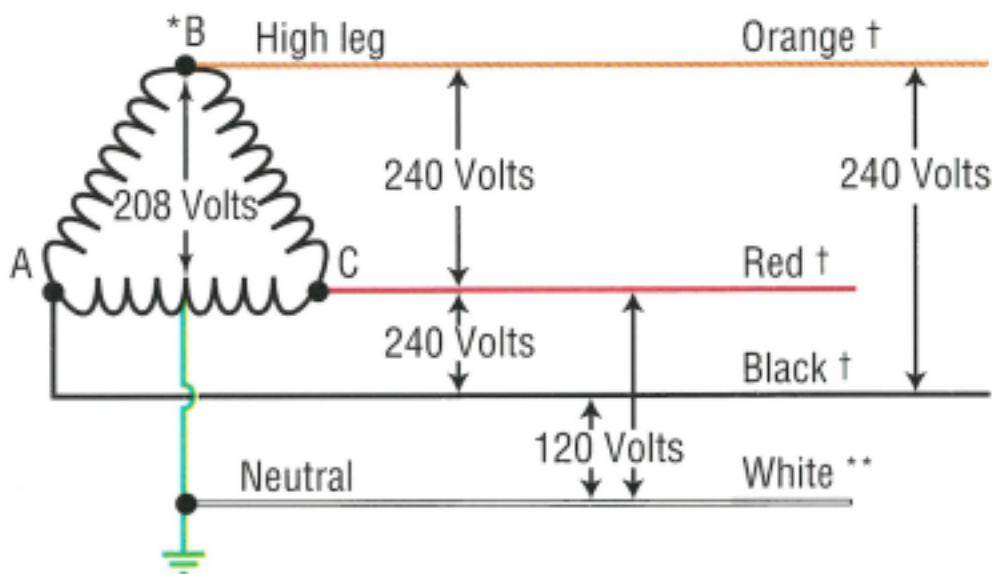


† • **Line one** ungrounded conductor colored **black**

† • **Line two** ungrounded conductor colored **red**

** • Grounded neutral conductor colored **white** or gray

120/240-Volt, Three-Phase, Four-Wire System (Delta High Leg)



† • **A** phase ungrounded conductor colored **black**

†* • **B** phase ungrounded conductor colored **orange** or tagged (high leg). (Caution: 208 volts orange to white)

† • **C** phase ungrounded conductor colored **red**

** • Grounded conductor colored **white** or gray (center tap)

** Grounded conductors are required to be white or gray or three white or gray stripes on other than green insulation. See *NEC 200.7*.

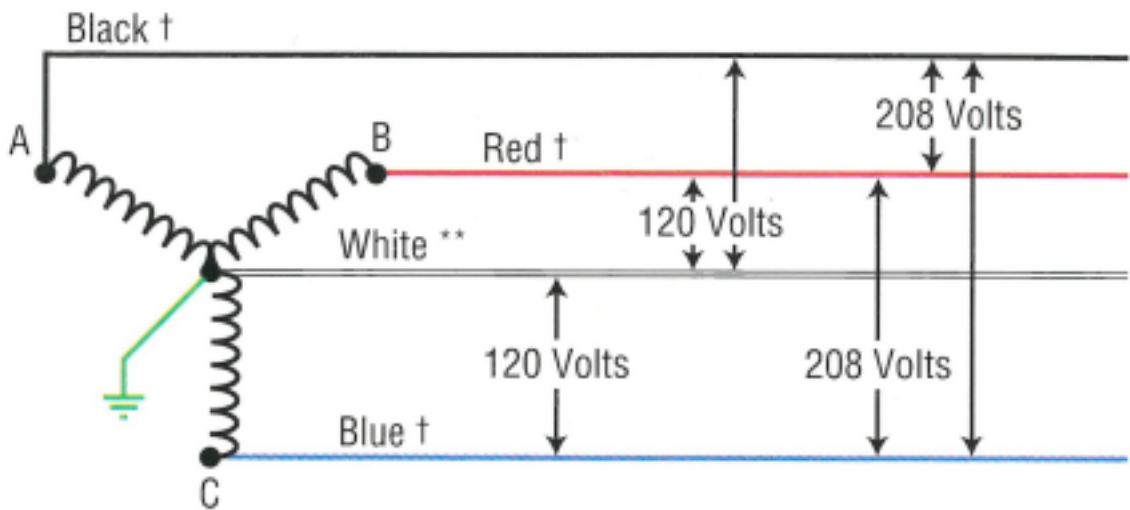
* B phase of delta high leg must be orange or tagged. See *NEC 110.15*.

† Ungrounded conductor colors may be other than shown; see local ordinances or specifications.



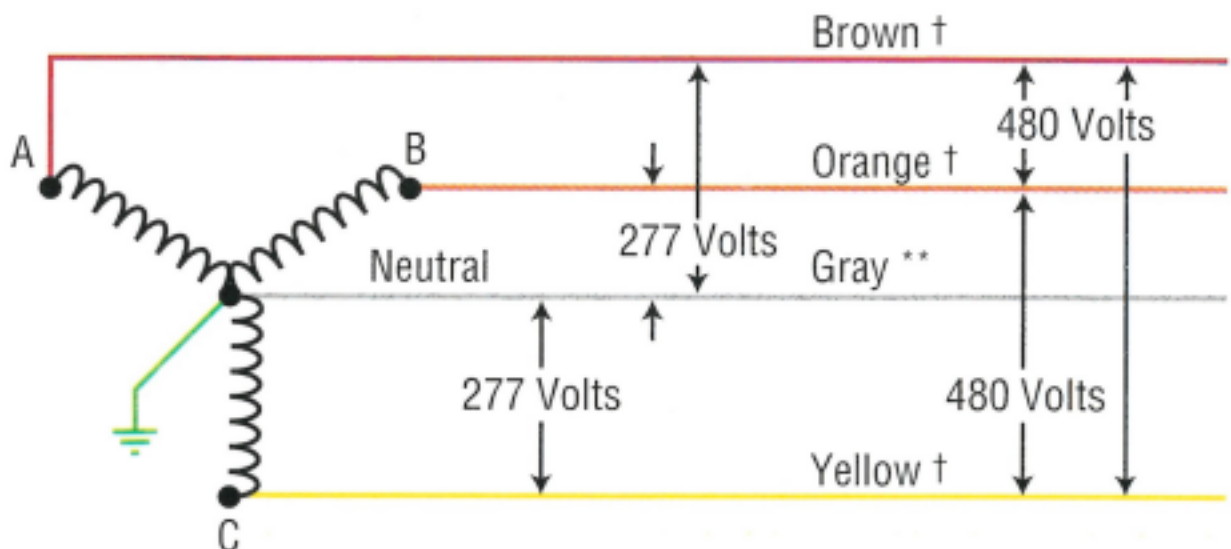
COMMON ELECTRICAL DISTRIBUTION SYSTEMS

120/208-Volt, Three-Phase, Four-Wire System (Wye Connected)



- † • A phase ungrounded conductor colored **black**
- † • B phase ungrounded conductor colored **red**
- † • C phase ungrounded conductor colored **blue**
- ** • Grounded neutral conductor colored **white** or gray

277/480-Volt, Three-Phase, Four-Wire System (Wye Connected)



- † • A phase ungrounded conductor colored **brown**
- † • B phase ungrounded conductor colored **orange**
- † • C phase ungrounded conductor colored **yellow**
- ** • Grounded neutral conductor colored **gray**

** Grounded conductors are required to be white or gray or three white or gray stripes on other than green insulation. See *NEC 200.7*.

† Ungrounded conductor colors may be other than shown; see local ordinances or specifications.



ELECTRICAL FORMULAS FOR CALCULATING AMPERES, HORSEPOWER, KILOWATTS, AND KVA

| To Find | Alternating Current | | |
|---|--|--|--|
| | Direct Current | Single Phase | Two Phase/Four Wire |
| Amperes when "HP" is known | $\frac{HP \times 746}{E \times \%EFF}$ | $\frac{HP \times 746}{E \times \%EFF \times PF}$ | $\frac{HP \times 746}{E \times \%EFF \times PF \times 1.73}$ |
| Amperes when "kW" is known | $\frac{KW \times 1000}{E}$ | $\frac{KW \times 1000}{E \times PF}$ | $\frac{KW \times 1000}{E \times PF \times 1.73}$ |
| Amperes when "kVA" is known | | $\frac{KVA \times 1000}{E}$ | $\frac{KVA \times 1000}{E \times 1.73}$ |
| Kilowatts (True power) | $\frac{E \times I}{1000}$ | $\frac{E \times I \times PF}{1000}$ | $\frac{E \times I \times PF \times 1.73}{1000}$ |
| kilovolt-Amperes "kVA" (Apparent power) | | $\frac{E \times I}{1000}$ | $\frac{E \times I \times 1.73}{1000}$ |
| Horsepower | $\frac{E \times I \times \%EFF}{746}$ | $\frac{E \times I \times \%EFF \times PF}{746}$ | $\frac{E \times I \times \%EFF \times PF \times 1.73}{746}$ |

Percent Efficiency = $\% EFF = \frac{\text{Output (Watts)}}{\text{Input (Watts)}}$ Power Factor = $PF = \frac{\text{Power Used (Watts)}}{\text{Apparent Power}} = \frac{KW}{KVA}$

E = Volts
I = Amperes
W = Watts

Note: Direct-current formulas do not use (PF, 2 or 1.73).
Single-phase formulas do not use (2 or 1.73).
Two-phase/four-wire formulas do not use (1.73).
Three-phase formulas do not use (2).

TO FIND AMPERES

Direct Current

A. When *horsepower* is known:

$$\text{Amperes} = \frac{\text{Horsepower} \times 746}{\text{Volts} \times \text{Efficiency}} \quad \text{or} \quad I = \frac{\text{HP} \times 746}{E \times \%EFF}$$

What current will a travel-trailer toilet draw when equipped with a 12-volt direct-current, $\frac{1}{8}$ -HP motor that has a 96% efficiency rating?

$$I = \frac{\text{HP} \times 746}{E \times \%EFF} = \frac{746 \times \frac{1}{8}}{12 \times 0.96} = \frac{93.25}{11.52} = 8.09 \text{ Amps}$$

B. When *kilowatts* are known:

$$\text{Amperes} = \frac{\text{Kilowatts} \times 1000}{\text{Volts}} \quad \text{or} \quad I = \frac{\text{KW} \times 1000}{E}$$

A 75-kW, 240-volt direct-current generator is used to power a variable-speed conveyor belt at a rock-crushing plant. Determine the current.

$$I = \frac{\text{KW} \times 1000}{E} = \frac{75 \times 1000}{240} = 312.5 \text{ Amps}$$

Single Phase

A. When *watts*, *volts*, and *power factor* are known:

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts} \times \text{Power Factor}} \quad \text{or} \quad \frac{P}{E \times PF}$$

Determine the current when a circuit has a 1500-watt load, a power factor of 86%, and operates from a single-phase, 230-volt source.

$$I = \frac{1500}{230 \times 0.86} = \frac{1500}{197.8} = 7.58 \text{ Amps}$$



TO FIND AMPERES

Single Phase (continued)

B. When *horsepower* is known:

$$\text{Amperes} = \frac{\text{Horsepower} \times 746}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor}}$$

Determine the amp-load of a single-phase, ½-HP, 115-volt motor. The motor has an efficiency rating of 92% and a power factor of 80%.

$$I = \frac{\text{HP} \times 746}{E \times \% \text{EFF} \times \text{PF}} = \frac{\frac{1}{2} \times 746}{115 \times 0.92 \times 0.80} = \frac{373}{84.64}$$

$$I = 4.4 \text{ Amps}$$

C. When *kilowatts* are known:

$$\text{Amperes} = \frac{\text{Kilowatts} \times 1000}{\text{Volts} \times \text{Power Factor}} \quad \text{or} \quad I = \frac{\text{KW} \times 1000}{E \times \text{PF}}$$

A 230-volt, single-phase circuit has a 12-kW power load, and operates at 84% power factor. Determine the current.

$$I = \frac{\text{KW} \times 1000}{E \times \text{PF}} = \frac{12 \times 1000}{230 \times 0.84} = \frac{12000}{193.2} = 62 \text{ Amps}$$

D. When *kilovolt-amperes* are known:

$$\text{Amperes} = \frac{\text{Kilovolt-Amperes} \times 1000}{\text{Volts}} \quad \text{or} \quad I = \frac{\text{KVA} \times 1000}{E}$$

A 115-volt, 2-kVA, single-phase generator operating at full load will deliver 17.4 amps.

$$I = \frac{2 \times 1000}{115} = \frac{2000}{115} = 17.4 \text{ Amps}$$

Remember: By definition, amperes is the rate of current flow.



TO FIND AMPERES

Three Phase

A. When *watts*, *volts*, and *power factor* are known:

$$\text{Amperes} = \frac{\text{Watts}}{\text{Volts} \times \text{Power Factor} \times 1.73}$$

$$\text{or} \quad I = \frac{P}{E \times \text{PF} \times 1.73}$$

Determine the current when a circuit has a 1500-watt load, a power factor of 86%, and operates from a three-phase, 230-volt source.

$$I = \frac{P}{E \times \text{PF} \times 1.73} = \frac{1500}{230 \times 0.86 \times 1.73} = \frac{1500}{342.2}$$

$$I = 4.4 \text{ Amps}$$

B. When *horsepower* is known:

$$\text{Amperes} = \frac{\text{Horsepower} \times 746}{\text{Volts} \times \text{Efficiency} \times \text{Power Factor} \times 1.73}$$

$$\text{or} \quad I = \frac{\text{HP} \times 746}{E \times \% \text{EFF} \times \text{PF} \times 1.73}$$

Determine the current draw of a three-phase, ½-HP, 230-volt motor. The motor has an efficiency rating of 92% and a power factor of 80%.

$$I = \frac{\text{HP} \times 746}{E \times \% \text{EFF} \times \text{PF} \times 1.73} = \frac{\frac{1}{2} \times 746}{230 \times 0.92 \times 0.80 \times 1.73}$$

$$= \frac{373}{293} = 1.27 \text{ Amps}$$

TO FIND AMPERES

Three Phase (continued)

C. When *kilowatts* are known:

$$\text{Amperes} = \frac{\text{Kilowatts} \times 1000}{\text{Volts} \times \text{Power Factor} \times 1.73}$$

$$\text{or} \quad I = \frac{\text{KW} \times 1000}{E \times \text{PF} \times 1.73}$$

A 230-volt, three-phase circuit, has a 12-kW power load and operates at 84% power factor. Determine the current.

$$I = \frac{\text{KW} \times 1000}{E \times \text{PF} \times 1.73} = \frac{12 \times 1000}{230 \times 0.84 \times 1.73} = \frac{12000}{334.24}$$

$$I = 35.9 \text{ Amps}$$

D. When *kilovolt-amperes* are known:

$$\text{Amperes} = \frac{\text{Kilovolt-Amperes} \times 1000}{E \times 1.73} = \frac{\text{KVA} \times 1000}{E \times 1.73}$$

A 230-volt, 4-kVA, three-phase generator operating at full load will deliver 10 amps.

$$I = \frac{\text{KVA} \times 1000}{E \times 1.73} = \frac{4 \times 1000}{230 \times 1.73} = \frac{4000}{397.9}$$

$$I = 10 \text{ Amps}$$



TO FIND HORSEPOWER

Direct Current

$$\text{Horsepower} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency}}{746}$$

A 12-volt motor draws a current of 8.1 amps and has an efficiency rating of 96%. Determine the horsepower.

$$\text{HP} = \frac{E \times I \times \%EFF}{746} = \frac{12 \times 8.09 \times 0.96}{746} = \frac{93.19}{746}$$

$$\text{HP} = 0.125 = \frac{1}{8} \text{ HP} \left(\frac{1}{8} = 1 \div 8 = 0.125 \right)$$

Single Phase

$$\text{HP} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor}}{746}$$

A single-phase, 115-volt ac motor has an efficiency rating of 92% and a power factor of 80%. Determine the horsepower if the amp-load is 4.4 amps.

$$\text{HP} = \frac{E \times I \times \%EFF \times PF}{746} = \frac{115 \times 4.4 \times 0.92 \times 0.80}{746}$$

$$\text{HP} = \frac{372.416}{746} = 0.4992 = \frac{1}{2} \text{ HP}$$

Three Phase

$$\text{HP} = \frac{\text{Volts} \times \text{Amperes} \times \text{Efficiency} \times \text{Power Factor} \times 1.73}{746}$$

A three-phase, 460-volt motor draws a current of 52 amps. The motor has an efficiency rating of 94% and a power factor of 80%. Determine the horsepower.

$$\text{HP} = \frac{E \times I \times \%EFF \times PF \times 1.73}{746} = \frac{460 \times 52 \times 0.94 \times 0.80 \times 1.73}{746}$$

$$\text{HP} = 41.7 \text{ HP}$$

TO FIND WATTS

The electrical power in any part of a circuit is equal to the current in that part multiplied by the voltage across that part of the circuit.

A watt is the power used when 1 volt causes 1 amps to flow in a circuit.

One horsepower is the amount of energy required to lift 33000 pounds, 1 foot, in 1 minute. The electrical equivalent of 1 HP is 745.6 watts.

One watt is the amount of energy required to lift 44.26 pounds, 1 foot, in 1 minute. Watts is power, and power is the amount of work done in a given time.

When *volts* and *amperes* are known:

$$\text{Power (Watts)} = \text{Volts} \times \text{Amperes}$$

A 120-volt ac circuit draws a current of 5 amps. Determine the power consumption.

$$P = E \times I = 120 \times 5 = 600 \text{ Watts}$$

Now determine the resistance of this circuit.

$$\text{Resistance} = \frac{\text{Watts}}{\text{Amps}^2}$$

$$R = \frac{P}{I^2} = \frac{600}{5 \times 5} = \frac{600}{25} = 24 \text{ Ohms}$$

or

$$\text{Resistance} = \frac{\text{Volts}^2}{\text{Watts}} \text{ or } R = \frac{E^2}{P}$$

$$R = \frac{120 \times 120}{600} = \frac{14400}{600} = 24 \text{ Ohms}$$

Note: Refer to the formulas of the Ohm's Law chart on page 1.

TO FIND KILOWATTS

Direct Current

$$\text{Kilowatts} = \frac{\text{Volts} \times \text{Amperes}}{1000}$$

A 120-volt dc motor draws a current of 40 amps.
Determine the kilowatts.

$$\text{KW} = \frac{E \times I}{1000} = \frac{120 \times 40}{1000} = \frac{4800}{1000} = 4.8 \text{ kW}$$

Single Phase

$$\text{Kilowatts} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor}}{1000}$$

A single-phase, 115-volt ac motor draws a current of 20 amps and has a power factor rating of 86%. Determine the kilowatts.

$$\text{KW} = \frac{E \times I \times \text{PF}}{1000} = \frac{115 \times 20 \times 0.86}{1000} = \frac{1978}{1000} = 1.978 = 2 \text{ kW}$$

Three Phase

$$\text{Kilowatts} = \frac{\text{Volts} \times \text{Amperes} \times \text{Power Factor} \times 1.73}{1000}$$

A three-phase, 460-volt ac motor draws a current of 52 amps and has a power factor rating of 80%. Determine the kilowatts.

$$\begin{aligned} \text{KW} &= \frac{E \times I \times \text{PF} \times 1.73}{1000} = \frac{460 \times 52 \times 0.80 \times 1.73}{1000} \\ &= \frac{33105}{1000} = 33.105 = 33 \text{ kW} \end{aligned}$$



TO FIND KILOVOLT-AMPERES

Single Phase

$$\text{Kilovolt-Amperes} = \frac{\text{Volts} \times \text{Amperes}}{1000}$$

A single-phase, 240-volt generator delivers 41.66 amps at full load. Determine the kilovolt-amperes rating.

$$\text{KVA} = \frac{E \times I}{1000} = \frac{240 \times 41.66}{1000} = \frac{9998.4}{1000} = 10 \text{ kVA}$$

Three Phase

$$\text{Kilovolt-Amperes} = \frac{\text{Volts} \times \text{Amperes} \times 1.73}{1000}$$

A three-phase, 460-volt generator delivers 52 amps. Determine the kilovolt-amperes rating.

$$\begin{aligned} \text{KVA} &= \frac{E \times I \times 1.73}{1000} = \frac{460 \times 52 \times 1.73}{1000} = \frac{41382}{1000} \\ &= 41.382 = 41 \text{ kVA} \end{aligned}$$

Note: KVA = Apparent Power = Power Before Used, such as the rating of a transformer.

Kirchhoff's Laws

First Law (Current):

The sum of the currents arriving at any point in a circuit must equal the sum of the currents leaving that point.

Second Law (Voltage):

The total voltage applied to any closed circuit path is always equal to the sum of the voltage drops in that path.

or

The algebraic sum of all the voltages encountered in any loop equals zero.

TO FIND CAPACITANCE

Capacitance (C)

$$C = \frac{Q}{E} \quad \text{or} \quad \text{Capacitance} = \frac{\text{Coulombs}}{\text{Volts}}$$

Capacitance is the property of a circuit or body that permits it to store an electrical charge equal to the accumulated charge divided by the voltage. Capacitance is expressed in farads.

- A. To determine the total capacity of capacitors and/or condensers connected in series:

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4}$$

Determine the total capacity of four 12-microfarad capacitors connected in series.

$$\begin{aligned} \frac{1}{C_T} &= \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} \\ &= \frac{1}{12} + \frac{1}{12} + \frac{1}{12} + \frac{1}{12} = \frac{4}{12} \end{aligned}$$

$$\frac{1}{C_T} = \frac{4}{12} \quad \text{or} \quad C_T \times 4 = 12 \quad \text{or} \quad C_T = \frac{12}{4} = 3 \text{ Microfarads}$$

- B. To determine the total capacity of capacitors and/or condensers connected in parallel:

$$C_T = C_1 + C_2 + C_3 + C_4$$

Determine the total capacity of four 12-microfarad capacitors connected in parallel:

$$C_T = C_1 + C_2 + C_3 + C_4$$

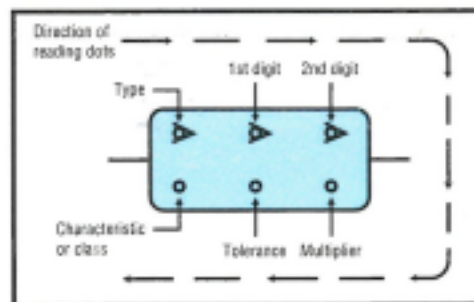
$$C_T = 12 + 12 + 12 + 12 = 48 \text{ Microfarads}$$

A farad is the unit of capacitance of a condenser that retains 1 coulomb of charge with 1 volt difference of potential.

$$1 \text{ Farad} = 1000000 \text{ Microfarads}$$



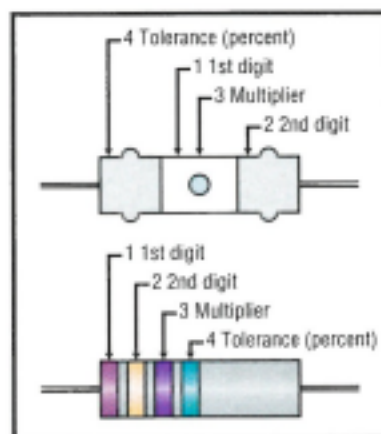
SIX-DOT COLOR CODE FOR MICA AND MOLDED PAPER CAPACITORS



| Type | Color | 1st Digit | 2nd Digit | Multiplier | Tolerance (%) | Characteristic or Class |
|--------------|--------|-----------|-----------|------------|---------------|--|
| JAN, Mica | Black | 0 | 0 | 1 | ± 1 | Applies to Temperature Coefficient or Methods of Testing |
| | Brown | 1 | 1 | 10 | ± 2 | |
| | Red | 2 | 2 | 100 | ± 3 | |
| | Orange | 3 | 3 | 1000 | ± 4 | |
| | Yellow | 4 | 4 | 10000 | ± 5 | |
| | Green | 5 | 5 | 100000 | ± 6 | |
| | Blue | 6 | 6 | 1000000 | ± 7 | |
| | Violet | 7 | 7 | 10000000 | ± 8 | |
| | Gray | 8 | 8 | 100000000 | ± 9 | |
| ETA, Mica | White | 9 | 9 | 1000000000 | | |
| Molded Paper | Gold | | | 0.1 | ± 10 | |
| | Silver | | | 0.01 | ± 20 | |



RESISTOR COLOR CODE



| Color | 1st Digit | 2nd Digit | Multiplier | Tolerance (%) |
|----------|-----------|-----------|------------|---------------|
| Black | 0 | 0 | 1 | |
| Brown | 1 | 1 | 10 | |
| Red | 2 | 2 | 100 | |
| Orange | 3 | 3 | 1000 | |
| Yellow | 4 | 4 | 10000 | |
| Green | 5 | 5 | 100000 | |
| Blue | 6 | 6 | 1000000 | |
| Violet | 7 | 7 | 10000000 | |
| Gray | 8 | 8 | 100000000 | |
| White | 9 | 9 | 1000000000 | |
| Gold | | | 0.1 | ± 5% |
| Silver | | | 0.01 | ± 10% |
| No Color | | | | ± 20% |



MAXIMUM PERMISSIBLE CAPACITOR KVAR FOR USE WITH OPEN-TYPE, THREE-PHASE, 60-CYCLE INDUCTION MOTORS

| Motor Rating (HP) | 3600 RPM | | 1800 RPM | | 1200 RPM | |
|-------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|
| | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) |
| 10 | 3 | 10 | 3 | 11 | 3.5 | 14 |
| 15 | 4 | 9 | 4 | 10 | 5 | 13 |
| 20 | 5 | 9 | 5 | 10 | 6.5 | 12 |
| 25 | 6 | 9 | 6 | 10 | 7.5 | 11 |
| 30 | 7 | 8 | 7 | 9 | 9 | 11 |
| 40 | 9 | 8 | 9 | 9 | 11 | 10 |
| 50 | 12 | 8 | 11 | 9 | 13 | 10 |
| 60 | 14 | 8 | 14 | 8 | 15 | 10 |
| 75 | 17 | 8 | 16 | 8 | 18 | 10 |
| 100 | 22 | 8 | 21 | 8 | 25 | 9 |
| 125 | 27 | 8 | 26 | 8 | 30 | 9 |
| 150 | 32.5 | 8 | 30 | 8 | 35 | 9 |
| 200 | 40 | 8 | 37.5 | 8 | 42.5 | 9 |

| Motor Rating (HP) | 900 RPM | | 720 RPM | | 600 RPM | |
|-------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|
| | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) | Maximum Capacitor Rating (KVAR) | Reduction in Line Current (%) |
| 10 | 5 | 21 | 6.5 | 27 | 7.5 | 31 |
| 15 | 6.5 | 18 | 8 | 23 | 9.5 | 27 |
| 20 | 7.5 | 16 | 9 | 21 | 12 | 25 |
| 25 | 9 | 15 | 11 | 20 | 14 | 23 |
| 30 | 10 | 14 | 12 | 18 | 16 | 22 |
| 40 | 12 | 13 | 15 | 16 | 20 | 20 |
| 50 | 15 | 12 | 19 | 15 | 24 | 19 |
| 60 | 18 | 11 | 22 | 15 | 27 | 19 |
| 75 | 21 | 10 | 26 | 14 | 32.5 | 18 |
| 100 | 27 | 10 | 32.5 | 13 | 40 | 17 |
| 125 | 32.5 | 10 | 40 | 13 | 47.5 | 16 |
| 150 | 37.5 | 10 | 47.5 | 12 | 52.5 | 15 |
| 200 | 47.5 | 10 | 60 | 12 | 65 | 14 |

Note: If capacitors of a lower rating than the values given in the table are used, the percentage reduction in line current given in the table should be reduced proportionately.



POWER FACTOR CORRECTION

Table Values × Kilowatt of Capacitors Needed to Correct from Existing to Desired Power Factor

| Existing Power Factor (%) | Corrected Power Factor | | | | | |
|---------------------------|------------------------|-------|-------|-------|-------|-------|
| | 100% | 95% | 90% | 85% | 80% | 75% |
| 50 | 1.732 | 1.403 | 1.247 | 1.112 | 0.982 | 0.850 |
| 52 | 1.643 | 1.314 | 1.158 | 1.023 | 0.893 | 0.761 |
| 54 | 1.558 | 1.229 | 1.073 | 0.938 | 0.808 | 0.676 |
| 55 | 1.518 | 1.189 | 1.033 | 0.898 | 0.768 | 0.636 |
| 56 | 1.479 | 1.150 | 0.994 | 0.859 | 0.729 | 0.597 |
| 58 | 1.404 | 1.075 | 0.919 | 0.784 | 0.654 | 0.522 |
| 60 | 1.333 | 1.004 | 0.848 | 0.713 | 0.583 | 0.451 |
| 62 | 1.265 | 0.936 | 0.780 | 0.645 | 0.515 | 0.383 |
| 64 | 1.201 | 0.872 | 0.716 | 0.581 | 0.451 | 0.319 |
| 65 | 1.168 | 0.839 | 0.683 | 0.548 | 0.418 | 0.286 |
| 66 | 1.139 | 0.810 | 0.654 | 0.519 | 0.389 | 0.257 |
| 68 | 1.078 | 0.749 | 0.593 | 0.458 | 0.328 | 0.196 |
| 70 | 1.020 | 0.691 | 0.535 | 0.400 | 0.270 | 0.138 |
| 72 | 0.964 | 0.635 | 0.479 | 0.344 | 0.214 | 0.082 |
| 74 | 0.909 | 0.580 | 0.424 | 0.289 | 0.159 | 0.027 |
| 75 | 0.882 | 0.553 | 0.397 | 0.262 | 0.132 | |
| 76 | 0.855 | 0.526 | 0.370 | 0.235 | 0.105 | |
| 78 | 0.802 | 0.473 | 0.317 | 0.182 | 0.052 | |
| 80 | 0.750 | 0.421 | 0.265 | 0.130 | | |
| 82 | 0.698 | 0.369 | 0.213 | 0.078 | | |
| 84 | 0.646 | 0.317 | 0.161 | | | |
| 85 | 0.620 | 0.291 | 0.135 | | | |
| 86 | 0.594 | 0.265 | 0.109 | | | |
| 88 | 0.540 | 0.211 | 0.055 | | | |
| 90 | 0.485 | 0.156 | | | | |
| 92 | 0.426 | 0.097 | | | | |
| 94 | 0.363 | 0.034 | | | | |
| 95 | 0.329 | | | | | |

Typical Problem: With a load of 500 kW at 70% power factor, it is desired to find the kVA of capacitors required to correct the power factor to 85%.

Solution: From the table, select the multiplying factor 0.400 corresponding to the existing 70%, and the corrected 85% power factor.
 $0.400 \times 500 = 200$ kVA of capacitors required.



POWER FACTOR AND EFFICIENCY EXAMPLE

A squirrel cage induction motor is rated 10 HP, 208 volt, three-phase, and has a nameplate rating of 27.79 amps. A wattmeter reading indicates 8 kilowatts of consumed (true) power. Calculate apparent power (kVA), power factor, efficiency, internal losses, and size of the capacitor in kilovolt-amperes reactive (KVAR) needed to correct the power factor to unity (100%).

Apparent input power: kilovolt-amperes (kVA)

$$\text{KVA} = (E \times I \times 1.73)/1000 = (208 \times 27.79 \times 1.73)/1000 = \mathbf{10 \text{ kVA}}$$

Power factor (PF) = ratio of true power (kW) to apparent power (kVA)

$$\text{Kilowatts/kilovolt-amperes} = 8 \text{ kW}/10 \text{ kVA} = 0.8 = \mathbf{80\% \text{ Power Factor}}$$

80% of the 10-kVA apparent power input performs work.

Motor output in kilowatts = 10 HP x 746 watts = 7460 watts = **7.46 kW**

$$\text{Efficiency} = \text{watts out/watts in} = 7.46 \text{ kW}/8 \text{ kW} = 0.9325 = \mathbf{93.25\% \text{ efficiency}}$$

$$\text{Internal losses (heat, friction, hysteresis)} = 8 \text{ kW} - 7.46 \text{ kW} = \mathbf{0.54 \text{ kW}} \text{ (540 Watts)}$$

Kilovolt-amperes reactive (KVAR) (Power stored in motor magnetic field)

$$\text{KVAR} = \sqrt{\text{kVA}^2 - \text{kW}^2} = \sqrt{10 \text{ kVA}^2 - 8 \text{ kW}^2} = \sqrt{100 - 64} = \sqrt{36} = \mathbf{6 \text{ KVAR}}$$

The size capacitor needed to equal the motor's stored reactive power is 6 KVAR. (A capacitor stores reactive power in its electrostatic field.)

The power source must supply the current to perform work and maintain the motor's magnetic field. Before power factor correction, this was 27.79 amperes. The motor magnetizing current after power factor correction is supplied by circulation of current between the motor and the electrostatic field of the capacitor and is no longer supplied by power source after initial startup. The motor feeder current after correction to 100% will equal the amount required by the input watts in this case $(8 \text{ kW})/(208 \text{ volts} \times 1.73) = (8 \times 1000)/(208 \text{ volts} \times 1.73) = \mathbf{22.2 \text{ amps}}$.

- Kilo = 1000. For example: 1000 Watts = 1 Kilowatt.
- Inductive loads (motors, coils) have lagging currents, and capacitive loads have leading currents.
- Inductance and capacitance have opposite effects in a circuit and can cancel each other.



TO FIND INDUCTANCE

Inductance (L)

Inductance is the production of magnetization or electrification in a body by the proximity of a magnetic field or electric charge, or of the electric current in a conductor by the variation of the magnetic field in its vicinity. The unit of measurement for inductance is the henry (H).

A. To find the total inductance of coils connected in series:

$$L_T = L_1 + L_2 + L_3 + L_4$$

Determine the total inductance of four coils connected in series. Each coil has an inductance of 4 Henries.

$$\begin{aligned} L_T &= L_1 + L_2 + L_3 + L_4 \\ &= 4 + 4 + 4 + 4 = 16 \text{ Henries} \end{aligned}$$

B. To find the total inductance of coils connected in parallel:

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \frac{1}{L_4}$$

Determine the total inductance of four coils connected in parallel. Each coil has an inductance of 4 Henries.

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \frac{1}{L_4}$$

$$\frac{1}{L_T} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4}$$

$$\frac{1}{L_T} = \frac{4}{4} \text{ or } L_T \times 4 = 1 \times 4 \text{ or } L_T = \frac{4}{4} = 1 \text{ Henry}$$

An induction coil is a device consisting of two concentric coils and an interrupter, which changes a low steady voltage into a high intermittent alternating voltage by electromagnetic induction. Most often used as a spark coil.



TO FIND IMPEDANCE

Impedance (Z)

Impedance is the total opposition to an alternating current presented by a circuit. Expressed in ohms.

A. When *volts* and *amperes* are known:

$$\text{Impedance} = \frac{\text{Volts}}{\text{Amperes}} \quad \text{or} \quad Z = \frac{E}{I}$$

Determine the impedance of a 120-volt ac circuit that draws a current of 4 amps.

$$Z = \frac{E}{I} = \frac{120}{4} = 30 \text{ Ohms}$$

B. When *resistance* and *reactance* are known:

$$Z = \sqrt{\text{Resistance}^2 + \text{Reactance}^2} = \sqrt{R^2 + X^2}$$

Determine the impedance of an ac circuit when the resistance is 6 ohms, and the reactance is 8 ohms.

$$Z = \sqrt{R^2 + X^2} = \sqrt{36 + 64} = \sqrt{100} = 10 \text{ Ohms}$$

C. When *resistance*, *inductive reactance*, and *capacitive reactance* are known:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Determine the impedance of an ac circuit that has a resistance of 6 ohms, an inductive reactance of 18 ohms, and a capacitive reactance of 10 ohms.

$$\begin{aligned} Z &= \sqrt{R^2 + (X_L - X_C)^2} \\ &= \sqrt{6^2 + (18 - 10)^2} = \sqrt{6^2 + (8)^2} \\ &= \sqrt{36 + 64} = \sqrt{100} = 10 \text{ Ohms} \end{aligned}$$

TO FIND REACTANCE

Reactance (X)

Reactance in a circuit is the opposition to an alternating current caused by inductance and capacitance, equal to the difference between capacitive and inductive reactance. Reactance is expressed in ohms.

A. Inductive Reactance X_L

Inductive reactance is the element of reactance in a circuit caused by self-inductance.

$$X_L = 2 \times 3.1416 \times \text{Frequency} \times \text{Inductance}$$
$$= 6.28 \quad \times \quad \text{F} \quad \times \quad \text{L}$$

Determine the reactance of a 4-Henry coil on a 60-cycle ac circuit.

$$X_L = 6.28 \times \text{F} \times \text{L} = 6.28 \times 60 \times 4 = 1507 \text{ Ohms}$$

B. Capacitive Reactance X_C

Capacitive reactance is the element of reactance in a circuit caused by capacitance.

$$X_C = \frac{1}{2 \times 3.1416 \times \text{Frequency} \times \text{Capacitance}}$$
$$= \frac{1}{6.28 \times \text{F} \times \text{C}}$$

Determine the reactance of a 4-microfarad condenser on a 60-cycle ac circuit.

$$X_C = \frac{1}{6.28 \times \text{F} \times \text{C}} = \frac{1}{6.28 \times 60 \times 0.000004}$$
$$= \frac{1}{0.0015072} = 663 \text{ Ohms}$$

A Henry is a unit of inductance equal to the inductance of a circuit in which the variation of a current at the rate of 1 amp per second induces an electromotive force of 1 volt.



FULL-LOAD CURRENT IN AMPERES: DIRECT-CURRENT (dc) MOTORS

| HP | Armature Voltage Rating* | | | | | |
|-----|--------------------------|-------|-------|-------|-------|-------|
| | 90 V | 120 V | 180 V | 240 V | 500 V | 550 V |
| ¼ | 4.0 | 3.1 | 2.0 | 1.6 | — | — |
| ½ | 5.2 | 4.1 | 2.6 | 2.0 | — | — |
| ¾ | 6.8 | 5.4 | 3.4 | 2.7 | — | — |
| 1 | 9.6 | 7.6 | 4.8 | 3.8 | — | — |
| 1 | 12.2 | 9.5 | 6.1 | 4.7 | — | — |
| 1½ | — | 13.2 | 8.3 | 6.6 | — | — |
| 2 | — | 17 | 10.8 | 8.5 | — | — |
| 3 | — | 25 | 16 | 12.2 | — | — |
| 5 | — | 40 | 27 | 20 | — | — |
| 7½ | — | 58 | — | 29 | 13.6 | 12.2 |
| 10 | — | 76 | — | 38 | 18 | 16 |
| 15 | — | — | — | 55 | 27 | 24 |
| 20 | — | — | — | 72 | 34 | 31 |
| 25 | — | — | — | 89 | 43 | 38 |
| 30 | — | — | — | 106 | 51 | 46 |
| 40 | — | — | — | 140 | 67 | 61 |
| 50 | — | — | — | 173 | 83 | 75 |
| 60 | — | — | — | 206 | 99 | 90 |
| 75 | — | — | — | 255 | 123 | 111 |
| 100 | — | — | — | 341 | 164 | 148 |
| 125 | — | — | — | 425 | 205 | 185 |
| 150 | — | — | — | 506 | 246 | 222 |
| 200 | — | — | — | 675 | 330 | 294 |

These values of full-load currents* are for motors running at base speed.

*These are average dc quantities.

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DIRECT-CURRENT MOTORS

Terminal Markings

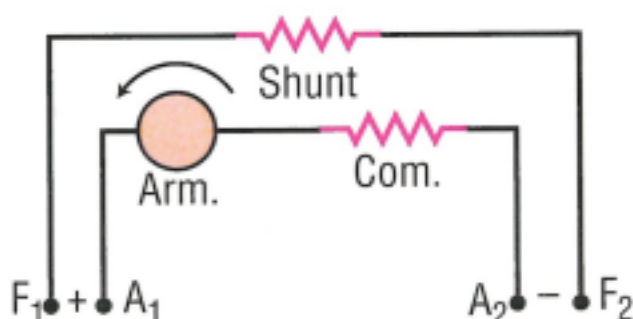
Terminal markings are used to tag terminals to which connections are to be made from outside circuits.

Facing the end opposite the drive (commutator end), the standard direction of shaft rotation is counterclockwise.

A_1 and A_2 indicate armature leads.

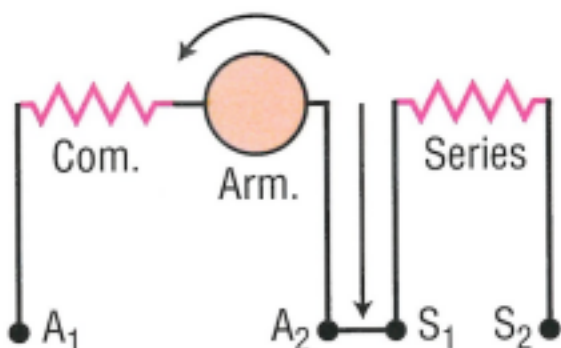
S_1 and S_2 indicate series-field leads.

F_1 and F_2 indicate shunt-field leads.



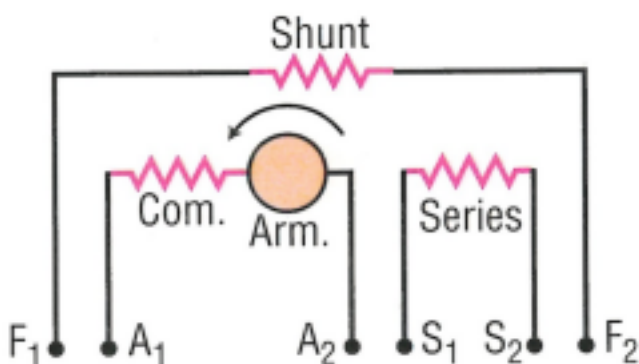
Shunt-Wound Motors

To change rotation, reverse either armature leads or shunt leads. **Do not** reverse both armature and shunt leads.



Series-Wound Motors

To change rotation, reverse either armature leads or series leads. **Do not** reverse both armature and series leads.



Compound-Wound Motors

To change rotation, reverse either armature leads or both the series and shunt leads. **Do not** reverse all three sets of leads.

Note: Standard rotation for a dc generator is clockwise.



FULL-LOAD CURRENT IN AMPERES: SINGLE-PHASE ALTERNATING-CURRENT (ac) MOTORS

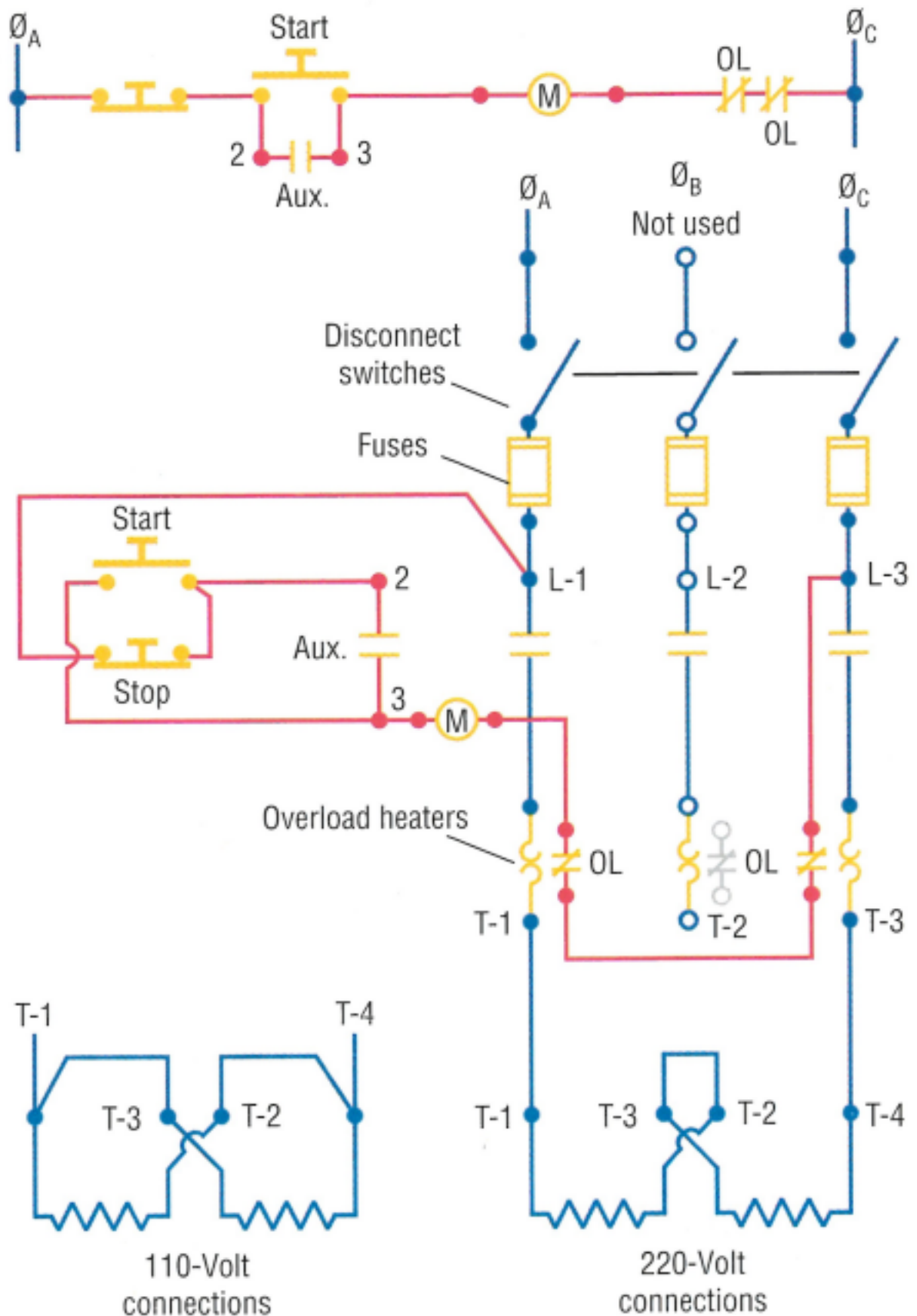
| HP | 115 V | 200 V | 208 V | 230 V |
|-------|-------|-------|-------|-------|
| 1/8 | 4.4 | 2.5 | 2.4 | 2.2 |
| 1/4 | 5.8 | 3.3 | 3.2 | 2.9 |
| 1/2 | 7.2 | 4.1 | 4.0 | 3.6 |
| 3/4 | 9.8 | 5.6 | 5.4 | 4.9 |
| 1 | 13.8 | 7.9 | 7.6 | 6.9 |
| 1 1/2 | 16 | 9.2 | 8.8 | 8.0 |
| 2 | 20 | 11.5 | 11 | 10 |
| 3 | 24 | 13.8 | 13.2 | 12 |
| 5 | 34 | 19.6 | 18.7 | 17 |
| 7 1/2 | 56 | 32.2 | 30.8 | 28 |
| 10 | 80 | 46 | 44 | 40 |
| 10 | 100 | 57.5 | 55 | 50 |

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120 and 220 to 240 volts.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 430.248.



SINGLE-PHASE MOTOR USING STANDARD THREE-PHASE STARTER

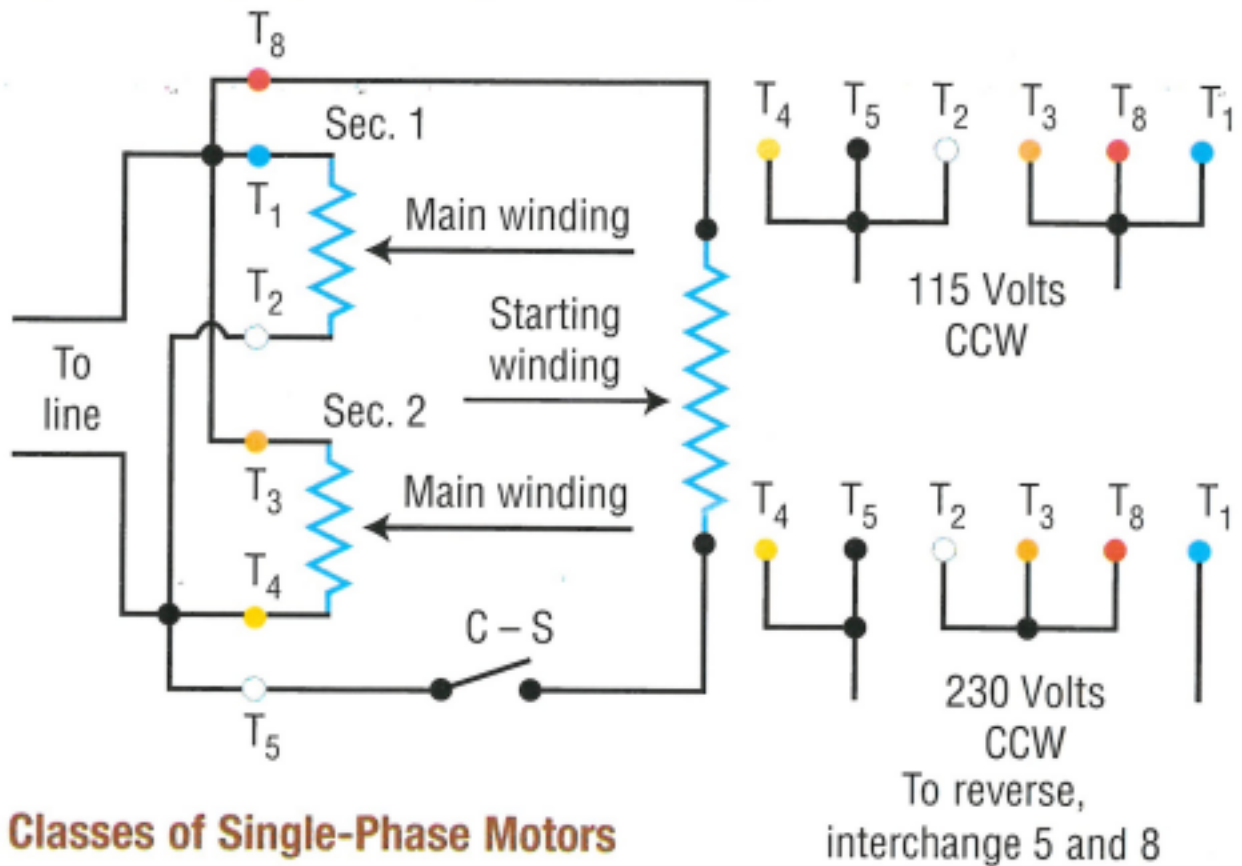


(M) = Motor starter coil



SINGLE-PHASE MOTORS

Split-Phase, Squirrel-Cage, Dual-Voltage Motor



Classes of Single-Phase Motors

1. Split-phase
 - A. Capacitor start
 - B. Repulsion start
 - C. Resistance start
 - D. Split capacitor
2. Commutator
 - A. Repulsion
 - B. Series

Terminal Color Marking

| | | |
|------------------------------|--------------------------------|-------------------------------|
| T ₁ <u>Blue</u> • | T ₃ <u>Orange</u> • | T ₅ <u>Black</u> • |
| T ₂ <u>White</u> | T ₄ <u>Yellow</u> • | T ₈ <u>Red</u> • |

Note: Split-phase motors are usually fractional horsepower. The majority of electric motors used in washing machines, refrigerators, etc. are of the split-phase type.

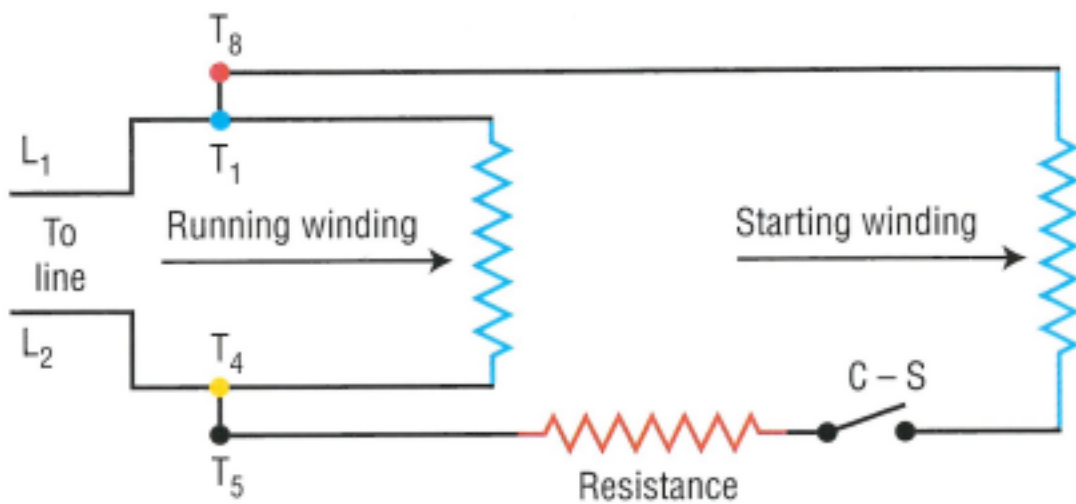
To change the speed of a split-phase motor, the number of poles must be changed.

1. Addition of running winding
2. Two starting windings and two running windings
3. Consequent pole connections

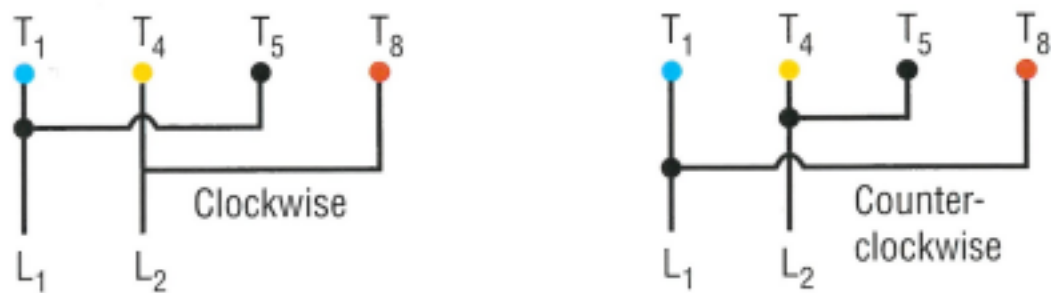
SINGLE-PHASE MOTORS

Split-Phase, Squirrel-Cage Motor

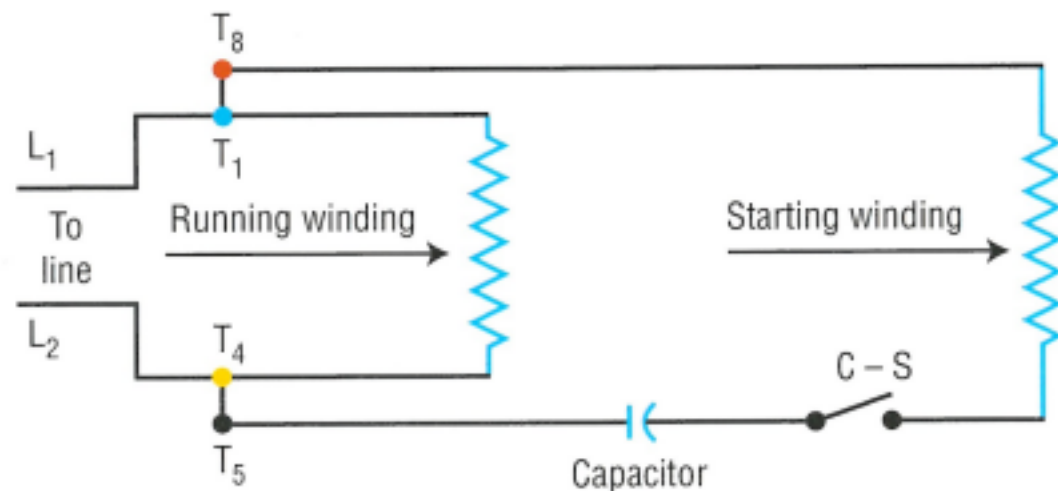
A. Resistance Start:



Centrifugal switch (cs) opens after reaching 75% of normal speed.



B. Capacitor Start:



- Note:*
1. A resistance start motor has a resistance connected in series with the starting winding.
 2. The capacitor start motor is employed where a high starting torque is required.



RUNNING OVERLOAD UNITS

| Kind of Motor | Supply System | Number and Location of Overload Units Such as Trip Coils or Relays |
|------------------|--|--|
| 1-phase ac or dc | 2-wire, 1-phase ac or dc, ungrounded | 1 in either conductor |
| 1-phase ac or dc | 2-wire, 1-phase ac or dc, one conductor grounded | 1 in ungrounded conductor |
| 1-phase ac or dc | 3-wire, 1-phase ac or dc, grounded neutral conductor | 1 in either ungrounded conductor |
| 1-phase ac | Any 3-phase | 1 in ungrounded conductor |
| 2-phase ac | 3-wire, 2-phase ac, ungrounded | 2, one in each phase |
| 2-phase ac | 3-wire, 2-phase ac, one conductor grounded | 2 in ungrounded conductors |
| 2-phase ac | 4-wire, 2-phase ac, grounded or ungrounded | 2, one for each phase in ungrounded conductors |
| 2-phase ac | Grounded neutral or 5-wire, 2-phase ac, ungrounded | 2, one for each phase in any ungrounded phase wire |
| 3-phase ac | Any 3-phase | 3, one in each phase* |

*Exception: An overload unit in each phase shall not be required where overload protection is provided by other approved means.

Source: NFPA 70®, *National Electrical Code*®, NFPA, 2026 edition, Quincy, MA, 2025, Table 430.37.



MOTOR BRANCH-CIRCUIT PROTECTIVE DEVICES: MAXIMUM RATING OR SETTING

| Type of Motor | Percent of Full-Load Current | | | |
|---|---------------------------------|---|----------------------------|-----------------------------------|
| | Nontime Delay Fuse ¹ | Dual Element (Time-Delay) Fuse ¹ | Instantaneous Trip Breaker | Inverse Time Breaker ² |
| Single-phase motors | 300 | 175 | 800 | 250 |
| Alternating-current (ac) polyphase motors other than wound rotor Squirrel cage — other than Design B or C energy-efficient — and Design B or C premium efficiency | 300 | 175 | 800 | 250 |
| Design B energy-efficient, Design B premium efficiency, Design BE, and Design CE | 300 | 175 | 1100 | 250 |
| Synchronous ³ | 300 | 175 | 800 | 250 |
| Wound rotor | 150 | 150 | 800 | 150 |
| Direct-current (dc) (constant voltage) | 150 | 150 | 250 | 150 |

Note: See 430.54 for certain exceptions to the values specified.

1 The values in the Nontime Delay Fuse column apply to time-delay Class CC fuses.

2 The values given in the Inverse Time Breaker column also cover the ratings of nonadjustable inverse time types of circuit breakers that can be modified as in 430.52(C)(1)(a) and 430.52(C)(1)(b).

3 Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as those used to drive reciprocating compressors, pumps, and so forth, that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200% of full-load current.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 430.52(C)(1).

Note: Where the result of the calculation for the branch circuit protective device does not correspond with a standard size fuse or circuit breaker, see 430.52(C)(1)(a).

Note: Where the rating specified in Table 430.52(C)(1), or the rating modified by 430.52(C)(1)(a), is not sufficient for the starting current of the motor, see 430.52(C)(1)(b).



FULL-LOAD CURRENT: THREE-PHASE ALTERNATING-CURRENT (ac) MOTORS

| HP | Induction-Type Squirrel Cage and Wound Rotor (Amperes) | | | | | | | Synchronous-Type Unity Power Factor* (Amperes) | | | |
|-------|--|----------|----------|----------|----------|----------|-----------|--|----------|----------|-----------|
| | 115 V | 200 V | 208 V | 230 V | 460 V | 575 V | 2300 V | 230 V | 460 V | 575 V | 2300 V |
| 1/2 | 4.4 | 2.5 | 2.4 | 2.2 | 1.1 | 0.9 | — | — | — | — | — |
| 3/4 | 6.4 | 3.7 | 3.5 | 3.2 | 1.6 | 1.3 | — | — | — | — | — |
| 1 | 8.4 | 4.8 | 4.6 | 4.2 | 2.1 | 1.7 | — | — | — | — | — |
| 1 1/2 | 12.0 | 6.9 | 6.6 | 6.0 | 3.0 | 2.4 | — | — | — | — | — |
| 2 | 13.6 | 7.8 | 7.5 | 6.8 | 3.4 | 2.7 | — | — | — | — | — |
| 3 | — | 11.0 | 10.6 | 9.6 | 4.8 | 3.9 | — | — | — | — | — |
| 5 | — | 17.5 | 16.7 | 15.2 | 7.6 | 6.1 | — | — | — | — | — |
| 7 1/2 | — | 25.3 | 24.2 | 22 | 11 | 9 | — | — | — | — | — |
| 10 | — | 32.2 | 30.8 | 28 | 14 | 11 | — | — | — | — | — |
| 15 | — | 48.3 | 46.2 | 42 | 21 | 17 | — | — | — | — | — |
| 20 | — | 62.1 | 59.4 | 54 | 27 | 22 | — | — | — | — | — |
| 25 | — | 78.2 | 74.8 | 68 | 34 | 27 | — | 53 | 26 | 21 | — |
| 30 | — | 92 | 88 | 80 | 40 | 32 | — | 63 | 32 | 26 | — |
| 40 | — | 120 | 114 | 104 | 52 | 41 | — | 83 | 41 | 33 | — |
| 50 | — | 150 | 143 | 130 | 65 | 52 | — | 104 | 52 | 42 | — |
| 60 | — | 177 | 169 | 154 | 77 | 62 | 16 | 123 | 61 | 49 | 12 |
| 75 | — | 221 | 211 | 192 | 96 | 77 | 20 | 155 | 78 | 62 | 15 |
| 100 | — | 285 | 273 | 248 | 124 | 99 | 26 | 202 | 101 | 81 | 20 |
| 125 | — | 359 | 343 | 312 | 156 | 125 | 31 | 253 | 126 | 101 | 25 |
| 150 | — | 414 | 396 | 360 | 180 | 144 | 37 | 302 | 151 | 121 | 30 |
| 200 | — | 552 | 528 | 480 | 240 | 192 | 49 | 400 | 201 | 161 | 40 |
| 250 | — | — | — | — | 302 | 242 | 60 | — | — | — | — |
| 300 | — | — | — | — | 361 | 289 | 72 | — | — | — | — |
| 350 | — | — | — | — | 414 | 336 | 83 | — | — | — | — |
| 400 | — | — | — | — | 477 | 382 | 95 | — | — | — | — |
| 450 | — | — | — | — | 515 | 412 | 103 | — | — | — | — |
| 500 | — | — | — | — | 590 | 472 | 118 | — | — | — | — |

*For 90% and 80% power factor, the figures shall be multiplied by 1.1 and 1.25, respectively.

Source: NFPA 70®, *National Electrical Code*®, NFPA, 2026 edition, Quincy, MA, 2025, Table 430.250.

The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 to 120, 220 to 240, 440 to 480, and 550 to 600 volts.



FULL-LOAD CURRENT AND OTHER DATA: THREE-PHASE ac MOTORS

| Motor Horsepower | | Motor Ampere Nameplate | Size Breaker ★ | Size Starter Nameplate | Heater Ampere ★★ | Size Wire | Size Conduit ★★★ |
|------------------|-------|---------------------------|-------------------|---------------------------|---------------------|-----------|---------------------|
| ½ | 230 V | 2.2 | 15 | 00 | 2.530 | 12 | ¾" |
| | 460 | 1.1 | 15 | 00 | 1.265 | 12 | ¾" |
| ¾ | 230 | 3.2 | 15 | 00 | 3.680 | 12 | ¾" |
| | 460 | 1.6 | 15 | 00 | 1.840 | 12 | ¾" |
| 1 | 230 | 4.2 | 15 | 00 | 4.830 | 12 | ¾" |
| | 460 | 2.1 | 15 | 00 | 2.415 | 12 | ¾" |
| 1½ | 230 | 6.0 | 15 | 00 | 6.900 | 12 | ¾" |
| | 460 | 3.0 | 15 | 00 | 3.450 | 12 | ¾" |
| 2 | 230 | 6.8 | 15 | 0 | 7.820 | 12 | ¾" |
| | 460 | 3.4 | 15 | 00 | 3.910 | 12 | ¾" |
| 3 | 230 | 9.6 | 20 | 0 | 11.040 | 12 | ¾" |
| | 460 | 4.8 | 15 | 0 | 5.520 | 12 | ¾" |
| 5 | 230 | 15.2 | 30 | 1 | 17.480 | 12 | ¾" |
| | 460 | 7.6 | 15 | 0 | 8.740 | 12 | ¾" |
| 7½ | 230 | 22 | 45 | 1 | 25.300 | 10 | ¾" |
| | 460 | 11 | 20 | 1 | 12.650 | 12 | ¾" |
| 10 | 230 | 28 | 60 | 2 | 32.200 | 10 | ¾" |
| | 460 | 14 | 30 | 1 | 16.100 | 12 | ¾" |
| 15 | 230 | 42 | 70 | 2 | 48.300 | 6 | 1 |
| | 460 | 21 | 40 | 2 | 24.150 | 10 | ¾" |
| 20 | 230 | 54 | 100 | 3 | 62.100 | 4 | 1 |
| | 460 | 27 | 50 | 2 | 31.050 | 10 | ¾" |
| 25 | 230 | 68 | 100 | 3 | 78.200 | 4 | 1½ |
| | 460 | 34 | 50 | 2 | 39.100 | 8 | 1 |
| 30 | 230 | 80 | 125 | 3 | 92.000 | 3 | 1½ |
| | 460 | 40 | 70 | 3 | 46.000 | 8 | 1 |
| 40 | 230 | 104 | 175 | 4 | 119.600 | 1 | 1½ |
| | 460 | 52 | 100 | 3 | 59.800 | 6 | 1 |
| 50 | 230 | 130 | 200 | 4 | 149.500 | 00 | 2 |
| | 460 | 65 | 150 | 3 | 74.750 | 4 | 1½ |
| 60 | 230 | 154 | 250 | 5 | 177.10 | 000 | 2 |
| | 460 | 77 | 200 | 4 | 88.55 | 3 | 1½ |

(continued on next page)



FULL-LOAD CURRENT AND OTHER DATA: THREE-PHASE ac MOTORS

| Motor Horsepower | Motor Voltage | Motor Ampere | Size Breaker * | Size Starter | Heater Ampere ** | Size Wire | Size Conduit *** |
|------------------|---------------|--------------|----------------|--------------|------------------|-----------|------------------|
| 75 | 230 V | 192 | 300 | 5 | 220.80 | 250 kcmil | 2½" |
| | 460 | 96 | 200 | 4 | 110.40 | 1 | 1½" |
| 100 | 230 | 248 | 400 | 5 | 285.20 | 350 kcmil | 3" |
| | 460 | 124 | 200 | 4 | 142.60 | 2/0 | 2" |
| 125 | 230 | 312 | 500 | 6 | 358.80 | 600 kcmil | 3½" |
| | 460 | 156 | 250 | 5 | 179.40 | 3/0 | 2" |
| 150 | 230 | 360 | 600 | 6 | 414.00 | 700 kcmil | 4" |
| | 460 | 180 | 300 | 5 | 207.00 | 4/0 | 2½" |

- * Overcurrent device may have to be increased due to starting current and load conditions. See *NEC* 430.52, Table 430.52(C)(1). Wire size based on 75°C (167°F) terminations and 75°C (167°F) insulation.
- ** Overload heater must be based on motor nameplate and sized per *NEC* 430.32 for continuous-duty motors and *NEC* 430.33 for intermittent and similar duty motors.
- *** Conduit size based on rigid metal conduit with some spare capacity. For minimum size and other conduit types, see *NEC* Annex C or *Ugly's* pages 84–97.



MOTOR AND MOTOR CIRCUIT CONDUCTOR PROTECTION

Motors can have large starting currents three to five times or more than that of the actual motor current. In order for motors to start, the motor and motor circuit conductors are allowed to be protected by circuit breakers and fuses at values that are higher than the actual motor and conductor ampere ratings. These larger overcurrent devices do not provide overload protection and will only open upon short circuits or ground faults. Overload protection must be used to protect the motor based on the actual nameplate amperes of the motor. This protection is usually in the form of heating elements in manual or magnetic motor starters. Small motors such as waste disposal motors have a red overload reset button built into the motor.

General Motor Rules

- Use full-load current from tables instead of nameplate.
- Branch circuit conductors: Use 125% of full-load current to find conductor size.
- Branch circuit OCP size: Use percentages given in tables for full-load current. (*Ugly's* pages 32, 34, and 39)
- Feeder conductor size: 125% of largest motor and sum of the rest.
- Feeder OCP: Use largest OCP plus rest of full-load currents.

(See examples on *Ugly's* page 42.)



MOTOR BRANCH CIRCUIT AND FEEDER EXAMPLE

General Motor Applications

Branch circuit conductors:

Use full-load, three-phase currents, from the table on *Ugly's* page 39 or 2026 *NEC* Table 430.250, 50-HP, 480-volt, 3-phase, motor Design B, 75-degree terminations = 65 Amps

125% of full-load current [*NEC* 430.22] (*Ugly's* page 41)

125% of 65 Amps = **81.25 Amps** conductor selection ampacity

Branch circuit overcurrent device: *NEC* 430.52(C)(1)

(Branch circuit short-circuit and ground fault protection)

Use percentages given in *Ugly's* page 38 or *NEC* Table 430.52(C)(1) for **Type** of circuit breaker or fuse used.

50-HP, 480-volt, 3-phase motor = 65 Amps (*Ugly's* page 39)

Nontime delay fuse = 300% (*Ugly's* page 38)

300% of 65 Amps = 195 Amps. *NEC* 430.52(C)(1)(a) Next size allowed *NEC* Table 240.6(A) = **200-amp fuse**.

Feeder connectors:

For 50-HP and 30-HP, 480-volt, 3-phase, Design B motors on same feeder:

Use 125% of the largest full-load current and 100% of the rest.
(*NEC* 430.24)

50-HP, 480-volt, 3-phase motor = 65 Amps; 30-HP, 480-volt, 3-phase motor = 40 Amps (125% of 65 Amps) + 40 Amps = **121.25 Amps** conductor selection ampacity

Feeder overcurrent device: *NEC* 430.62(A) (specific load)

(Feeder short-circuit and ground-fault protection)

Use largest overcurrent protection device **plus** full-load currents of the rest of the motors.

50 HP = 200-Amp fuse (65 FLC)

30 HP = 125-Amp fuse (40 FLC)

200-Amp fuse + 40 Amp (FLC) = 240 Amp. Do not exceed this value on feeder. The next standard size fuse below 240 is a **225-amp** fuse.



LOCKED-ROTOR INDICATING CODE LETTERS

| Code Letter | Kilovolt-Amperes per Horsepower with Locked Rotor | Code Letter | Kilovolt-Amperes per Horsepower with Locked Rotor |
|-------------|---|-------------|---|
| A..... | 0–3.14 | L..... | 9.0–9.99 |
| B..... | 3.15–3.54 | M..... | 10.0–11.19 |
| C..... | 3.55–3.99 | N..... | 11.2–12.49 |
| D..... | 4.0–4.49 | P..... | 12.5–13.99 |
| E..... | 4.5–4.99 | R..... | 14.0–15.99 |
| F..... | 5.0–5.59 | S..... | 16.0–17.99 |
| G..... | 5.6–6.29 | T..... | 18.0–19.99 |
| H..... | 6.3–7.09 | U..... | 20.0–22.39 |
| J..... | 7.1–7.99 | V..... | 22.4 and up |
| K..... | 8.0–8.99 | | |

Source: NFPA 70®, *National Electrical Code*®, NFPA, 2026 edition, Quincy, MA, 2025, Table 430.7(B), as modified.

The *National Electrical Code*® requires that all alternating-current (ac) motors rated ½ HP or more (except for polyphase wound-rotor motors) must have code letters on their nameplates indicating motor input with locked rotor (in kilovolt-amperes per horsepower). The motor's horsepower, voltage, and locked-rotor code letter are needed to calculate the motor's locked-rotor current. Use the following formulas:

Single-Phase Motors:

$$\text{Locked-Rotor Current} = \frac{\text{HP} \times \text{KVA}_{\text{hp}} \times 1000}{E}$$

Three-Phase Motors:

$$\text{Locked-Rotor Current} = \frac{\text{HP} \times \text{KVA}_{\text{hp}} \times 1000}{E \times 1.73}$$

Example: What is the maximum locked-rotor current for a 480-volt, 25-HP, code letter F motor?

(From the above table, code letter F = 5.59 kVA_{hp})

$$I = \frac{\text{HP} \times \text{kVA}_{\text{hp}} \times 1000}{E \times 1.73} = \frac{25 \times 5.59 \times 1000}{480 \times 1.73} = \mathbf{168.29 \text{ Amps}}$$



MAXIMUM MOTOR LOCKED-ROTOR CURRENT IN AMPERES, SINGLE PHASE

| HP | 115 V | 208 V | 230 V | HP | 115 V | 208 V | 230 V |
|----|-------|-------|-------|----|-------|-------|-------|
| ½ | 58.8 | 32.5 | 29.4 | 3 | 204 | 113 | 102 |
| ¾ | 82.8 | 45.8 | 41.4 | 5 | 336 | 186 | 168 |
| 1 | 96 | 53 | 48 | 7½ | 480 | 265 | 240 |
| 1½ | 120 | 66 | 60 | 10 | 1000 | 332 | 300 |
| 2 | 144 | 80 | 72 | | | | |

Note: For use only with 430.110, 440.12, 440.41, and 455.8(C).

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 430.251(A), as modified.



MAXIMUM MOTOR LOCKED-ROTOR CURRENT IN AMPERES, TWO AND THREE PHASE, DESIGN B, C, AND D*

| HP | 115 V | 200 V | 208 V | 230 V | 460 V | 575 V |
|-----|-------|-------|-------|-------|-------|-------|
| ½ | 40 | 23 | 22.1 | 20 | 10 | 8 |
| ¾ | 50 | 28.8 | 27.6 | 25 | 12.5 | 10 |
| 1 | 60 | 34.5 | 33 | 30 | 15 | 12 |
| 1½ | 80 | 46 | 44 | 40 | 20 | 16 |
| 2 | 100 | 57.5 | 55 | 50 | 25 | 20 |
| 3 | — | 73.6 | 71 | 64 | 32 | 25.6 |
| 5 | — | 105.8 | 102 | 92 | 46 | 36.8 |
| 7½ | — | 146 | 140 | 127 | 63.5 | 50.8 |
| 10 | — | 186.3 | 179 | 162 | 81 | 64.8 |
| 15 | — | 267 | 257 | 232 | 116 | 93 |
| 20 | — | 334 | 321 | 290 | 145 | 116 |
| 25 | — | 420 | 404 | 365 | 183 | 146 |
| 30 | — | 500 | 481 | 435 | 218 | 174 |
| 40 | — | 667 | 641 | 580 | 290 | 232 |
| 50 | — | 834 | 802 | 725 | 363 | 290 |
| 60 | — | 1001 | 962 | 870 | 435 | 348 |
| 75 | — | 1248 | 1200 | 1085 | 543 | 434 |
| 100 | — | 1668 | 1603 | 1450 | 725 | 580 |
| 125 | — | 2087 | 2007 | 1815 | 908 | 726 |
| 150 | — | 2496 | 2400 | 2170 | 1085 | 868 |
| 200 | — | 3335 | 3207 | 2900 | 1450 | 1160 |

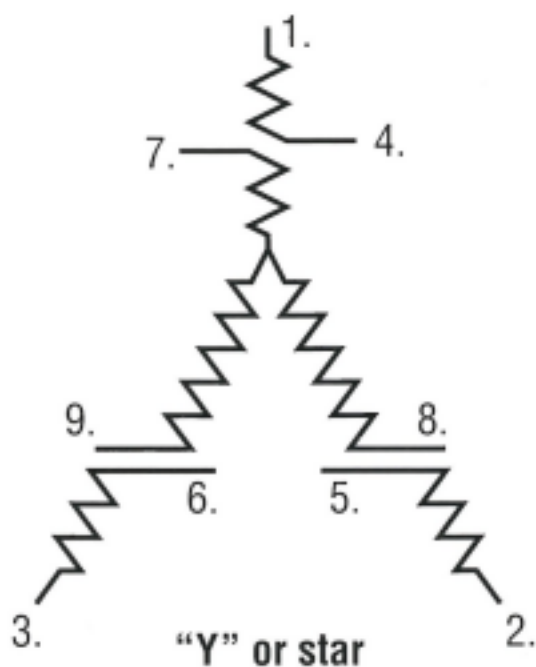
* Design A motors are not limited to a maximum starting current or locked-rotor current.

Note: For use only with 430.110, 440.12, 440.41, and 455.8(C).

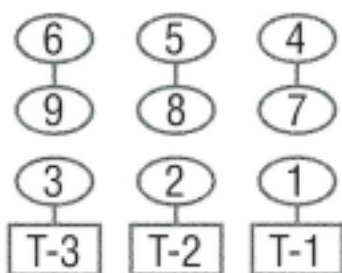
Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 430.251(B), as modified.



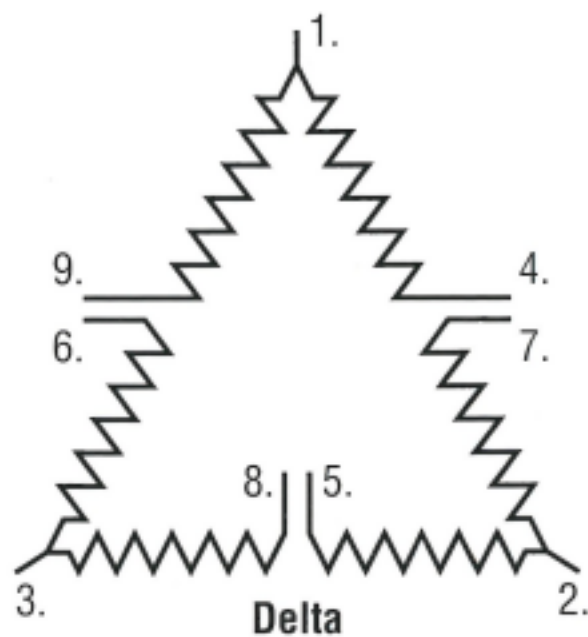
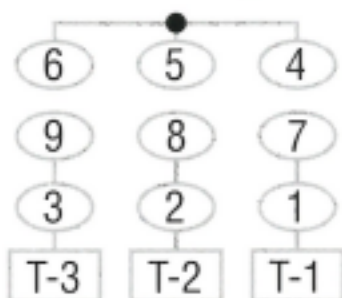
THREE-PHASE ac MOTOR WINDINGS AND CONNECTIONS



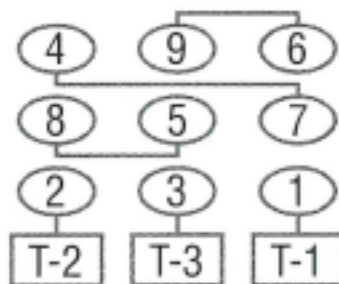
High voltage



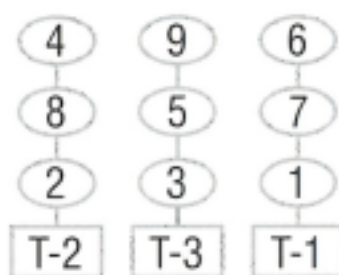
Low voltage



High voltage



Low voltage

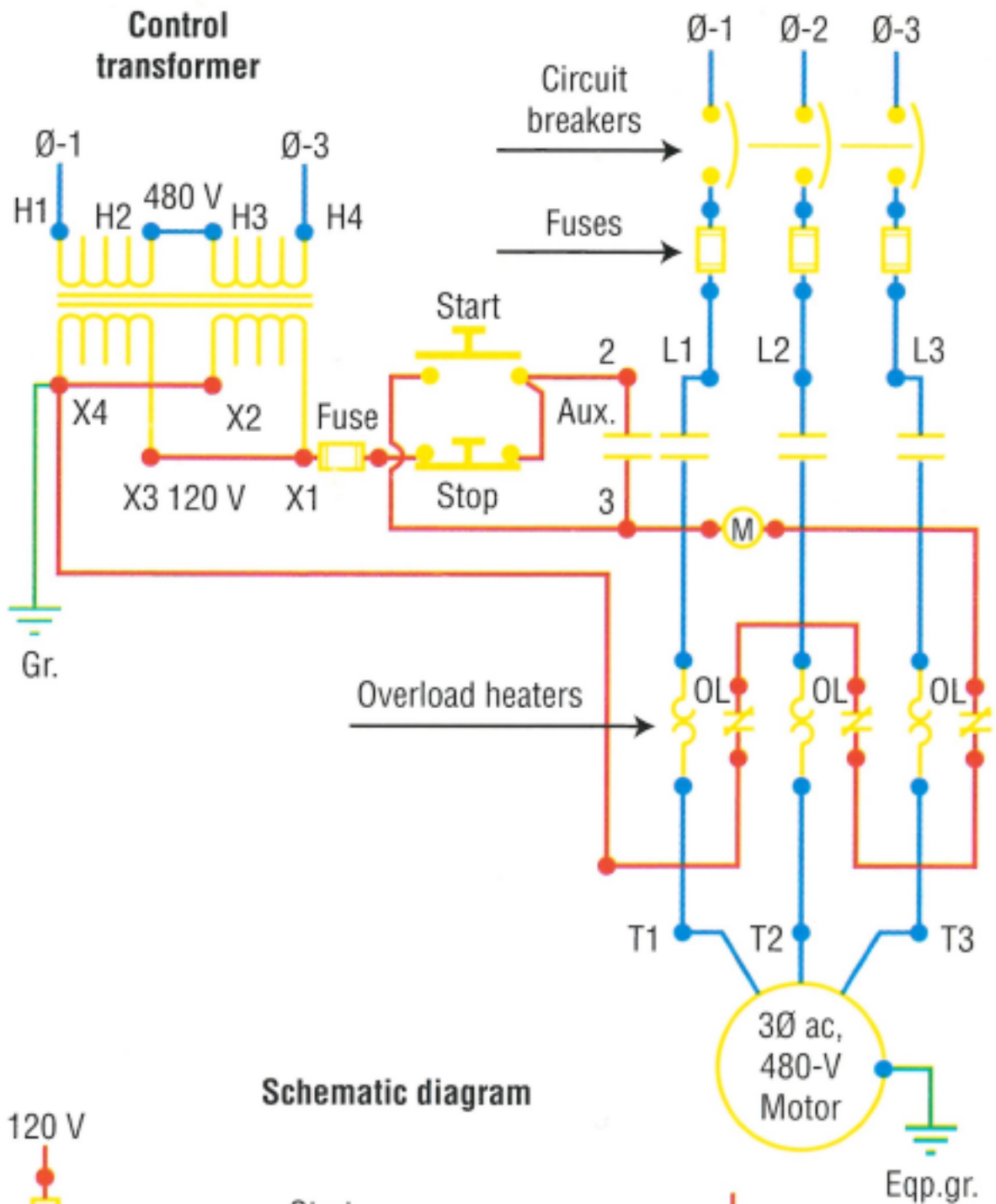


- Note:*
1. The most important part of any motor is the nameplate. Check the data given on the plate before making the connections.
 2. To change rotation direction of 3-phase motor, swap any two T-leads.

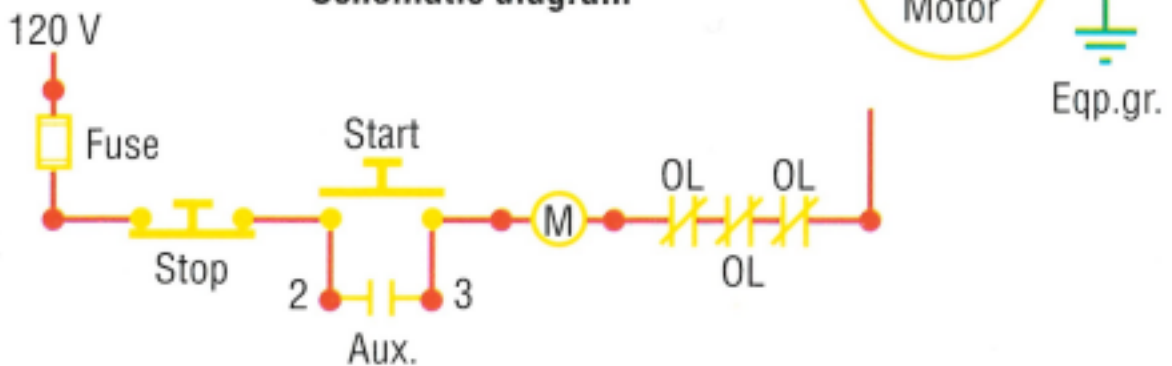


THREE-WIRE STOP-START STATION

Wiring diagram



Schematic diagram

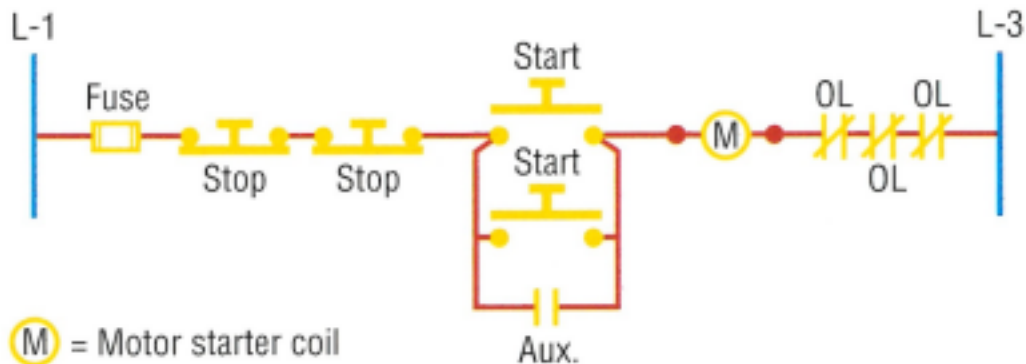
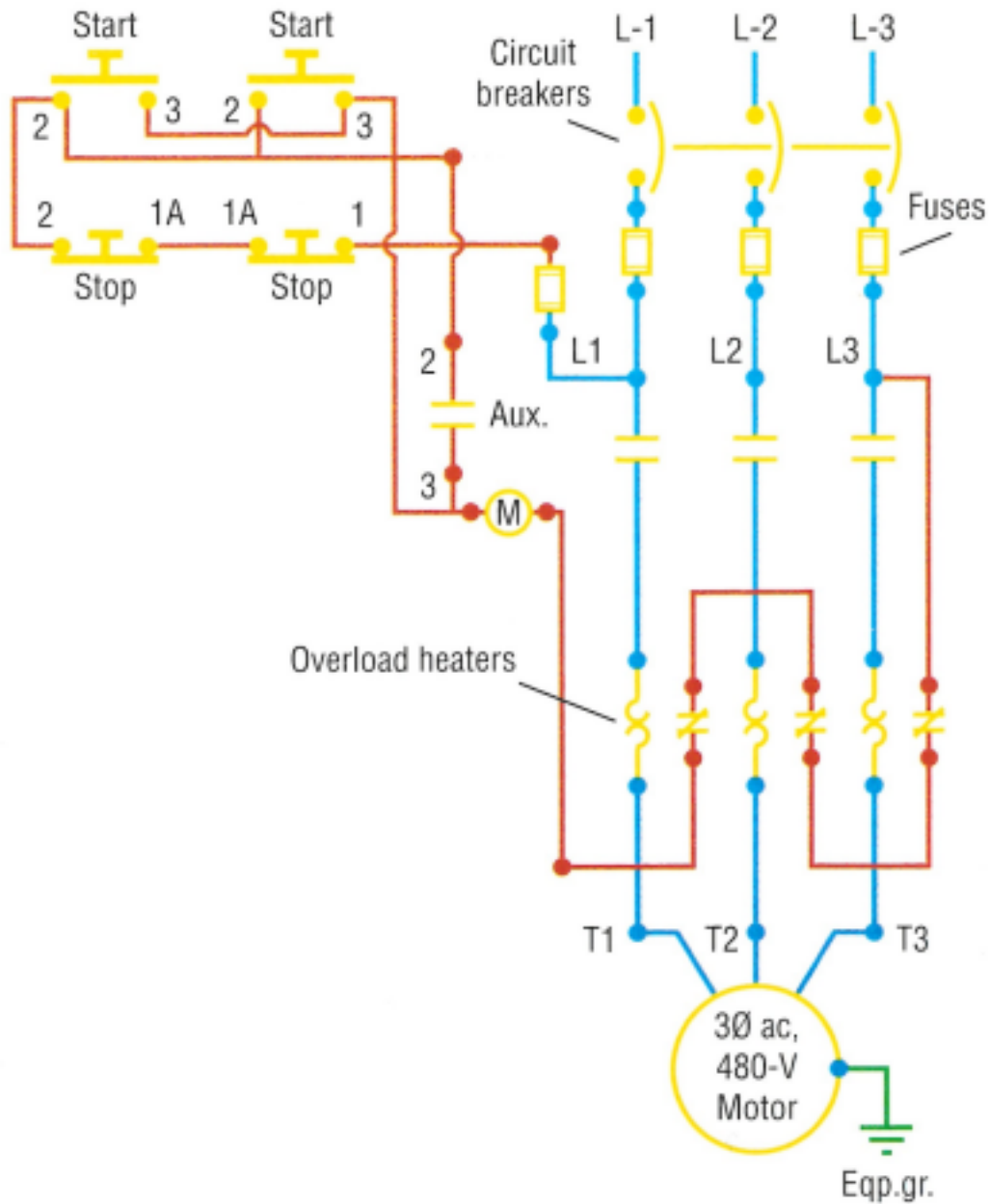


(M) = Motor starter coil

Note: Controls and motor are of different voltages.



TWO THREE-WIRE STOP-START STATIONS



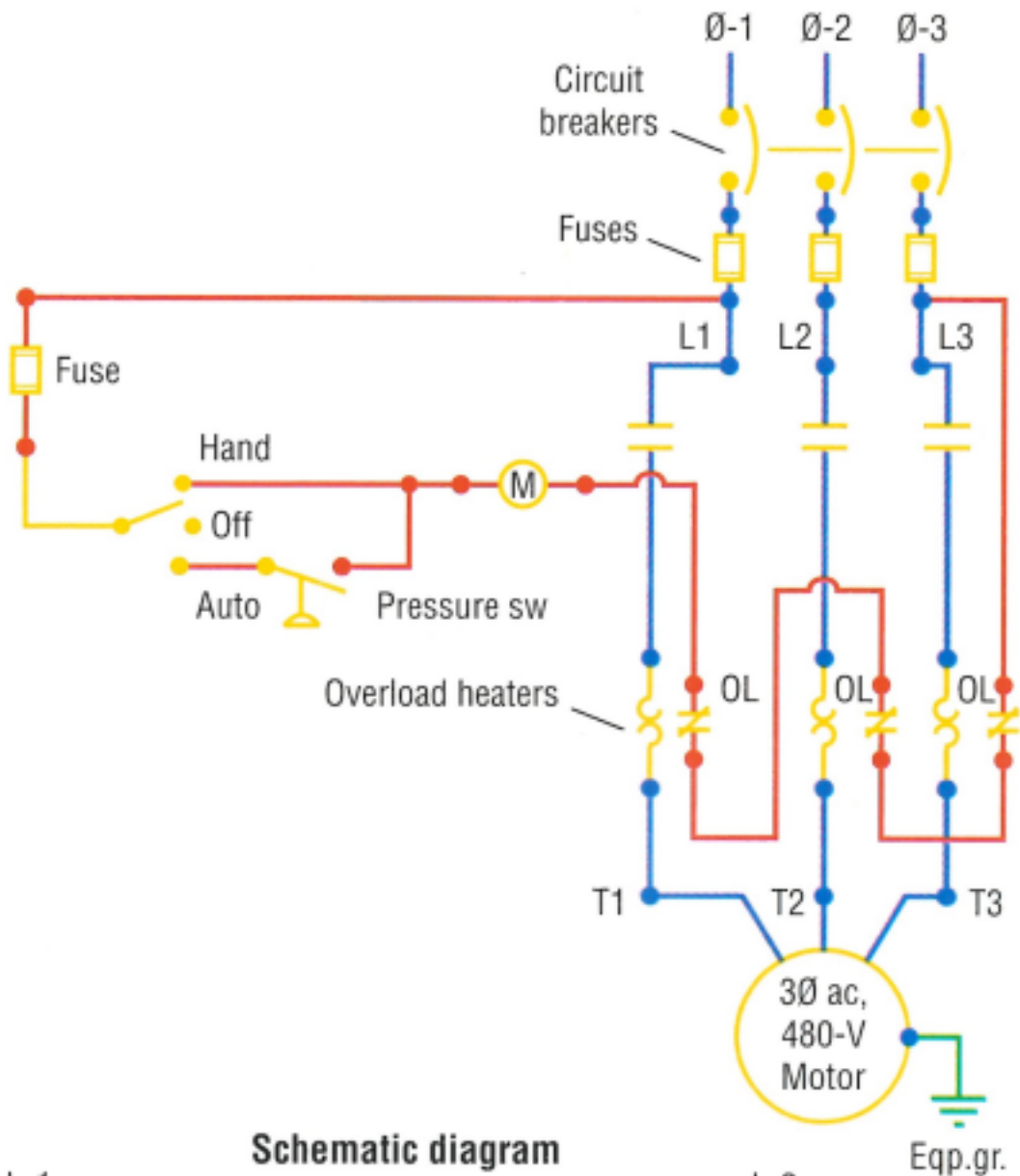
Note: Controls and motor are of the same voltage.

If low-voltage controls are used, see *Ugly's* page 46 for control transformer connections.

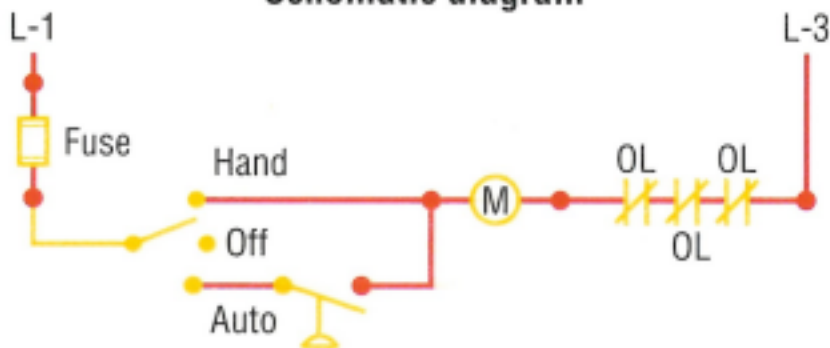


HAND-OFF AUTOMATIC CONTROL

Wiring diagram



Schematic diagram



(M) = Motor starter coil

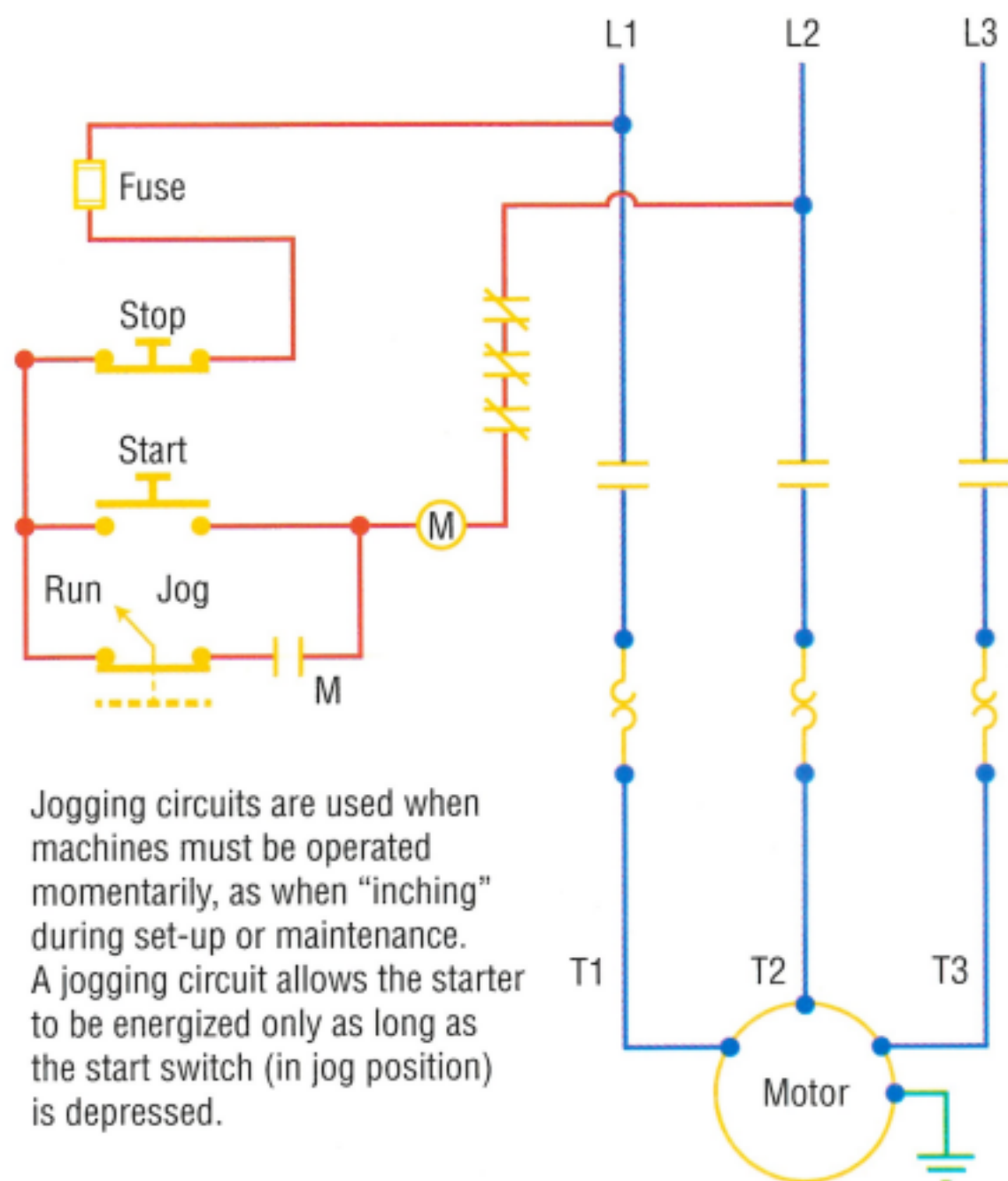
Note: Controls and motor are of the same voltage.

If low-voltage controls are used, see *Ugly's* page 46 for control transformer connections.

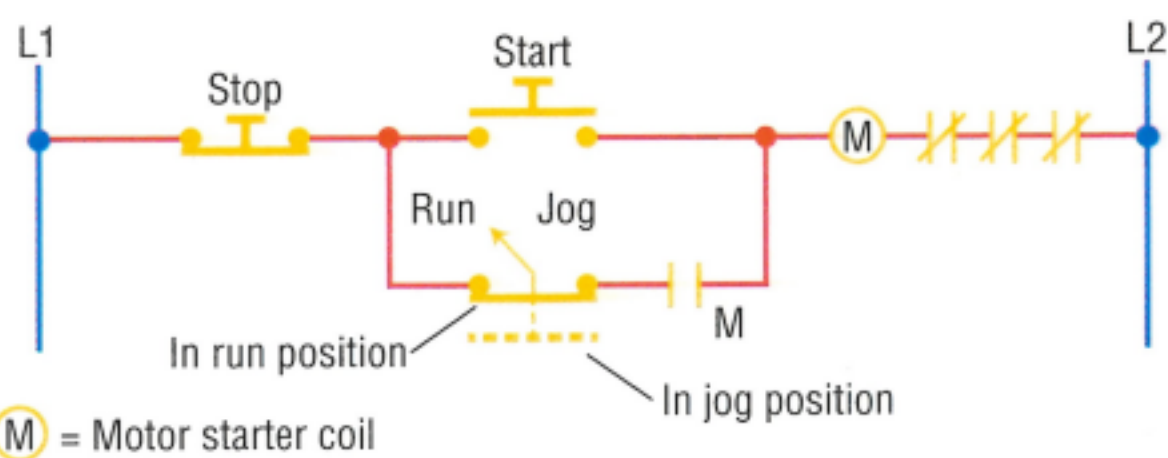


JOGGING WITH SELECTOR SWITCH

Jogging control



Jogging circuits are used when machines must be operated momentarily, as when “inching” during set-up or maintenance. A jogging circuit allows the starter to be energized only as long as the start switch (in jog position) is depressed.





VOLTAGE DROP CALCULATIONS: INDUCTANCE NEGLIGIBLE

- Vd = Voltage Drop
 I = Current in Conductor (Amperes)
 L = One-way Length of Circuit (Feet)
 Cm = Cross-Sectional Area of Conductor (Circular Mils) (page 71)
 K = Resistance in Ohms of 1 Circular Mil Foot of Conductor
K = 12.9 for Copper Conductors @ 75°C (167°F)
K = 21.2 for Aluminum Conductors @ 75°C (167°F)

Note: K value changes with temperature and other factors. See NEC Chapter 9, Table 8, Note 1.

Single-Phase Circuits

$$Vd = \frac{2K \times L \times I}{Cm} \quad \text{or} \quad *Cm = \frac{2K \times L \times I}{Vd}$$

Three-Phase Circuits

$$Vd = \frac{1.73K \times L \times I}{Cm} \quad \text{or} \quad *Cm = \frac{1.73K \times L \times I}{Vd}$$

*Note: Always check ampacity tables to ensure conductor's ampacity is equal to load after voltage drop calculation.

Refer to *Ugly's* pages 71–82 for conductor size, type, and ampacity.

See *Ugly's* pages 51–52 for examples.



VOLTAGE DROP EXAMPLES

Distance (One Way) for 2% Voltage Drop for 120 Volts Single Phase

| AMPS | VOLTS | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG | 1/0 AWG |
|------|-------|--------|--------|-------|-------|-------|-------|-------|-------|---------|
| 20 | 120 | 30 | 48 | 77 | 122 | 194 | 245 | 309 | 389 | 491 |
| | 240 | 60 | 96 | 154 | 244 | 388 | 490 | 618 | 778 | 982 |
| 30 | 120 | | 32 | 51 | 81 | 129 | 163 | 206 | 260 | 327 |
| | 240 | | 64 | 102 | 162 | 258 | 326 | 412 | 520 | 654 |
| 40 | 120 | | | 38 | 61 | 97 | 122 | 154 | 195 | 246 |
| | 240 | | | 76 | 122 | 194 | 244 | 308 | 390 | 492 |
| 50 | 120 | | | | 49 | 78 | 98 | 123 | 156 | 196 |
| | 240 | | | | 98 | 156 | 196 | 246 | 312 | 392 |
| 60 | 120 | | | | | 65 | 82 | 103 | 130 | 164 |
| | 240 | | | | | 130 | 164 | 206 | 260 | 328 |
| 70 | 240 | | | | | 111 | 140 | 176 | 222 | 281 |
| 80 | 240 | | | | | | 122 | 154 | 195 | 246 |
| 90 | 240 | | | | | | | 137 | 173 | 218 |
| 100 | 240 | | | | | | | | 156 | 196 |

(See Footnotes on Page 51 Concerning Circuit Load Limitations.)



VOLTAGE DROP EXAMPLES

Typical Voltage Drop Values Based on Conductor Size and One-Way Length* (60°C [140°F] Termination and Insulation)

| 25 Feet | | | | | | | | |
|---------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 1.98 | 1.24 | 0.78 | 0.49 | 0.31 | 0.25 | 0.19 | 0.15 |
| 30 | | 1.86 | 1.17 | 0.74 | 0.46 | 0.37 | 0.29 | 0.23 |
| 40 | | | 1.56 | 0.98 | 0.62 | 0.49 | 0.39 | 0.31 |
| 50 | | | | 1.23 | 0.77 | 0.61 | 0.49 | 0.39 |
| 60 | | | | | 0.93 | 0.74 | 0.58 | 0.46 |

| 50 Feet | | | | | | | | |
|---------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 3.95 | 2.49 | 1.56 | 0.98 | 0.62 | 0.49 | 0.39 | 0.31 |
| 30 | | 3.73 | 2.34 | 1.47 | 0.93 | 0.74 | 0.58 | 0.46 |
| 40 | | | 3.13 | 1.97 | 1.24 | 0.98 | 0.78 | 0.62 |
| 50 | | | | 2.46 | 1.55 | 1.23 | 0.97 | 0.77 |
| 60 | | | | | 1.85 | 1.47 | 1.17 | 0.92 |

| 75 Feet | | | | | | | | |
|---------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 5.93 | 3.73 | 2.34 | 1.47 | 0.93 | 0.74 | 0.58 | 0.46 |
| 30 | | 5.59 | 3.52 | 2.21 | 1.39 | 1.10 | 0.87 | 0.69 |
| 40 | | | 4.69 | 2.95 | 1.85 | 1.47 | 1.17 | 0.92 |
| 50 | | | | 3.69 | 2.32 | 1.84 | 1.46 | 1.16 |
| 60 | | | | | 2.78 | 2.21 | 1.75 | 1.39 |

| 100 Feet | | | | | | | | |
|----------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 7.90 | 4.97 | 3.13 | 1.97 | 1.24 | 0.98 | 0.78 | 0.62 |
| 30 | | 7.46 | 4.69 | 2.95 | 1.85 | 1.47 | 1.17 | 0.92 |
| 40 | | | 6.25 | 3.93 | 2.47 | 1.96 | 1.56 | 1.23 |
| 50 | | | | 4.92 | 3.09 | 2.45 | 1.94 | 1.54 |
| 60 | | | | | 3.71 | 2.94 | 2.33 | 1.85 |

| 125 Feet | | | | | | | | |
|----------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 9.88 | 6.21 | 3.91 | 2.46 | 1.55 | 1.23 | 0.97 | 0.77 |
| 30 | | 9.32 | 5.86 | 3.69 | 2.32 | 1.84 | 1.46 | 1.16 |
| 40 | | | 7.81 | 4.92 | 3.09 | 2.45 | 1.94 | 1.54 |
| 50 | | | | 6.15 | 3.86 | 3.06 | 2.43 | 1.93 |
| 60 | | | | | 4.64 | 3.68 | 2.92 | 2.31 |

| 150 Feet | | | | | | | | |
|----------|--------|--------|-------|-------|-------|-------|-------|-------|
| | 12 AWG | 10 AWG | 8 AWG | 6 AWG | 4 AWG | 3 AWG | 2 AWG | 1 AWG |
| 20 A | 11.85 | 7.46 | 4.69 | 2.95 | 1.85 | 1.47 | 1.17 | 0.92 |
| 30 | | 11.18 | 7.03 | 4.42 | 2.78 | 2.21 | 1.75 | 1.39 |
| 40 | | | 9.38 | 5.90 | 3.71 | 2.94 | 2.33 | 1.85 |
| 50 | | | | 7.37 | 4.64 | 3.68 | 2.92 | 2.31 |
| 60 | | | | | 5.56 | 4.41 | 3.50 | 2.77 |

A 2-wire, 20-amp circuit using 12 AWG with a one-way distance of 25 feet will drop 1.98 volts.
 120 Volts – 1.98 Volts = 118.02 Volts as the load voltage.
 240 Volts – 1.98 Volts = 238.02 Volts as the load voltage.

*Better economy and efficiency will result using the voltage drop method on page 50.

A continuous load cannot exceed 80% of the circuit rating.

A motor or heating load cannot exceed 80% of the circuit rating.

For motor overcurrent devices and conductor sizing, see *Ugly's* pages 40–42.



VOLTAGE DROP CALCULATION EXAMPLES

Single-Phase Voltage Drop

What is the voltage drop of a 240-volt, single-phase circuit consisting of #8 THWN copper conductors feeding a 30-amp load that is 150 feet in length?

Voltage Drop Formula (see *Ugly's* page 50)

$$Vd = \frac{2K \times L \times I}{Cm} = \frac{2 \times 12.9 \times 150 \times 30}{16510} = \frac{116100}{16510} = 7 \text{ Volts}$$

Percentage voltage drop = 7 Volts/240 Volts = 0.029 = **2.9%**
Voltage at load = 240 Volts – 7 Volts = **233 Volts**

Three-Phase Voltage Drop

What is the voltage drop of a 480-volt, 3-phase circuit consisting of 250-kcmil THWN copper conductors that supply a 250-amp load that is 500 feet from the source?

250 kcmil = 250000 circular mils

Voltage Drop Formula (see *Ugly's* page 50)

$$Vd = \frac{1.73K \times L \times I}{Cm} = \frac{1.73 \times 12.9 \times 500 \times 250}{250000} = \frac{2789625}{250000} = 11 \text{ Volts}$$

Percentage voltage drop = 11 Volts/480 Volts = 0.0229 = **2.29%**
Voltage at load = 480 Volts – 11 Volts = **469 Volts**

Note: Always check ampacity tables for conductors selected.

Refer to *Ugly's* pages 71–82 for conductor size, type, and ampacity.



SHORT-CIRCUIT CALCULATION

(Courtesy of Cooper Bussmann)

Basic Short-Circuit Calculation Procedure

1. Determine transformer full-load amperes from either:

- Nameplate
- Formula:

$$3\emptyset \text{ transformer } I_{l.l.} = \frac{\text{KVA} \times 1000}{E_{L-L} \times 1.732}$$

$$1\emptyset \text{ transformer } I_{l.l.} = \frac{\text{KVA} \times 1000}{E_{L-L}}$$

2. Find transformer multiplier.

$$\text{Multiplier} = \frac{100}{*\%Z_{\text{trans}}}$$

3. Determine transformer let-through short-circuit current. **

$$I_{s.c.} = I_{l.l.} \times \text{Multiplier}$$

4. Calculate "f" factor.

$$3\emptyset \text{ faults } f = \frac{1.732 \times L \times I_{3\emptyset}}{C \times E_{L-L}}$$

$$1\emptyset \text{ line-to-line (L-L) faults } f = \frac{2 \times L \times I_{L-L}}{C \times E_{L-L}}$$

on 1 \emptyset Center Tapped Transformer

$$1\emptyset \text{ line-to-neutral (L-N) } f = \frac{2 \times L \times I_{L-N}^{***}}{C \times E_{L-N}}$$

faults on 1 \emptyset Center Tapped Transformer

L = Length (feet) of conductor to the fault

C = Constant from Table C (page 55) for conductors and busway. For parallel runs, multiply C values by the number of conductors per phase.

I = Available short-circuit current in amperes at beginning of circuit.

5. Calculate "M" (multiplier) $M = \frac{1}{1 + f}$

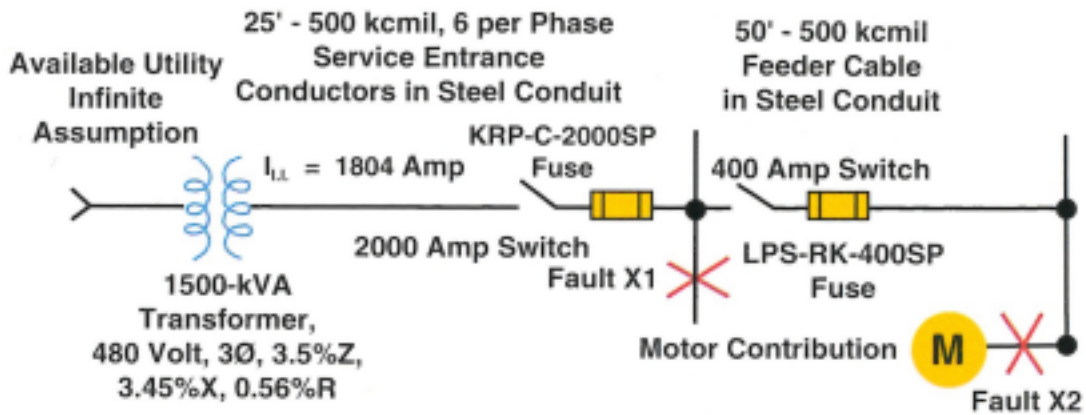
6. Calculate the available short-circuit symmetrical RMS current at the point of fault.

$$I_{s.c. \text{ sym RMS}} = I_{s.c.} \times M$$



SHORT-CIRCUIT CALCULATION

(Courtesy of Cooper Bussmann)



Example: Short-Circuit Calculation

(Fault #1)

- $$I_{L-L} = \frac{\text{KVA} \times 1000}{E_{L-L} \times 1.732} = \frac{1500 \times 1000}{480 \times 1.732} = 1804 \text{ Amps}$$
- $$\text{Multiplier} = \frac{100}{\%Z_{\text{trans}}} = \frac{100}{3.5} = 28.57$$
- $$I_{S.C.} = 1804 \times 28.57 = 51540 \text{ Amps}$$
- $$f = \frac{1.732 \times L \times I_{3\phi}}{C \times E_{L-L}} = \frac{1.73 \times 25 \times 51540}{6 \times 22185 \times 480} = 0.0349$$
- $$M = \frac{1}{1 + f} = \frac{1}{1 + 0.0349} = 0.9663$$
- $$I_{S.C. \text{ sym RMS}} = I_{S.C.} \times M = 51540 \times 0.9663 = 49803 \text{ Amps}$$

$$I_{S.C. \text{ motor contrib}} = 4 \times 1804 = 7216 \text{ Amps}$$

$$I_{\text{total S.C. sym RMS}} = 49803 + 7216 = 57019 \text{ Amps}$$

(Fault #2)

- Use $I_{S.C. \text{ sym RMS}}$ @ Fault X_1 to calculate "f"

$$f = \frac{1.73 \times 50 \times 49803}{22185 \times 480} = 0.4050$$
- $$M = \frac{1}{1 + 0.4050} = 0.7117$$
- $$I_{S.C. \text{ sym RMS}} = 49803 \times 0.7117 = 35445 \text{ Amps}$$

$$I_{\text{sym motor contrib}} = 4 \times 1804 = 7216 \text{ Amps}$$

$$I_{\text{total S.C. sym RMS}} = 35445 + 7216 = 42661 \text{ Amps}$$



SHORT-CIRCUIT CALCULATION

“C” Values for Conductors (Courtesy of Cooper Bussmann)

| AWG or MCM | Copper Three Single Conductors Steel Conduit | | | | | | Copper Three Conductor Cable Steel Conduit | | | | | |
|------------------|--|-------|-------|-------|---------------------|-------|--|-------|-------|-------|---------------------|-------|
| | 5 kV | | 15 kV | | Nonmagnetic Conduit | | 5 kV | | 15 kV | | Nonmagnetic Conduit | |
| | 600 V | 15 kV | 600 V | 15 kV | 600 V | 15 kV | 600 V | 15 kV | 600 V | 15 kV | 600 V | 15 kV |
| 12 | 617 | 617 | 617 | 617 | 617 | 617 | 617 | 617 | 617 | 617 | 617 | 617 |
| 10 | 981 | 981 | 981 | 981 | 981 | 981 | 981 | 981 | 981 | 981 | 981 | 981 |
| 8 | 1557 | 1557 | 1557 | 1557 | 1558 | 1555 | 1558 | 1557 | 1559 | 1558 | 1558 | 1559 |
| 6 | 2425 | 2406 | 2389 | 2389 | 2430 | 2417 | 2406 | 2424 | 2431 | 2414 | 2428 | 2420 |
| 4 | 3806 | 3750 | 3695 | 3695 | 3825 | 3789 | 3752 | 3811 | 3830 | 3778 | 3823 | 3798 |
| 3 | 4760 | 4760 | 4760 | 4760 | 4802 | 4802 | 4802 | 4790 | 4760 | 4760 | 4802 | 4802 |
| 2 | 5906 | 5736 | 5574 | 5574 | 6044 | 5926 | 5809 | 5929 | 5989 | 5827 | 6022 | 5957 |
| 1 | 7292 | 7029 | 6758 | 6758 | 7493 | 7306 | 7108 | 7364 | 7454 | 7188 | 7507 | 7364 |
| 1/0 | 8924 | 8543 | 7973 | 7973 | 9317 | 9033 | 8590 | 9086 | 9209 | 8707 | 9372 | 9052 |
| 2/0 | 10755 | 10061 | 9389 | 9389 | 11423 | 10877 | 10318 | 11045 | 11244 | 10500 | 11528 | 11052 |
| 3/0 | 12843 | 11804 | 11021 | 11021 | 13923 | 13048 | 12360 | 13333 | 13656 | 12613 | 14118 | 13461 |
| 4/0 | 15082 | 13605 | 12542 | 12542 | 16673 | 15351 | 14347 | 15890 | 16391 | 14813 | 17019 | 16012 |
| 250 | 16483 | 14924 | 13643 | 13643 | 18593 | 17120 | 15865 | 17850 | 18310 | 16465 | 19352 | 18001 |
| 300 | 18176 | 16292 | 14768 | 14768 | 20867 | 18975 | 17408 | 20051 | 20617 | 18318 | 22524 | 20163 |
| 350 | 19703 | 17385 | 15678 | 15678 | 22736 | 20526 | 18672 | 21914 | 22646 | 19821 | 24904 | 21982 |
| 400 | 20565 | 18235 | 16365 | 16365 | 24296 | 21786 | 19731 | 23371 | 24253 | 21042 | 26915 | 23517 |
| 500 | 22185 | 19172 | 17492 | 17492 | 26706 | 23277 | 21329 | 25449 | 26980 | 23125 | 30028 | 25916 |
| 600 | 22965 | 20567 | 17962 | 17962 | 28033 | 25203 | 22097 | 27974 | 28752 | 24896 | 32236 | 27766 |
| 750 | 24136 | 21386 | 18888 | 18888 | 28303 | 25430 | 22690 | 30024 | 31050 | 26932 | 32404 | 28303 |
| 1000 | 25278 | 22539 | 19923 | 19923 | 31490 | 28083 | 24887 | 32688 | 33864 | 29320 | 37197 | 31959 |

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(continued on next page)



SHORT-CIRCUIT CALCULATION

(Courtesy of Cooper Bussmann)

Notes:

*Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows:

The transformer secondary is short circuited. Voltage is applied to the primary, which causes full-load current to flow in the secondary. This applied voltage divided by the rated primary voltage is the impedance of the transformer.

Example:

For a 480-volt rated primary, if 9.6 volts causes secondary full-load current to flow through the shorted secondary, the transformer impedance is $9.6 \div 480 = 0.02 = 2\%Z$.

In addition, U.L. listed transformers 25 kVA and larger have a $\pm 10\%$ impedance tolerance. Short-circuit amperes can be affected by this tolerance.

**Motor short-circuit contribution, if significant, may be added to the transformer secondary short-circuit current value as determined in Step 3. Proceed with this adjusted figure through Steps 4, 5, and 6. A practical estimate of motor short-circuit contribution is to multiply the total motor current in amperes by 4.

***The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows:

At L-N center tapped transformer terminals,

$$I_{L-N} = 1.5 \times I_{L-L} \text{ at Transformer Terminals.}$$



COMPONENT PROTECTION

(Courtesy of Cooper Bussmann)

How to Use Current-Limitation Charts

Example: An 800-amps circuit and an 800-amps, low-peak, current-limiting, time-delay fuse

How to Use the Let-Through Charts:

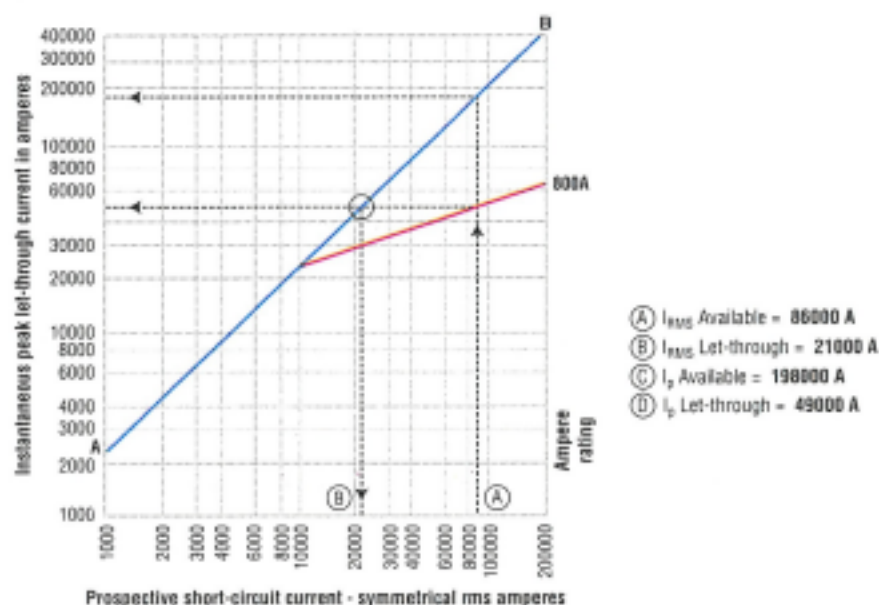
Using the example above, one can determine the pertinent let-through data for the KRP-C-800SP ampere, low-peak fuse. The let-through chart pertaining to the 800-amps, low-peak fuse is illustrated.

A. Determine the PEAK let-through CURRENT.

1. Enter the chart on the Prospective Short-Circuit Current scale at 86000 amp and proceed vertically until the 800-amps fuse curve is intersected.
2. Follow horizontally until the Instantaneous Peak Let-Through Current scale is intersected.
3. Read the PEAK let-through CURRENT as 49000 amps. (If a fuse had not been used, the peak current would have been 198000 amps.)

B. Determine the APPARENT PROSPECTIVE RMS SYMMETRICAL let-through CURRENT.

1. Enter the chart on the Prospective Short-Circuit current scale at 86000 amps and proceed vertically until the 800-amps fuse curve is intersected.
2. Follow horizontally until line A-B is intersected.
3. Proceed vertically down to the Prospective Short-Circuit Current.
4. Read the APPARENT PROSPECTIVE RMS SYMMETRICAL let-through CURRENT as 21000 amps. (The RMS SYMMETRICAL let-through CURRENT would be 86000 amps if there were no fuse in the circuit.)

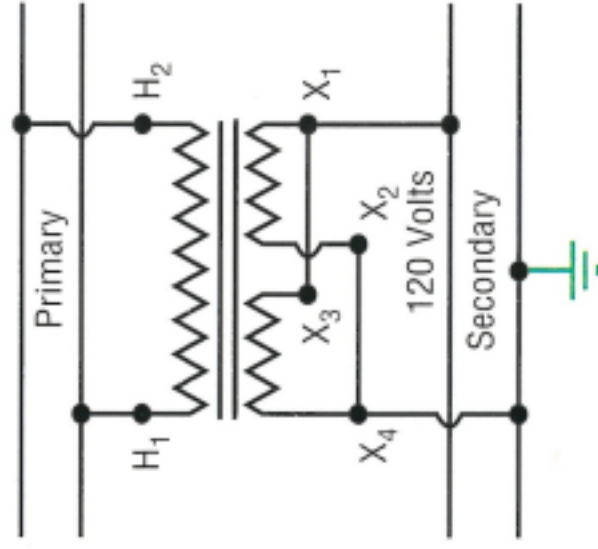


The data that can be obtained from the Fuse Let-Through Charts and their physical effects are:

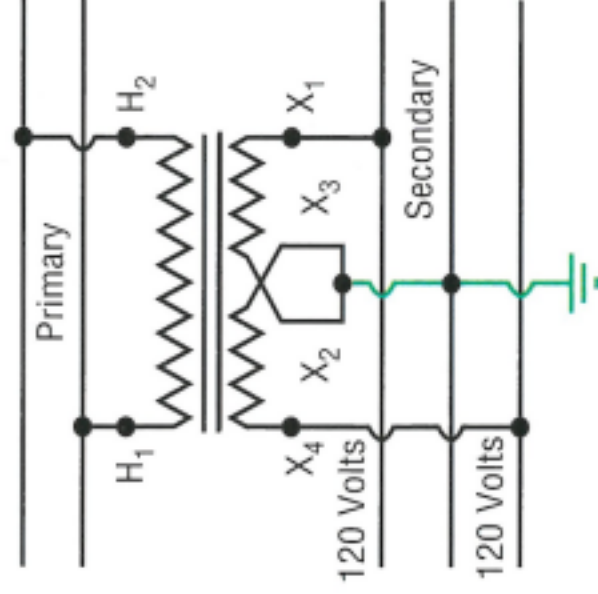
- 1) Peak let-through current: Mechanical forces
- 2) Apparent prospective RMS symmetrical let-through current: Heating effect
- 3) Clearing time: Less than $\frac{1}{2}$ cycle when fuse is in its current-limiting range (beyond where fuse curve intersects A-B line)



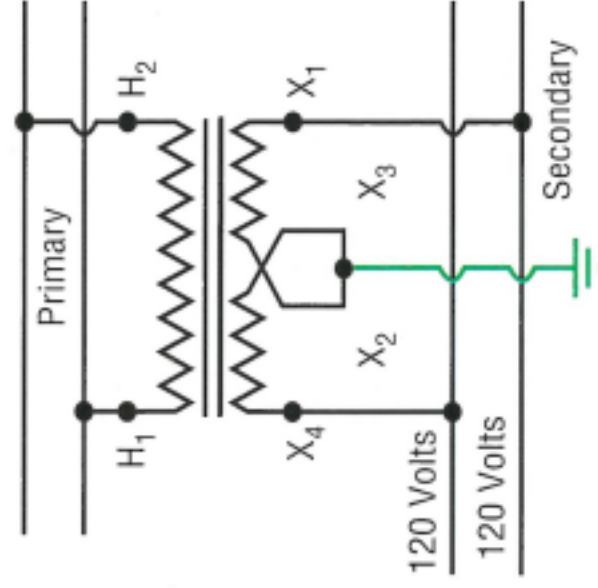
SINGLE-PHASE TRANSFORMER CONNECTIONS



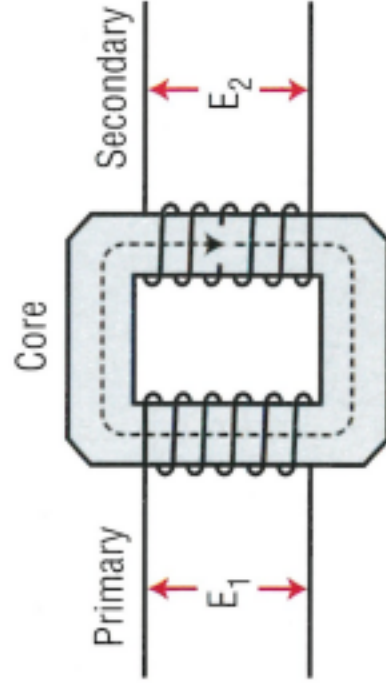
Single phase to supply 120-volt lighting load. Often used for single customer.



Single phase to supply 120/240-volt, 3-wire lighting and power load. Used in urban distribution circuits.



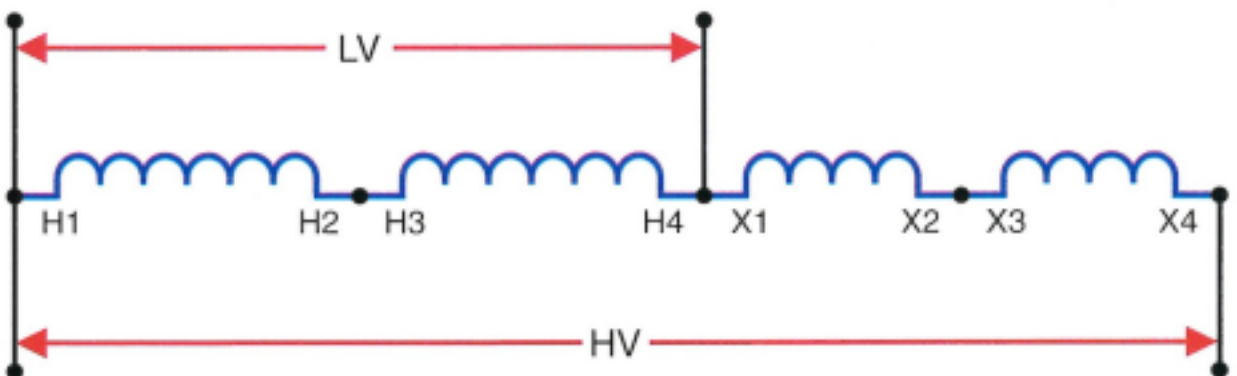
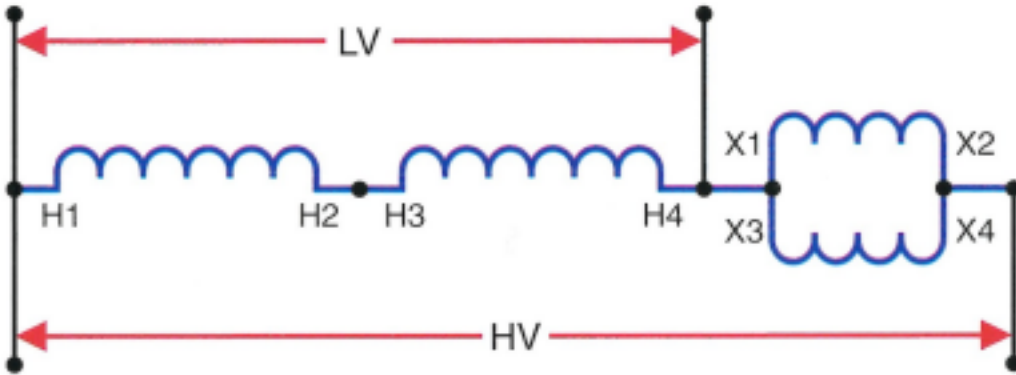
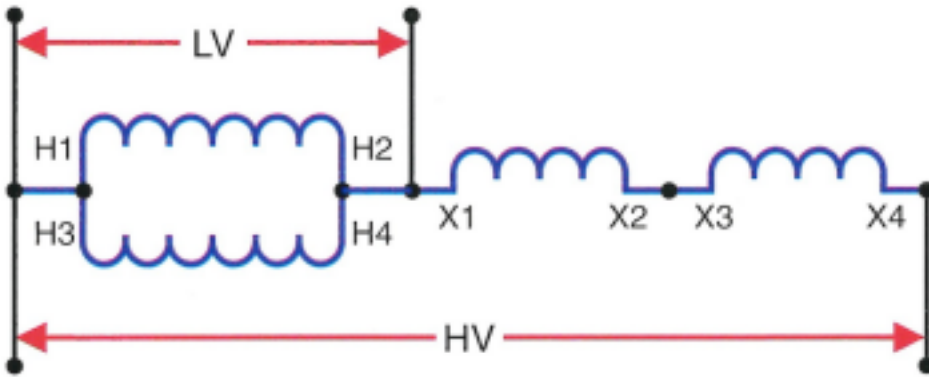
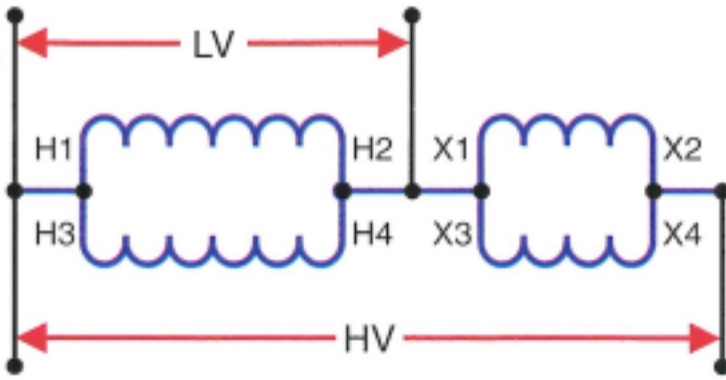
Single phase for power. Used for small industrial applications.



Single \emptyset transformer circuit



BUCK-AND-BOOST TRANSFORMER CONNECTIONS





FULL-LOAD CURRENTS

| Three-Phase Transformer's Voltage (Line to Line) | | | | | | Single-Phase Transformer's Voltage | | | | | |
|--|---------|---------|--------|--------|--------|------------------------------------|--------|--------|--------|--------|-------|
| kVA Rating | 208 | 240 | 480 | 2400 | 4160 | kVA Rating | 120 | 208 | 240 | 480 | 2400 |
| 3 | 8.3 | 7.2 | 3.6 | .72 | .416 | 1 | 8.33 | 4.81 | 4.17 | 2.08 | .42 |
| 6 | 16.7 | 14.4 | 7.2 | 1.44 | .83 | 3 | 25.0 | 14.4 | 12.5 | 6.25 | 1.25 |
| 9 | 25.0 | 21.7 | 10.8 | 2.17 | 1.25 | 5 | 41.7 | 24.0 | 20.8 | 10.4 | 2.08 |
| 15 | 41.6 | 36.1 | 18.0 | 3.6 | 2.08 | 7.5 | 62.5 | 36.1 | 31.3 | 15.6 | 3.13 |
| 30 | 83.3 | 72.2 | 36.1 | 7.2 | 4.16 | 10 | 83.3 | 48.1 | 41.7 | 20.8 | 4.17 |
| 45 | 124.9 | 108.3 | 54.1 | 10.8 | 6.25 | 15 | 125.0 | 72.1 | 62.5 | 31.3 | 6.25 |
| 75 | 208.2 | 180.4 | 90.2 | 18.0 | 10.4 | 25 | 208.3 | 120.2 | 104.2 | 52.1 | 10.4 |
| 100 | 277.6 | 240.6 | 120.3 | 24.1 | 13.9 | 37.5 | 312.5 | 180.3 | 156.3 | 78.1 | 15.6 |
| 112.5 | 312.5 | 270.6 | 135.3 | 27.1 | 15.6 | 50 | 416.7 | 240.4 | 208.3 | 104.2 | 20.8 |
| 150 | 416.4 | 360.9 | 180.4 | 36.1 | 20.8 | 75 | 625.0 | 360.6 | 312.5 | 156.3 | 31.3 |
| 225 | 624.6 | 541.3 | 270.6 | 54.1 | 31.2 | 100 | 833.3 | 480.8 | 416.7 | 208.3 | 41.7 |
| 300 | 832.7 | 721.7 | 360.9 | 72.2 | 41.6 | 125 | 1041.7 | 601.0 | 520.8 | 260.4 | 52.1 |
| 500 | 1387.9 | 1202.8 | 601.4 | 120.3 | 69.4 | 167.5 | 1395.8 | 805.3 | 697.9 | 349.0 | 69.8 |
| 750 | 2081.9 | 1804.3 | 902.1 | 180.4 | 104.1 | 200 | 1666.7 | 961.5 | 833.3 | 416.7 | 83.3 |
| 1000 | 2775.8 | 2405.7 | 1202.8 | 240.6 | 138.8 | 250 | 2083.3 | 1201.9 | 1041.7 | 520.8 | 104.2 |
| 1500 | 4163.7 | 3608.5 | 1804.3 | 360.9 | 208.2 | 333 | 2775.0 | 1601.0 | 1387.5 | 693.8 | 138.8 |
| 2000 | 5551.6 | 4811.4 | 2405.7 | 481.1 | 277.6 | 500 | 4166.7 | 2403.8 | 2083.3 | 1041.7 | 208.3 |
| 2500 | 6939.5 | 6014.2 | 3007.1 | 601.4 | 347.0 | | | | | | |
| 5000 | 13879.0 | 12028.5 | 6014.2 | 1202.8 | 694.0 | | | | | | |
| 7500 | 20818.5 | 18042.7 | 9021.4 | 1804.3 | 1040.9 | | | | | | |

$$I = \frac{\text{kVA} \times 1000}{E \times 1.73} \quad \text{or} \quad \text{kVA} = \frac{E \times I \times 1.73}{1000} \quad \text{or} \quad \text{kVA} = \frac{E \times I}{1000}$$



TRANSFORMER CALCULATIONS

To better understand the following formulas, review the rule of transposition in equations.

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.

1. Voltage and Current: Primary (p) and Secondary (s)

Power (p) = Power (s) or $E_p \times I_p = E_s \times I_s$

A. $E_p = \frac{E_s \times I_s}{I_p}$

B. $I_p = \frac{E_s \times I_s}{E_p}$

C. $\frac{E_p \times I_p}{E_s} = I_s$

D. $\frac{E_p \times I_p}{I_s} = E_s$

2. Voltage and Turns in Coil:

Voltage (p) x Turns (s) = Voltage (s) x Turns (p)

or

$$E_p \times T_s = E_s \times T_p$$

A. $E_p = \frac{E_s \times T_p}{T_s}$

B. $T_s = \frac{E_s \times T_p}{E_p}$

C. $\frac{E_p \times T_s}{E_s} = T_p$

D. $\frac{E_p \times T_s}{T_p} = E_s$

3. Amperes and Turns in Coil:

Amperes (p) x Turns (p) = Amperes (s) x Turns (s)

or

$$I_p \times T_p = I_s \times T_s$$

A. $I_p = \frac{I_s \times T_s}{T_p}$

B. $T_p = \frac{I_s \times T_s}{I_p}$

C. $\frac{I_p \times T_p}{I_s} = T_s$

D. $\frac{I_p \times T_p}{T_s} = I_s$



SIZING TRANSFORMERS

Single-Phase Transformers

Size a 480-volt, primary, or 240/120-volt, secondary, single-phase transformer for the following single-phase incandescent lighting load consisting of 48 recessed fixtures each rated 2 amps, 120 volts. Each fixture has a 150-watt lamp.

*(These fixtures can be evenly balanced on the transformer.)

Find total volt-amperes using fixture ratings—**do not use lamp watt rating.**

$$2 \text{ Amps} \times 120 \text{ Volts} = 240 \text{ Volt-Amperes}$$

$$240 \text{ VA} \times 48 = 11520 \text{ VA}$$

$$11520 \text{ VA}/1000 = 11.52 \text{ kVA}$$

The single-phase transformer that meets or exceeds this value is **15 kVA.**

*24 lighting fixtures would be connected line one to the common neutral, and 24 lighting fixtures would be connected line two to the common neutral.

Three-Phase Transformers

Size a 480-volt, primary, or 208/120-volt, secondary, 3-phase transformer (polyphase unit) to supply one 280-volt, 3-phase, 25-kVA process heater and one 120-volt, 5-kW unit heater.

The 5-kW unit heater cannot be balanced across all three phases. The 5 kW will be on one phase only. Adding the loads directly will undersize the transformer. Common practice is to put an imaginary load equal to the single-phase load on the other two phases.

$$5 \text{ kW} \times 3 = 15 \text{ kW}^*$$

The 25 kVA is three phase; use 25 kVA.

$$25 \text{ kVA} + 15 \text{ kVA}^* = 40 \text{ kVA}$$

The nearest 3-phase transformer that meets or exceeds this value is a **45 kVA.**

*(kVA = kW at unity power factor) (Transformers are rated in kVA.)



SINGLE-PHASE TRANSFORMER

Primary and Secondary Amperes

A 480/240-volt, single-phase, 50-kVA transformer ($Z = 2\%$) is to be installed. Calculate primary and secondary amperes and short-circuit amperes.

Primary amperes:

$$I_p = \frac{\text{kVA} \times 1000}{E_p} = \frac{50 \times 1000}{480} = \frac{50000}{480} = \mathbf{104 \text{ Amps}}$$

Secondary amperes:

$$I_s = \frac{\text{kVA} \times 1000}{E_s} = \frac{50 \times 1000}{240} = \frac{50000}{240} = \mathbf{208 \text{ Amps}}$$

Short-circuit amperes:*

$$I_{sc} = \frac{I_s}{\%Z} = \frac{208}{0.02} = \mathbf{10400 \text{ Amps}}$$



THREE-PHASE TRANSFORMER

Primary and Secondary Amperes

A 480/208-volt, 3-phase, 100-kVA transformer ($Z = 1\%$) is to be installed. Calculate primary and secondary amperes and short-circuit amperes.

Primary amperes:

$$I_p = \frac{\text{kVA} \times 1000}{E_p \times 1.73} = \frac{100 \times 1000}{480 \times 1.73} = \frac{100000}{831} = \mathbf{120 \text{ Amps}}$$

Secondary amperes:

$$I_s = \frac{\text{kVA} \times 1000}{E_s \times 1.73} = \frac{100 \times 1000}{208 \times 1.73} = \frac{100000}{360} = \mathbf{278 \text{ Amps}}$$

Short-circuit amperes:*

$$I_{sc} = \frac{I_s}{\%Z} = \frac{278}{0.01} = \mathbf{27800 \text{ Amps}}$$

*Short-circuit amperes is the current that would flow if the transformers' secondary terminals were shorted phase to phase. See *Ugly's* pages 53–56 for calculating short-circuit amperes point to point using the Cooper Bussmann method.



THREE-PHASE CONNECTIONS

Wye (Star)

Voltage from "A," "B," or "C" to Neutral = E_{PHASE} (E_P)

Voltage between A and B, B and C, or C and A = E_{LINE} (E_L)

$I_L = I_P$, if balanced.

If unbalanced,

$$I_N = \sqrt{I_A^2 + I_B^2 + I_C^2 - (I_A \times I_B) - (I_B \times I_C) - (I_C \times I_A)}$$

$$E_L = E_P \times 1.73$$

$$E_P = E_L \div 1.73$$

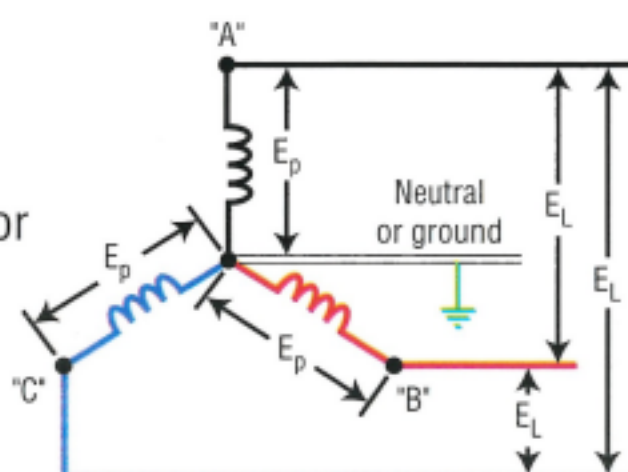
(True Power)

Power =

$$I_L \times E_L \times 1.73 \times \text{Power Factor (cosine)}$$

(Apparent Power)

$$\text{Volt-Amperes} = I_L \times E_L \times 1.73$$



Delta

$$E_{\text{LINE}} (E_L) = E_{\text{PHASE}} (E_P)$$

$$I_{\text{LINE}} = I_P \times 1.73$$

$$I_{\text{PHASE}} = I_L \div 1.73$$

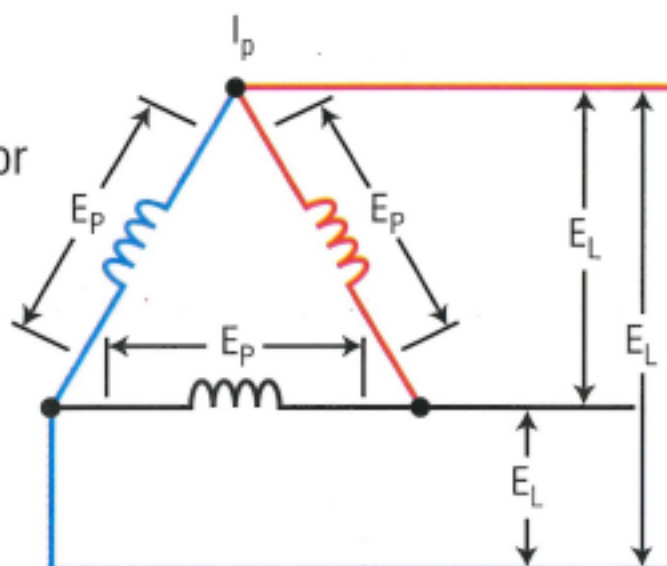
(True Power)

Power =

$$I_L \times E_L \times 1.73 \times \text{Power Factor (cosine)}$$

(Apparent Power)

$$\text{Volt-Amperes} = I_L \times E_L \times 1.73$$



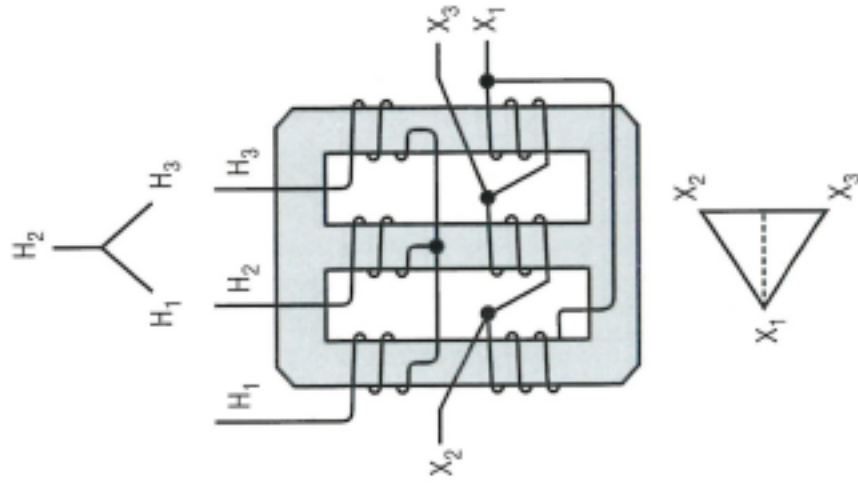
*Neutral could be ungrounded.
Also see *NEC* Article 250,
Grounding and Bonding.



THREE-PHASE STANDARD PHASE ROTATION

Transformers

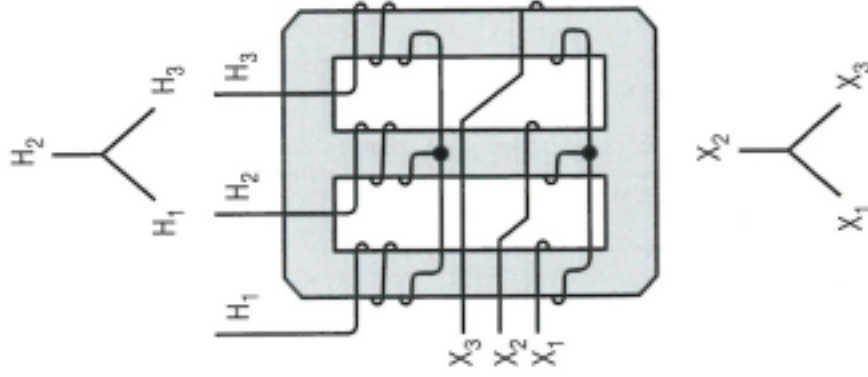
Star-Delta



Additive Polarity

30° Angular Displacement

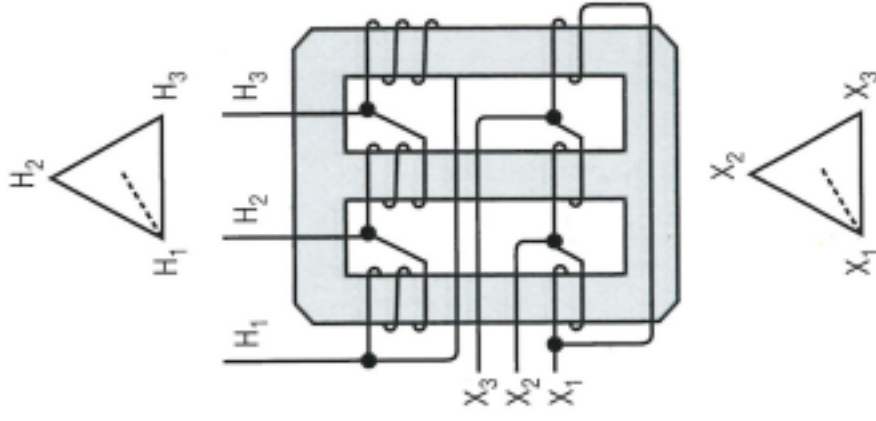
Star-Star



Subtractive Polarity

0° Phase Displacement

Delta-Delta



Subtractive Polarity

0° Phase Displacement

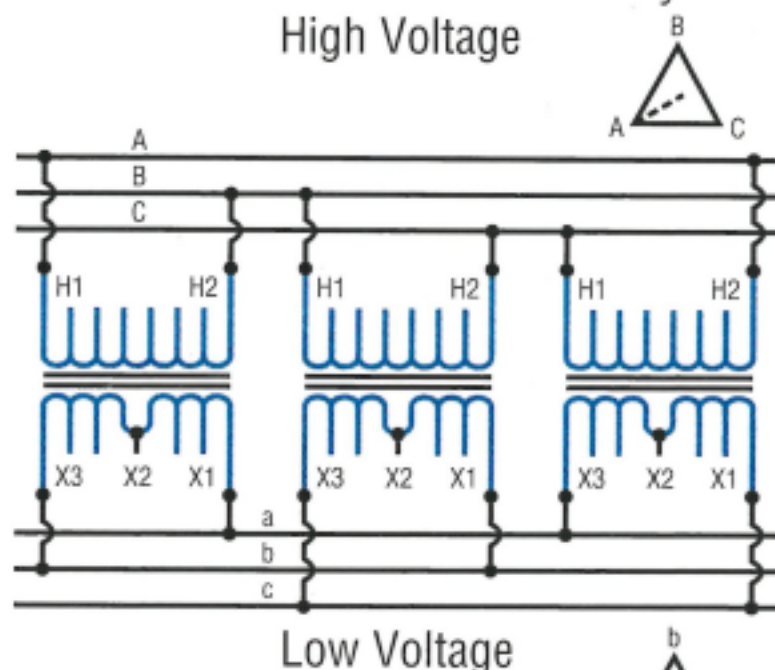


TRANSFORMER CONNECTIONS

Series Connections of Low-Voltage Windings

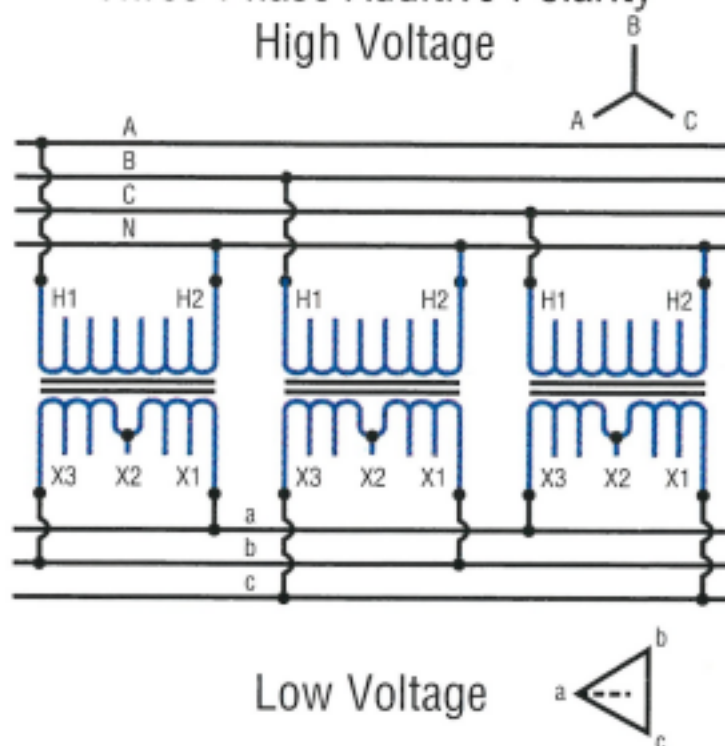
Delta-Delta

Three-Phase Additive Polarity
High Voltage



Star-Delta

Three-Phase Additive Polarity
High Voltage

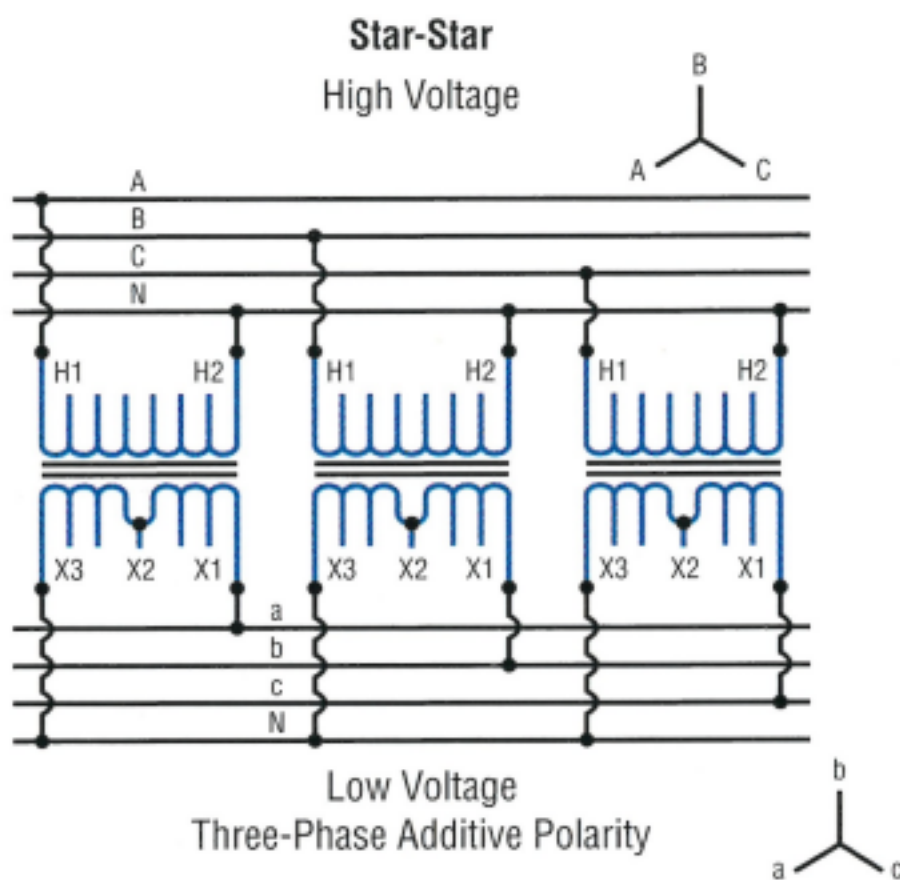
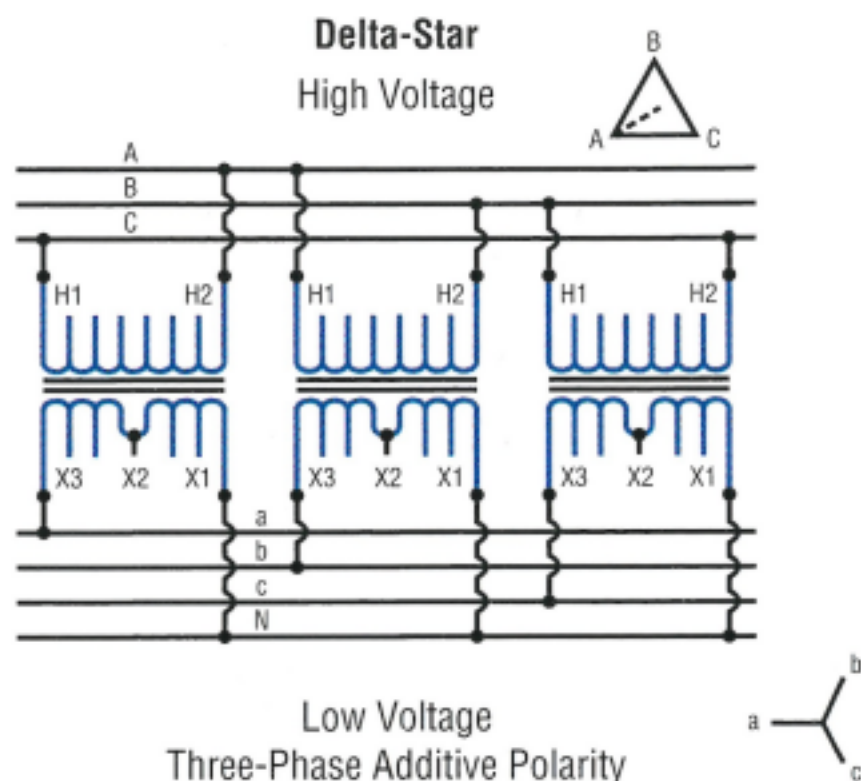


Note: Single-phase transformers should be thoroughly checked for impedance, polarity, and voltage ratio before installation.



TRANSFORMER CONNECTIONS

Series Connections of Low-Voltage Windings (*continued*)

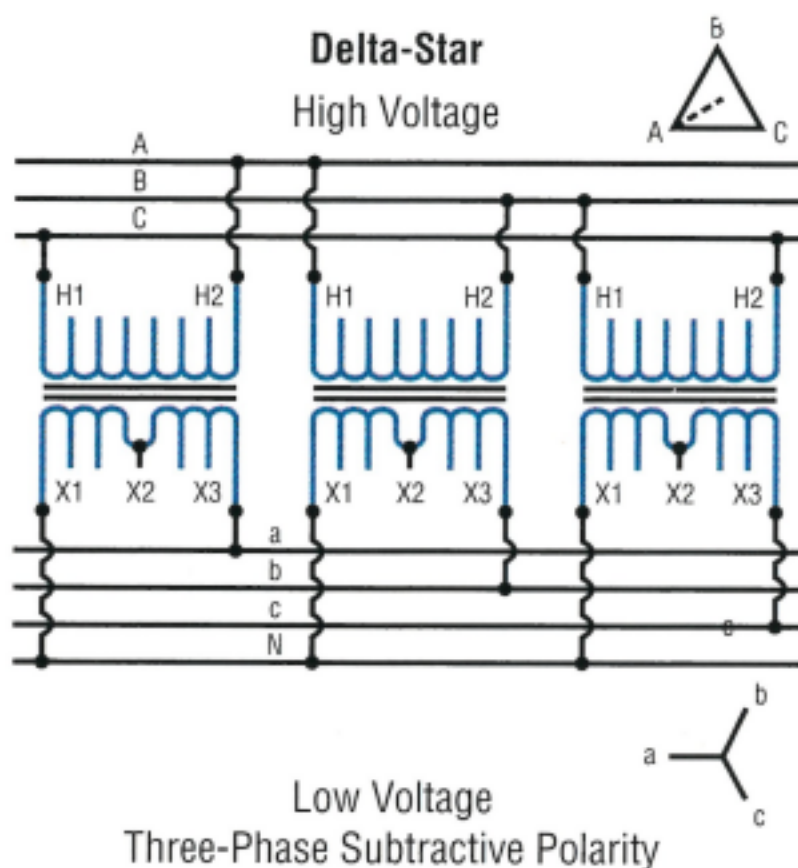
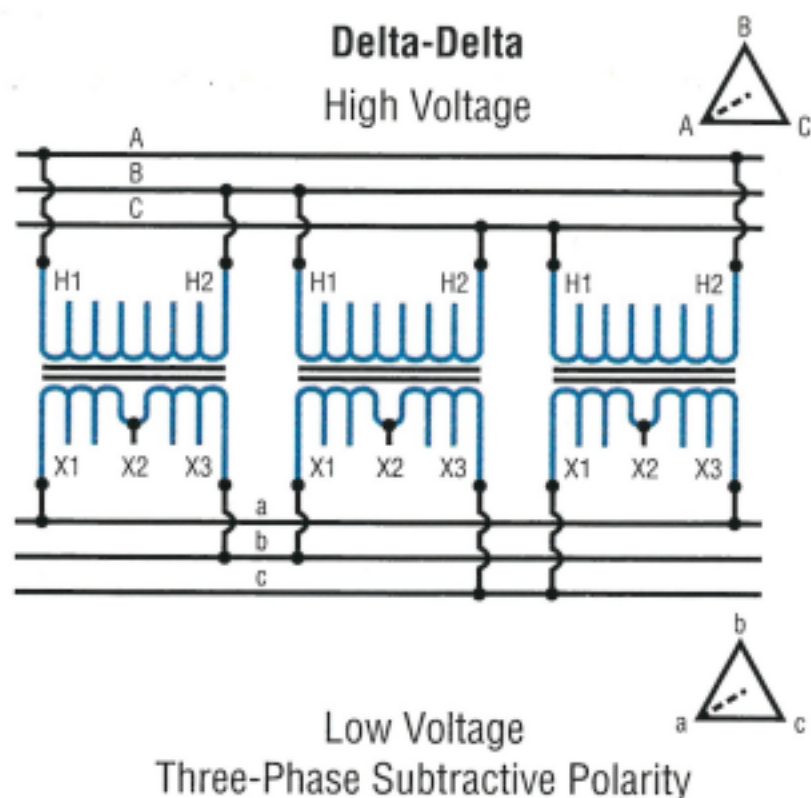


Note: For additive polarity, the H1 and the X1 bushings are diagonally opposite to each other.



TRANSFORMER CONNECTIONS

Series Connections of Low-Voltage Windings (*continued*)

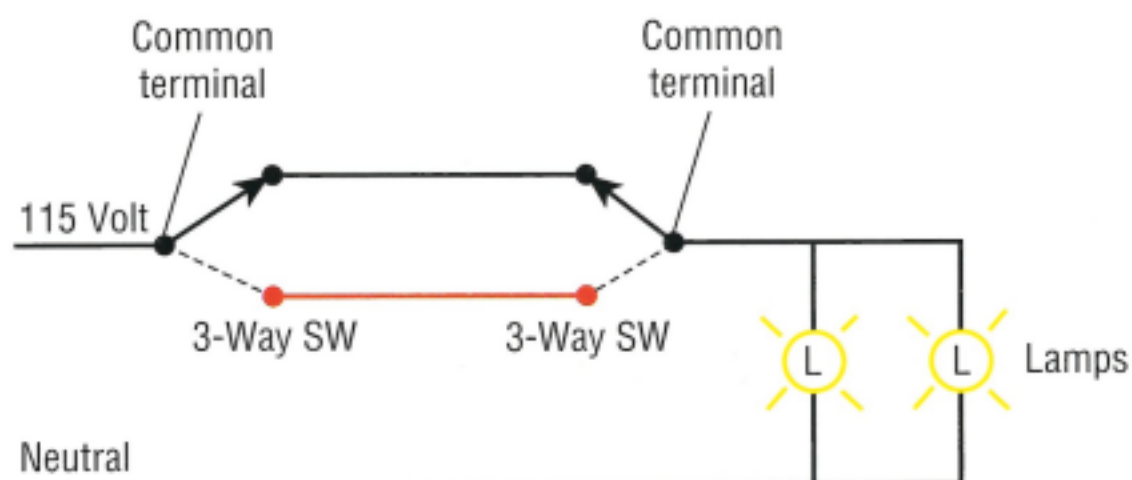


Note: For subtractive polarity, the H1 and the X1 bushings are directly opposite to each other.

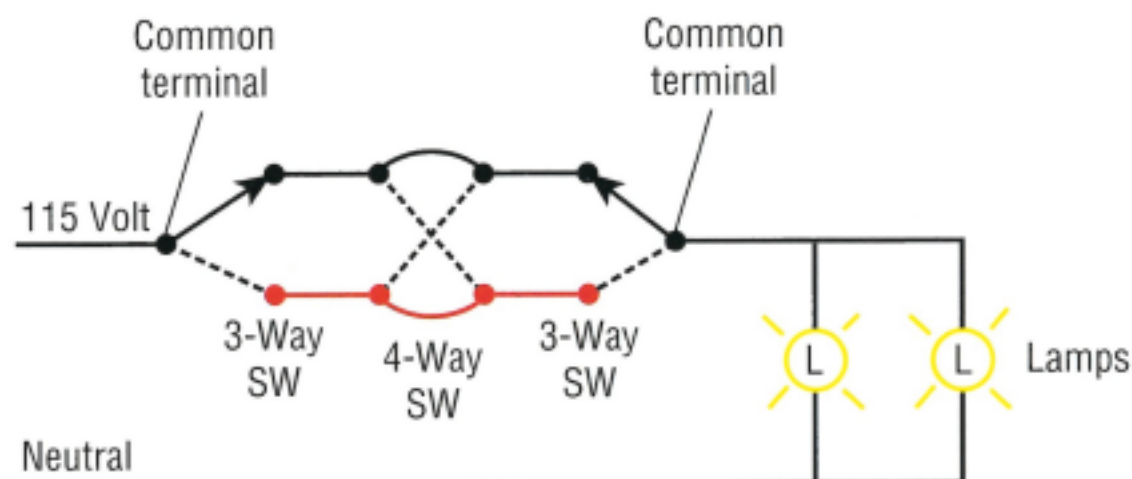


MISCELLANEOUS WIRING DIAGRAMS

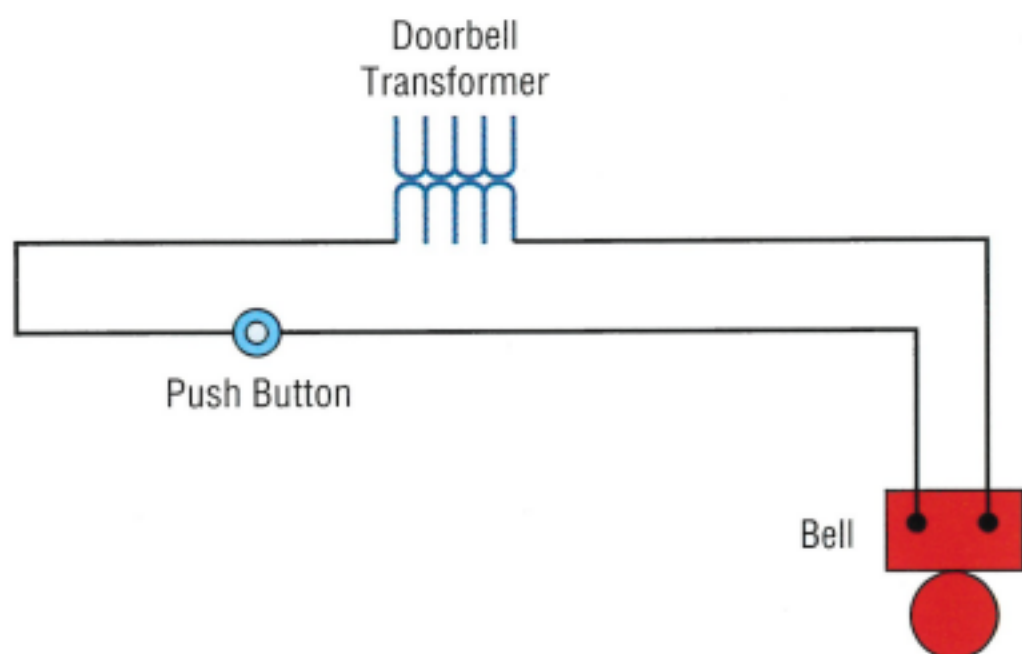
Two Three-Way Switches



Two Three-Way Switches and One Four-Way Switch



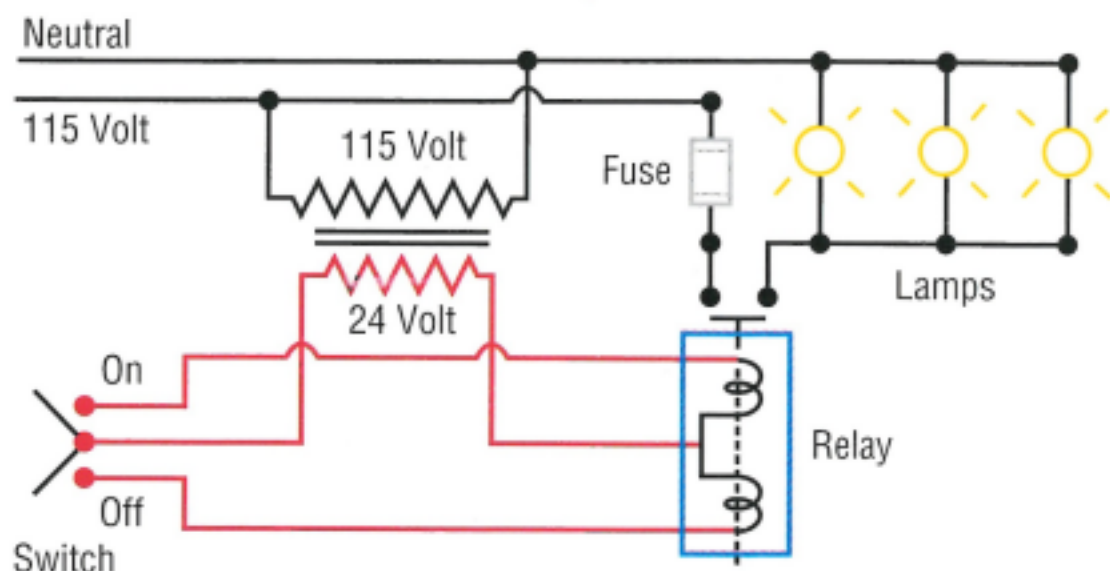
Bell Circuit





MISCELLANEOUS WIRING DIAGRAMS

Remote-Control Circuit: One Relay and One Switch



SUPPORTS FOR RIGID METAL CONDUIT

| Conduit Size | Maximum Distance Between Supports |
|---------------|-----------------------------------|
| ½"–¾" | 10 Feet |
| 1" | 12 Feet |
| 1¼"–1½" | 14 Feet |
| 2"–2½" | 16 Feet |
| 3" and larger | 20 Feet |

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 344.30(B), as modified.



SUPPORTS FOR RIGID PVC CONDUIT CONDUIT

| Conduit Size | Maximum Distance Between Supports |
|--------------|-----------------------------------|
| ½"–1" | 3 Feet |
| 1¼"–2" | 5 Feet |
| 2½"–3" | 6 Feet |
| 3½"–5" | 7 Feet |
| 6 | 8 Feet |

For SI units: (Supports) 1 foot = 0.3048 meter.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 352.30(B), as modified.



CONDUCTOR PROPERTIES

| Size AWG/ kcmil | Area Cir. Mils | Conductors | | | | dc Resistance at 75°C (167°F) | | |
|-----------------------|----------------------|---------------|----------------|----------------|-----------------------------|-------------------------------|-------------------|-------------|
| | | Stranding | | Overall | | Copper | | Aluminum |
| | | Quan- tity | Diam. (in.) | Diam. (in.) | Area (in. ²) | Uncoated ohm/kFT | Coated ohm/kFT | ohm/ kFT |
| 18 | 1620 | 1 | — | 0.040 | 0.001 | 7.77 | 8.08 | 12.8 |
| 18 | 1620 | 7 | 0.015 | 0.046 | 0.002 | 7.95 | 8.45 | 13.1 |
| 16 | 2580 | 1 | — | 0.051 | 0.002 | 4.89 | 5.08 | 8.05 |
| 16 | 2580 | 7 | 0.019 | 0.058 | 0.003 | 4.99 | 5.29 | 8.21 |
| 14 | 4110 | 1 | — | 0.064 | 0.003 | 3.07 | 3.19 | 5.06 |
| 14 | 4110 | 7 | 0.024 | 0.073 | 0.004 | 3.14 | 3.26 | 5.17 |
| 12 | 6530 | 1 | — | 0.081 | 0.005 | 1.93 | 2.01 | 3.18 |
| 12 | 6530 | 7 | 0.030 | 0.092 | 0.006 | 1.98 | 2.05 | 3.25 |
| 10 | 10380 | 1 | — | 0.102 | 0.008 | 1.21 | 1.26 | 2.00 |
| 10 | 10380 | 7 | 0.038 | 0.116 | 0.011 | 1.24 | 1.29 | 2.04 |
| 8 | 16510 | 1 | — | 0.128 | 0.013 | 0.764 | 0.786 | 1.26 |
| 8 | 16510 | 7 | 0.049 | 0.146 | 0.017 | 0.778 | 0.809 | 1.28 |
| 6 | 26240 | 7 | 0.061 | 0.184 | 0.027 | 0.491 | 0.510 | 0.808 |
| 4 | 41740 | 7 | 0.077 | 0.232 | 0.042 | 0.308 | 0.321 | 0.508 |
| 3 | 52620 | 7 | 0.087 | 0.260 | 0.053 | 0.245 | 0.254 | 0.403 |
| 2 | 66360 | 7 | 0.097 | 0.292 | 0.067 | 0.194 | 0.201 | 0.319 |
| 1 | 83690 | 19 | 0.066 | 0.332 | 0.087 | 0.154 | 0.160 | 0.253 |
| 1/0 | 105600 | 19 | 0.074 | 0.372 | 0.109 | 0.122 | 0.127 | 0.201 |
| 2/0 | 133100 | 19 | 0.084 | 0.418 | 0.137 | 0.0967 | 0.101 | 0.159 |
| 3/0 | 167800 | 19 | 0.094 | 0.470 | 0.173 | 0.0766 | 0.0797 | 0.126 |
| 4/0 | 211600 | 19 | 0.106 | 0.528 | 0.219 | 0.0608 | 0.0626 | 0.100 |
| 250 | — | 37 | 0.082 | 0.575 | 0.260 | 0.0515 | 0.0535 | 0.0847 |
| 300 | — | 37 | 0.090 | 0.630 | 0.312 | 0.0429 | 0.0446 | 0.0707 |
| 350 | — | 37 | 0.097 | 0.681 | 0.364 | 0.0367 | 0.0382 | 0.0605 |
| 400 | — | 37 | 0.104 | 0.728 | 0.416 | 0.0321 | 0.0331 | 0.0529 |
| 500 | — | 37 | 0.116 | 0.813 | 0.519 | 0.0258 | 0.0265 | 0.0424 |
| 600 | — | 61 | 0.099 | 0.893 | 0.626 | 0.0214 | 0.0223 | 0.0353 |
| 700 | — | 61 | 0.107 | 0.964 | 0.730 | 0.0184 | 0.0189 | 0.0303 |
| 750 | — | 61 | 0.111 | 0.998 | 0.782 | 0.0171 | 0.0176 | 0.0282 |
| 800 | — | 61 | 0.114 | 1.030 | 0.834 | 0.0161 | 0.0166 | 0.0265 |
| 900 | — | 61 | 0.122 | 1.094 | 0.940 | 0.0143 | 0.0147 | 0.0235 |
| 1000 | — | 61 | 0.128 | 1.152 | 1.042 | 0.0129 | 0.0132 | 0.0212 |
| 1250 | — | 91 | 0.117 | 1.289 | 1.305 | 0.0103 | 0.0106 | 0.0169 |
| 1500 | — | 91 | 0.128 | 1.412 | 1.566 | 0.00858 | 0.00883 | 0.0141 |
| 1750 | — | 127 | 0.117 | 1.526 | 1.829 | 0.00735 | 0.00756 | 0.0121 |
| 2000 | — | 127 | 0.126 | 1.632 | 2.092 | 0.00643 | 0.00662 | 0.0106 |

These resistance values are valid ONLY for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.

Equation for temperature change: $R_2 = R_1 [1 + \alpha(T_2 - 75)]$ where $\alpha_{Cu} = 0.00323$, $\alpha_{Al} = 0.00330$ at 75°C (167°F).

See NEC Chapter 9, Table 8. See Ugly's pages 139–140 for metric conversions.

Source: NFPA 70®, National Electrical Code®, 2026 edition, NFPA, Quincy, MA, 2025, Chapter 9, Table 8, as modified.



ac RESISTANCE AND REACTANCE FOR 600-VOLT CABLES, THREE-PHASE, 60-HZ, 75°C (167°F): THREE SINGLE CONDUCTORS IN CONDUIT

| Ohms to Neutral per 1000 Feet | | | | | | | | | | | | | | | |
|-------------------------------|---|------------------|--|----------------|------------------|-------------------------------------|----------------|------------------|---|----------------|------------------|--|----------------|------------------|-----------------------|
| Size AWG/ kcmil | X _c (Reactance) for All Wires | | ac Resistance for Uncoated Copper Wires | | | ac Resistance for Aluminum Wires | | | Effective Z at 0.85 PF for Uncoated Copper Wires | | | Effective Z at 0.85 PF for Aluminum Wires | | | Size AWG/ kcmil |
| | PVC Conduit | Steel Conduit | PVC Conduit | Al. Conduit | Steel Conduit | PVC Conduit | Al. Conduit | Steel Conduit | PVC Conduit | Al. Conduit | Steel Conduit | PVC Conduit | Al. Conduit | Steel Conduit | |
| 14 | 0.058 | 0.073 | 3.1 | 3.1 | 3.1 | — | — | — | 2.7 | 2.7 | 2.7 | — | — | — | 14 |
| 12 | 0.054 | 0.068 | 2.0 | 2.0 | 2.0 | 3.2 | 3.2 | 3.2 | 1.7 | 1.7 | 1.7 | 2.8 | 2.8 | 2.8 | 12 |
| 10 | 0.050 | 0.063 | 1.2 | 1.2 | 1.2 | 2.0 | 2.0 | 2.0 | 1.1 | 1.1 | 1.1 | 1.8 | 1.8 | 1.8 | 10 |
| 8 | 0.052 | 0.065 | 0.78 | 0.78 | 0.78 | 1.3 | 1.3 | 1.3 | 0.69 | 0.69 | 0.69 | 1.1 | 1.1 | 1.1 | 8 |
| 6 | 0.051 | 0.064 | 0.49 | 0.49 | 0.49 | 0.81 | 0.81 | 0.81 | 0.44 | 0.45 | 0.45 | 0.71 | 0.72 | 0.72 | 6 |
| 4 | 0.048 | 0.060 | 0.31 | 0.31 | 0.31 | 0.51 | 0.51 | 0.51 | 0.29 | 0.29 | 0.29 | 0.46 | 0.46 | 0.46 | 4 |
| 3 | 0.047 | 0.059 | 0.25 | 0.25 | 0.25 | 0.40 | 0.41 | 0.40 | 0.23 | 0.24 | 0.24 | 0.37 | 0.37 | 0.37 | 3 |
| 2 | 0.045 | 0.057 | 0.19 | 0.20 | 0.20 | 0.32 | 0.32 | 0.32 | 0.19 | 0.19 | 0.19 | 0.30 | 0.30 | 0.30 | 2 |
| 1 | 0.046 | 0.057 | 0.15 | 0.16 | 0.16 | 0.25 | 0.26 | 0.25 | 0.16 | 0.16 | 0.16 | 0.24 | 0.24 | 0.25 | 1 |
| 1/0 | 0.044 | 0.055 | 0.12 | 0.13 | 0.12 | 0.20 | 0.21 | 0.20 | 0.13 | 0.13 | 0.13 | 0.19 | 0.20 | 0.20 | 1/0 |
| 2/0 | 0.043 | 0.054 | 0.10 | 0.10 | 0.10 | 0.16 | 0.16 | 0.16 | 0.11 | 0.11 | 0.11 | 0.16 | 0.16 | 0.16 | 2/0 |
| 3/0 | 0.042 | 0.052 | 0.077 | 0.082 | 0.079 | 0.13 | 0.13 | 0.13 | 0.088 | 0.092 | 0.094 | 0.13 | 0.13 | 0.14 | 3/0 |
| 4/0 | 0.041 | 0.051 | 0.062 | 0.067 | 0.063 | 0.10 | 0.11 | 0.10 | 0.074 | 0.078 | 0.080 | 0.11 | 0.11 | 0.11 | 4/0 |
| 250 | 0.041 | 0.052 | 0.052 | 0.057 | 0.054 | 0.085 | 0.090 | 0.086 | 0.066 | 0.070 | 0.073 | 0.094 | 0.098 | 0.10 | 250 |
| 300 | 0.041 | 0.051 | 0.044 | 0.049 | 0.045 | 0.071 | 0.076 | 0.072 | 0.059 | 0.063 | 0.065 | 0.082 | 0.086 | 0.088 | 300 |
| 350 | 0.040 | 0.050 | 0.038 | 0.043 | 0.039 | 0.061 | 0.066 | 0.063 | 0.053 | 0.058 | 0.060 | 0.073 | 0.077 | 0.080 | 350 |
| 400 | 0.040 | 0.049 | 0.033 | 0.038 | 0.035 | 0.054 | 0.059 | 0.055 | 0.049 | 0.053 | 0.056 | 0.066 | 0.071 | 0.073 | 400 |
| 500 | 0.039 | 0.048 | 0.027 | 0.032 | 0.029 | 0.043 | 0.048 | 0.045 | 0.043 | 0.048 | 0.050 | 0.057 | 0.061 | 0.064 | 500 |
| 600 | 0.039 | 0.048 | 0.023 | 0.028 | 0.025 | 0.036 | 0.041 | 0.038 | 0.040 | 0.044 | 0.047 | 0.051 | 0.055 | 0.058 | 600 |
| 750 | 0.038 | 0.048 | 0.019 | 0.024 | 0.021 | 0.029 | 0.034 | 0.031 | 0.036 | 0.040 | 0.043 | 0.045 | 0.049 | 0.052 | 750 |
| 1000 | 0.037 | 0.046 | 0.015 | 0.019 | 0.018 | 0.023 | 0.027 | 0.025 | 0.032 | 0.036 | 0.040 | 0.039 | 0.042 | 0.046 | 1000 |

Notes: See NEC Chapter 9, Table 9 for assumptions and explanations. See *Ugly's* pages 139–140 for metric conversions.
Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Chapter 9, Table 9, as modified.



AMPACITIES OF INSULATED CONDUCTORS

Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried)

| Size AWG or kcmil | Temperature Rating of Conductor [See Table 310.4(1).] | | | | | | |
|----------------------------|---|---|--|----------------------------------|--|--|--------------------|
| | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | Size |
| | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, XHWN, USE, ZW | Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2 | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, XHWN, USE | Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN-2, XHHN | AWG or kcmil |
| | Copper | | | Aluminum or Copper-Clad Aluminum | | | |
| 16 ¹ | 10 | 15 ² | 20 ² | — | — | — | — |
| 14 ¹ | 15 | 20 | 25 | 10 ³ | 15 ^{2,3} | 20 ^{2,3} | 14 ¹ |
| 12 ¹ | 20 | 25 | 30 | 15 | 20 | 25 | 12 ¹ |
| 10 ¹ | 30 | 35 | 40 | 25 | 30 | 35 | 10 ¹ |
| 8 | 40 | 50 | 55 | 35 | 40 | 45 | 8 |
| 6 | 55 | 65 | 75 | 40 | 50 | 55 | 6 |
| 4 | 70 | 85 | 95 | 55 | 65 | 75 | 4 |
| 3 | 85 | 100 | 115 | 65 | 75 | 85 | 3 |
| 2 | 95 | 115 | 130 | 75 | 90 | 100 | 2 |
| 1 | 110 | 130 | 145 | 85 | 100 | 115 | 1 |
| 1/0 | 125 | 150 | 170 | 100 | 120 | 135 | 1/0 |
| 2/0 | 145 | 175 | 195 | 115 | 135 | 150 | 2/0 |
| 3/0 | 165 | 200 | 225 | 130 | 155 | 175 | 3/0 |
| 4/0 | 195 | 230 | 260 | 150 | 180 | 205 | 4/0 |
| 250 | 215 | 255 | 290 | 170 | 205 | 230 | 250 |
| 300 | 240 | 285 | 320 | 195 | 230 | 260 | 300 |
| 350 | 260 | 310 | 350 | 210 | 250 | 280 | 350 |
| 400 | 280 | 335 | 380 | 225 | 270 | 305 | 400 |
| 500 | 320 | 380 | 430 | 260 | 310 | 350 | 500 |
| 600 | 350 | 420 | 475 | 285 | 340 | 385 | 600 |
| 700 | 385 | 460 | 520 | 315 | 375 | 425 | 700 |
| 750 | 400 | 475 | 535 | 320 | 385 | 435 | 750 |
| 800 | 410 | 490 | 555 | 330 | 395 | 445 | 800 |
| 900 | 435 | 520 | 585 | 355 | 425 | 480 | 900 |
| 1000 | 455 | 545 | 615 | 375 | 445 | 500 | 1000 |
| 1250 | 495 | 590 | 665 | 405 | 485 | 545 | 1250 |
| 1500 | 525 | 625 | 705 | 435 | 520 | 585 | 1500 |
| 1750 | 545 | 650 | 735 | 455 | 545 | 615 | 1750 |
| 2000 | 555 | 665 | 750 | 470 | 560 | 630 | 2000 |

Notes:

- Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).
 - Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
 - Section 310.16 shall be referenced for conditions of use.
 - Ampacity for 18 AWG copper Type MI and Type MTW shall be 14 amperes at 90°C (194°F).
 - Ampacity for 16 AWG copper Type MI and Type MTW shall be 18 amperes at 90°C (194°F).
- ¹Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.
²Ampacity shall be used for adjustment or correction only.
³Ampacity shall be applicable only to copper-clad aluminum conductors.

See *Ugly's* page 77 for Adjustment Examples.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.16, as modified.



AMPACITIES OF INSULATED CONDUCTORS

Ampacities of Single-Insulated Conductors in Free Air

| Size AWG or kcmil | Temperature Rating of Conductor [See Table 310.4(1).] | | | | | | Size AWG or kcmil |
|----------------------------|---|---|--|--------------------|--|---|----------------------------|
| | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | |
| | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, XHWN, ZW | Types TBS, SA, SIS, FEP, FEPB, MI, PFA, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN, Z, ZW-2 | Types TW, UF | Types RHW, THHW, THW, THWN, XHHW, XHWN | Types TBS, SA, SIS, THHN, THHW, THW-2, THWN-2, RHH, RHW-2, USE-2, XHH, XHHW, XHHW-2, XHWN, XHWN-2, XHHN | |
| Copper | | | Aluminum or Copper-Clad Aluminum | | | | |
| 18 | — | — | 18 | — | — | — | — |
| 16 | — | — | 24 | — | — | — | — |
| 14* | 25 | 30 | 35 | — | — | — | — |
| 12* | 30 | 35 | 40 | 25 | 30 | 35 | 12* |
| 10* | 40 | 50 | 55 | 35 | 40 | 45 | 10* |
| 8 | 60 | 70 | 80 | 45 | 55 | 60 | 8 |
| 6 | 80 | 95 | 105 | 60 | 75 | 85 | 6 |
| 4 | 105 | 125 | 140 | 80 | 100 | 115 | 4 |
| 3 | 120 | 145 | 165 | 95 | 115 | 130 | 3 |
| 2 | 140 | 170 | 190 | 110 | 135 | 150 | 2 |
| 1 | 165 | 195 | 220 | 130 | 155 | 175 | 1 |
| 1/0 | 195 | 230 | 260 | 150 | 180 | 205 | 1/0 |
| 2/0 | 225 | 265 | 300 | 175 | 210 | 235 | 2/0 |
| 3/0 | 260 | 310 | 350 | 200 | 240 | 270 | 3/0 |
| 4/0 | 300 | 360 | 405 | 235 | 280 | 315 | 4/0 |
| 250 | 340 | 405 | 455 | 265 | 315 | 355 | 250 |
| 300 | 375 | 445 | 500 | 290 | 350 | 395 | 300 |
| 350 | 420 | 505 | 570 | 330 | 395 | 445 | 350 |
| 400 | 455 | 545 | 615 | 355 | 425 | 480 | 400 |
| 500 | 515 | 620 | 700 | 405 | 485 | 545 | 500 |
| 600 | 575 | 690 | 780 | 455 | 540 | 615 | 600 |
| 700 | 630 | 755 | 850 | 500 | 595 | 670 | 700 |
| 750 | 655 | 785 | 885 | 515 | 620 | 700 | 750 |
| 800 | 680 | 815 | 920 | 535 | 645 | 725 | 800 |
| 900 | 730 | 870 | 980 | 580 | 700 | 790 | 900 |
| 1000 | 780 | 935 | 1055 | 625 | 750 | 845 | 1000 |
| 1250 | 890 | 1065 | 1200 | 710 | 855 | 965 | 1250 |
| 1500 | 980 | 1175 | 1325 | 795 | 950 | 1070 | 1500 |
| 1750 | 1070 | 1280 | 1445 | 875 | 1050 | 1185 | 1750 |
| 2000 | 1155 | 1385 | 1560 | 960 | 1150 | 1295 | 2000 |

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 30°C (86°F).

2. Section 310.17 shall be referenced for conditions of use.

*Section 240.4(D) shall be referenced for conductor overcurrent protection limitations, except as modified elsewhere in the code.

See *Ugly's* page 77 for Adjustment Examples.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.17, as modified.



AMPACITIES OF INSULATED CONDUCTORS

Ampacities of Insulated Conductors with Not More Than Three Current-Carrying Conductors in Raceway or Cable

| Size AWG or kcmil | Temperature Rating of Conductor [See Table 310.4(1).] | | | | Size AWG or kcmil |
|----------------------------|---|--------------------------------------|--------------------------------------|--|----------------------------|
| | 150°C (302°F) | 200°C (392°F) | 250°C (482°F) | 150°C (302°F) | |
| | Type Z | Types FEP, FEPB, PFA, SA | Types PFAH, TFE | Type Z | |
| | Copper | | Nickel or Nickel-Coated Copper | Aluminum or Copper-Clad Aluminum | |
| 14 | 34 | 36 | 39 | — | 14 |
| 12 | 43 | 45 | 54 | 30 | 12 |
| 10 | 55 | 60 | 73 | 44 | 10 |
| 8 | 76 | 83 | 93 | 57 | 8 |
| 6 | 96 | 110 | 117 | 75 | 6 |
| 4 | 120 | 125 | 148 | 94 | 4 |
| 3 | 143 | 152 | 166 | 109 | 3 |
| 2 | 160 | 171 | 191 | 124 | 2 |
| 1 | 186 | 197 | 215 | 145 | 1 |
| 1/0 | 215 | 229 | 244 | 169 | 1/0 |
| 2/0 | 251 | 260 | 273 | 198 | 2/0 |
| 3/0 | 288 | 297 | 308 | 227 | 3/0 |
| 4/0 | 332 | 346 | 361 | 260 | 4/0 |

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).
2. Section 310.15(C)(1) shall be referenced for more than three current-carrying conductors.
3. Section 310.18 shall be referenced for conditions of use.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.18 as modified.



AMPACITIES OF INSULATED CONDUCTORS

Ampacities of Single-Insulated Conductors in Free Air

| Size AWG or kcmil | Temperature Rating of Conductor [See Table 310.4(1).] | | | | Size AWG or kcmil |
|----------------------------|---|--------------------------------------|--------------------------------------|--|----------------------------|
| | 150°C (302°F) | 200°C (392°F) | 250°C (482°F) | 150°C (302°F) | |
| | Type Z | Types FEP, FEPB, PFA, SA | Types PFAH, TFE | Type Z | |
| | Copper | | Nickel or Nickel-Coated Copper | Aluminum or Copper-Clad Aluminum | |
| 14 | 46 | 54 | 59 | — | 14 |
| 12 | 60 | 68 | 78 | 47 | 12 |
| 10 | 80 | 90 | 107 | 63 | 10 |
| 8 | 106 | 124 | 142 | 83 | 8 |
| 6 | 155 | 165 | 205 | 112 | 6 |
| 4 | 190 | 220 | 278 | 148 | 4 |
| 3 | 214 | 252 | 327 | 170 | 3 |
| 2 | 255 | 293 | 381 | 198 | 2 |
| 1 | 293 | 344 | 440 | 228 | 1 |
| 1/0 | 339 | 399 | 532 | 263 | 1/0 |
| 2/0 | 390 | 467 | 591 | 305 | 2/0 |
| 3/0 | 451 | 546 | 708 | 351 | 3/0 |
| 4/0 | 529 | 629 | 830 | 411 | 4/0 |

Notes:

1. Section 310.15(B) shall be referenced for ampacity correction factors where the ambient temperature is other than 40°C (104°F).

2. Section 310.19 shall be referenced for conditions of use.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.19 as modified.



AMPACITY CORRECTION AND ADJUSTMENT FACTORS

Examples

Ugly's page 73 shows ampacity values for not more than three current-carrying conductors in a raceway, cable and the wiring installed in a 30°C (86°F) ambient temperature.

Example 1: A raceway contains three 3 AWG THWN conductors for a three-phase circuit at an ambient temperature of 30°C (86°F).

Ugly's page 73, 75°C (167°F) column indicates **100 amps**.

Example 2: A raceway contains three 3 AWG THWN conductors for a three-phase circuit at an ambient temperature of 40°C (104°F). *Ugly's* page 73, 75°C (167°F) column indicates **100 amps**. This value must be corrected for ambient temperature (see note on Temperature Correction Factors at bottom of *Ugly's* page 73). 40°C (104°F) factor is **0.88**.

$100 \text{ Amps} \times 0.88 = \mathbf{88 \text{ Amps}}$ = corrected ampacity

Example 3: A raceway contains six 3 AWG THWN conductors for two three-phase circuits at an ambient temperature of 30°C (86°F).

Ugly's page 73, 75°C (167°F) column indicates **100 amps**. This value must be adjusted for more than three current-carrying conductors. The table on *Ugly's* page 78 requires an adjustment of **80%** for four through six current-carrying conductors.

$100 \text{ Amps} \times 80\% = \mathbf{80 \text{ Amps}}$

The adjusted ampacity is **80 Amps**.

Example 4: A raceway contains six 3 AWG THWN conductors for two three-phase circuits in an ambient temperature of 40°C (104°F). These conductors must be corrected and adjusted (or derated) for both ambient temperature and number of current-carrying conductors.

Ugly's page 73, 75°C (167°F) column indicates **100 amps**.

NEC Table 310.15(B)(1)(1), 40°C (104°F) temperature factor is **0.88**.

Ugly's page 78, 4 - 6 conductor factor is **0.80**.

$100 \text{ Amps} \times 0.88 \times 0.80 = \mathbf{70.4 \text{ Amps}}$

The new derated ampacity is **70.4 Amps**.

ADJUSTMENT FACTORS

For More Than Three Current-Carrying Conductors in a Raceway or Cable

| Number of Current-Carrying Conductors* | Percent of Values in Table 310.16, 310.18, and 310.20 as Adjusted for Ambient Temperature if Necessary |
|--|--|
| 4–6 | 80 |
| 7–9 | 70 |
| 10–20 | 50 |
| 21–30 | 45 |
| 31–40 | 40 |
| 41 and above | 35 |

*Number of conductors is the total number of conductors in the raceway or cable, including spare conductors. The count shall be adjusted in accordance with 310.15(E) and 310.15(F). The count shall not include conductors that are connected to electrical components that cannot be simultaneously energized.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.15(C)(1).

Conductor and Equipment Termination Ratings*

Examples:

A 150-amps circuit breaker is labeled for 75°C (167°F) terminations and is selected to be used for a 145-amps, noncontinuous load. It would be permissible to use a 1/0 THWN conductor that has a 75°C (167°F) insulation rating and has an ampacity of 150 amps (*Ugly's* page 73).

When a THHN (90°C [194°F]) conductor is connected to a 75°C (167°F) termination, it is limited to the 75°C (167°F) ampacity. Therefore, if a 1 THHN conductor with a rating of 145 amps were connected to a 75°C (167°F) terminal, its ampacity would be limited to 130 amps instead of 150 amps, which is too small for the load (*Ugly's* page 73).

If the 145-amp, noncontinuous load listed above uses 1/0 THWN conductors rated 150 amps and the conductors are in an ambient temperature of 40°C (104°F), the conductors would have to be corrected for the ambient temperature.

ADJUSTMENT FACTORS

From *NEC* Table 310.15(B)(1)(1), 40°C (104°F) ambient temperature correction factor = **0.88**

1/0 THWN = 150 Amps

150 Amps \times 0.88 = **132 Amps** (which is too small for the 145-amp load, so a larger size conductor is required).

Apply temperature correction factors to the next size THWN conductor.

2/0 THWN = 175 Amps (from the 75°C [167°F] column—*Ugly's* page 73)

175 Amps \times 0.88 = **154 Amps**. This size is suitable for the 145-amps load.

The advantage of using 90°C (194°F) conductors is that you can apply ampacity derating factors to the higher 90°C (194°F) ampacity rating, and it may save you from going to a larger conductor.

1/0 THHN = 170 Amps (from the 90°C [194°F] column—*Ugly's* page 73).

40°C [104°F] ambient temperature correction factor for a 90°C conductor = 0.91 (*NEC* Table 310.15(B)(1)(1))

170 Amps \times 0.91 = **154.7 Amps**.

This size is suitable for the 145-amp load.

This 90°C [194°F] conductor can be used but can never have a final derated ampacity over the rating of 1/0 THWN 75°C [167°F] rating of 150 amps.

You are allowed to use higher temperature (insulated conductors) such as THHN (90°C [194°F]) conductors on 60°C (140°F) or 75°C (167°F) terminals of circuit breakers and equipment, and you are allowed to derate from the higher value for temperature and number of conductors, but the final derated ampacity is limited to the 60°C or 75°C (140°F or 167°F) terminal insulation labels.

*See *NEC* 2026 Section 110.14(C)(1).



CONDUCTOR APPLICATIONS AND INSULATIONS

| Trade Name | Letter | Max. Temp. | Application Provisions |
|---|-------------|---------------|---|
| Fluorinated Ethylene Propylene | FEP or FEPB | 90°C (194°F) | Dry and Damp Locations |
| | | 200°C (392°F) | Dry Locations—Special Applications ¹ |
| Mineral Insulation (Metal Sheathed) | MI | 90°C (194°F) | Dry and Wet Locations |
| | | 250°C (482°F) | Special Applications ¹ |
| Moisture-, Heat-, and Oil-Resistant Thermoplastic | MTW | 60°C (140°F) | Machine Tool Wiring in Wet Locations |
| | | 90°C (194°F) | Machine Tool Wiring in Dry Locations, Informational Note: See NFPA 79 |
| Paper | | 85°C (185°F) | For Underground Service Conductors, or By Special Permission |
| Perfluoro-Alkoxy | PFA | 90°C (194°F) | Dry and Damp Locations |
| | | 200°C (392°F) | Dry Locations—Special Applications ¹ |
| Perfluoro-Alkoxy | PFAH | 250°C (482°F) | Dry Locations Only. Only For Leads Within Apparatus or Within Raceways Connected to Apparatus (Nickel or Nickel-Coated Copper Only) |
| Thermoset | RHH | 90°C (194°F) | Dry and Damp Locations |
| Moisture-Resistant Thermoset | RHW | 75°C (167°F) | Dry and Wet Locations |
| Moisture-Resistant Thermoset | RHW-2 | 90°C (194°F) | Dry and Wet Locations |
| Silicone | SA | 90°C (194°F) | Dry and Damp Locations |
| | | 200°C (392°F) | Special Applications ¹ |
| Thermoset | SIS | 90°C (194°F) | Switchboard and Switchgear Wiring Only |
| Thermoplastic and Fibrous Outer Braid | TBS | 90°C (194°F) | Switchboard and Switchgear Wiring Only |

See *Ugly's* page 82 for footnotes on special provisions and/or applications.

(continued on next page)



CONDUCTOR APPLICATIONS AND INSULATIONS

| Trade Name | Letter | Max. Temp. | Application Provisions |
|--|--------|---|--|
| Extruded Polytetrafluoro-Ethylene | TFE | 250°C (482°F) | Dry Locations Only, Only for Leads Within Apparatus or Within Raceways Connected to Apparatus, or as Open Wiring (Nickel or Nickel-Coated Copper Only) |
| Heat-Resistant Thermoplastic | THHN | 90°C (194°F) | Dry and Damp Locations |
| Moisture- and Heat-Resistant Thermoplastic | THHW | 75°C (167°F) | Wet Location |
| | | 90°C (194°F) | Dry Location |
| Moisture- and Heat-Resistant Thermoplastic | THW | 75°C (167°F) | Dry and Wet Locations |
| | | 90°C (194°F) | Special Appl. Within Electric Discharge Lighting Equipment, Limited to 1000 Open-Circuit Volts or Less (Size 14-8 Only as Permitted in Section 410.68) |
| | THW-2 | 90°C (194°F) | Dry and Wet Locations |
| Moisture- and Heat-Resistant Thermoplastic | THWN | 75°C (167°F) | Dry and Wet Locations |
| | THWN-2 | 90°C (194°F) | |
| Moisture-Resistant Thermoplastic | TW | 60°C (140°F) | Dry and Wet Locations |
| Underground Feeder and Branch-Circuit Cable Single Conductor (For Type "UF" Cable Employing More Than 1 Conductor, See Part II of Article 340) | UF | 60°C (140°F) 75°C (167°F) ² | See <i>NEC</i> Article 340, Part II |

See *Ugly's* page 82 for footnotes on special provisions and/or applications.

(continued on next page)



CONDUCTOR APPLICATIONS AND INSULATIONS

| Trade Name | Letter | Max. Temp. | Application Provisions |
|--|--------|---------------------------|---|
| Underground Service-Entrance Cable Single Conductor (For Type "USE" Cable Employing More Than 1 Conductor, See Part II of Article 338) | USE | 75°C (167°F) ² | See <i>NEC</i> Article 338, Part II |
| | USE-2 | 90°C (194°F) | |
| Thermoset | XHH | 90°C (194°F) | Dry and Damp Locations |
| Flame-Retardant Thermoset | XHHN | 90°C (194°F) | Dry and Damp Locations |
| Moisture-Resistant Thermoset | XHHW | 90°C (194°F) | Dry and Damp Locations |
| | | 75°C (167°F) | Wet Locations |
| Moisture-Resistant, Thermoset | XHHW-2 | 90°C (194°F) | Dry and Wet Locations |
| Flame-Retardant, Moisture-Resistant Thermoset | XHWN | 75°C (167°F) | Dry and Wet Locations |
| | XHWN-2 | 90°C (194°F) | |
| Modified Ethylene Tetrafluoro-Ethylene | Z | 90°C (194°F) | Dry and Damp Locations |
| | | 150°C (302°F) | Dry Locations—Special Applications ¹ |
| Modified Ethylene Tetrafluoro-Ethylene | ZW | 75°C (167°F) | Wet Locations |
| | | 90°C (194°F) | Dry and Damp Locations |
| | | 150°C (302°F) | Dry Locations—Special Applications ¹ |
| | ZW-2 | 90°C (194°F) | Dry and Wet Locations |

- Higher temperature-rated constructions shall be permitted where design conditions require maximum conductor operating temperatures above 90°C (194°F).
- The ampacity of Type UF cable shall be limited in accordance with 340.80.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 310.4(1), as modified.

Note: Conductors in Table 310.4(1) shall be permitted to be rated up to 1000 volts if listed and marked.



MAXIMUM NUMBER OF CONDUCTORS IN TRADE SIZES OF CONDUIT OR TUBING

The *National Electrical Code*[®] shows a separate table for each type of conduit. In order to keep *Ugly's Electrical References* in a compact and easy-to-use format, the following tables are included:

Electrical Metallic Tubing (EMT), Electrical Nonmetallic Tubing (ENT), PVC 40, PVC 80, Rigid Metal Conduit, Flexible Metal Conduit, and Liquidtight Flexible Metal Conduit.

When other types of conduit are used, refer to *NEC* Informative Annex C or use method shown below to figure conduit size.

Example #1: All Same Wire Size and Type Insulation.

10 – 12 AWG RHH (with outer covering) in Intermediate Metal Conduit.
Go to the RHH Conductor Square Inch Area Table. (Ugly's page 98)

12 AWG RHH = 0.0353 sq. in. 10 x 0.0353 sq. in. = 0.353 sq. in.

Go to Intermediate Metal Conduit Square Inch Area Table. (Ugly's page 101)

Use "Over 2 Wires 40%" column.

¾-inch conduit = 0.235 sq. in. (less than 0.353, so it's too small).

1-inch conduit = 0.384 sq. in. (greater than 0.353, so it's correct size).

Example #2: Different Wire Sizes or Types Insulation.

10 – 12 AWG RHH (with outer covering) and 10 – 10 AWG THHN in Liquidtight Nonmetallic Conduit (LFNC-B).

Go to the RHH Conductor Square Inch Area Table. (Ugly's page 98)

12 AWG RHH = 0.0353 sq. in. 10 x 0.0353 sq. in. = 0.353 sq. in.

Go to the THHN Conductor Square Inch Area Table. (Ugly's page 98)

10 AWG THHN = 0.0211 sq. in. 10 x 0.0211 sq. in. = 0.211 sq. in.

0.353 sq. in. + 0.211 sq. in. = 0.564 sq. in.

Go to Liquidtight Flexible Nonmetallic Conduit (LFNC-B) Square Inch Table. (Ugly's page 102)

Use "Over 2 Wires 40%" column.

1-inch conduit = 0.349 sq. in. (less than 0.564, so it's too small).

1¼-inch conduit = 0.611 sq. in. (greater than 0.564, so it's the correct size).

*Note 1**: All conductors must be counted including grounding conductors for fill percentage.

Note 2: When all conductors are of same type and size, decimals 0.8 and larger can be rounded up.

*Note 3***: These are minimum size calculations, under certain conditions jamming can occur and the next size conduit must be used.

*Note 4****: **Caution**—When over three current carrying conductors are used in the same circuit, conductor ampacity must be lower (adjusted).

* See Appendix C and Chapter 9 2026 *NEC* for complete tables and examples.

** See Chapter 9 Table 1 and Notes to Tables 1–10, 2026 *NEC*.

*** See 2026 *NEC* 310.15 for adjustment factors for temperature and number of current-carrying conductors.



MAXIMUM NUMBER OF CONDUCTORS IN ELECTRICAL METALLIC TUBING

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| RHH, RHW, RHW-2 | 14 | 4 | 7 | 11 | 20 | 27 | 46 | 80 | 120 | 157 | 201 | 302 | 427 |
| | 12 | 3 | 6 | 9 | 17 | 23 | 38 | 66 | 100 | 131 | 167 | 251 | 354 |
| | 10 | 2 | 5 | 8 | 13 | 18 | 30 | 53 | 81 | 105 | 135 | 203 | 286 |
| | 8 | 1 | 2 | 4 | 7 | 9 | 16 | 28 | 42 | 55 | 70 | 106 | 150 |
| | 6 | 1 | 1 | 3 | 5 | 8 | 13 | 22 | 34 | 44 | 56 | 85 | 120 |
| | 4 | 1 | 1 | 2 | 4 | 6 | 10 | 17 | 26 | 34 | 44 | 66 | 94 |
| | 3 | 1 | 1 | 1 | 4 | 5 | 9 | 15 | 23 | 30 | 38 | 58 | 82 |
| | 2 | 1 | 1 | 1 | 3 | 4 | 7 | 13 | 20 | 26 | 33 | 50 | 71 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 5 | 9 | 13 | 17 | 22 | 33 | 47 |
| | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 15 | 19 | 29 | 41 |
| | 2/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 | 25 | 35 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 | 21 | 30 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 12 | 18 | 26 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 14 | 20 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 12 | 17 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 11 | 16 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 10 | 14 |
| 500 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 6 | 8 | 12 | |
| 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 10 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 6 | 8 | |
| TW, THHW, THW, THW-2 | 14 | 8 | 15 | 25 | 43 | 58 | 96 | 168 | 254 | 332 | 424 | 638 | 900 |
| | 12 | 6 | 11 | 19 | 33 | 45 | 74 | 129 | 195 | 255 | 326 | 490 | 691 |
| | 10 | 5 | 8 | 14 | 24 | 33 | 55 | 96 | 145 | 190 | 243 | 365 | 515 |
| | 8 | 2 | 5 | 8 | 13 | 18 | 30 | 53 | 81 | 105 | 135 | 203 | 286 |
| RHH*, RHW*, RHW-2* | 14 | 6 | 10 | 16 | 28 | 39 | 64 | 112 | 169 | 221 | 282 | 424 | 599 |
| | 12 | 4 | 8 | 13 | 23 | 31 | 51 | 90 | 136 | 177 | 227 | 341 | 481 |
| | 10 | 3 | 6 | 10 | 18 | 24 | 40 | 70 | 106 | 138 | 177 | 266 | 376 |
| | 8 | 1 | 4 | 6 | 10 | 14 | 24 | 42 | 63 | 83 | 106 | 159 | 225 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 3 | 4 | 8 | 11 | 18 | 32 | 48 | 63 | 81 | 122 | 172 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 13 | 24 | 36 | 47 | 60 | 91 | 128 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 12 | 20 | 31 | 40 | 52 | 78 | 110 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 | 17 | 26 | 34 | 44 | 66 | 94 |
| | 1 | 1 | 1 | 1 | 3 | 4 | 7 | 12 | 18 | 24 | 31 | 46 | 66 |
| | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 | 10 | 16 | 20 | 26 | 40 | 56 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 5 | 9 | 13 | 17 | 22 | 33 | 47 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 15 | 19 | 28 | 40 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 12 | 16 | 24 | 33 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 19 | 27 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 11 | 16 | 23 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 | 7 | 10 | 15 | 21 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 13 | 19 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 11 | 16 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | 13 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 10 |
| THHN, THWN, THWN-2 | 14 | 12 | 22 | 35 | 61 | 84 | 138 | 241 | 364 | 476 | 608 | 914 | 1290 |
| | 12 | 9 | 16 | 26 | 45 | 61 | 101 | 176 | 266 | 347 | 443 | 666 | 941 |
| | 10 | 5 | 10 | 16 | 28 | 38 | 63 | 111 | 167 | 219 | 279 | 420 | 593 |
| | 8 | 3 | 6 | 9 | 16 | 22 | 36 | 64 | 96 | 126 | 161 | 242 | 342 |
| | 6 | 2 | 4 | 7 | 12 | 16 | 26 | 46 | 69 | 91 | 116 | 175 | 247 |
| | 4 | 1 | 2 | 4 | 7 | 10 | 16 | 28 | 43 | 56 | 71 | 107 | 152 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 13 | 24 | 36 | 47 | 60 | 91 | 128 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 | 20 | 30 | 40 | 51 | 76 | 108 |
| | 1 | 1 | 1 | 1 | 4 | 5 | 8 | 15 | 22 | 29 | 37 | 56 | 80 |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN ELECTRICAL METALLIC TUBING

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|------|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| THHN, THWN, THWN-2 | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 12 | 19 | 25 | 32 | 47 | 67 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 10 | 16 | 20 | 26 | 40 | 56 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 13 | 17 | 22 | 33 | 46 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 14 | 18 | 27 | 38 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 11 | 15 | 22 | 31 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 19 | 27 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 11 | 17 | 24 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 | 8 | 10 | 15 | 21 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 12 | 17 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 10 | 14 |
| 700 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | 12 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 12 |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 12 | 21 | 34 | 60 | 81 | 134 | 234 | 354 | 462 | 590 | 886 | 1252 |
| | 12 | 9 | 15 | 25 | 43 | 59 | 98 | 171 | 258 | 337 | 430 | 647 | 913 |
| | 10 | 6 | 11 | 18 | 31 | 42 | 70 | 122 | 185 | 241 | 309 | 464 | 655 |
| | 8 | 3 | 6 | 10 | 18 | 24 | 40 | 70 | 106 | 138 | 177 | 266 | 376 |
| | 6 | 2 | 4 | 7 | 12 | 17 | 28 | 50 | 75 | 98 | 126 | 189 | 267 |
| | 4 | 1 | 3 | 5 | 9 | 12 | 20 | 35 | 53 | 69 | 88 | 132 | 187 |
| | 3 | 1 | 2 | 4 | 7 | 10 | 16 | 29 | 44 | 57 | 73 | 110 | 155 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 13 | 24 | 36 | 47 | 60 | 91 | 128 |
| PFA, PFAH, TFE | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 16 | 25 | 33 | 42 | 63 | 89 |
| PFA, PFAH, TFE, Z | 1/0 | 1 | 1 | 1 | 3 | 5 | 8 | 14 | 21 | 27 | 35 | 53 | 74 |
| | 2/0 | 0 | 1 | 1 | 3 | 4 | 6 | 11 | 17 | 22 | 29 | 43 | 61 |
| | 3/0 | 0 | 1 | 1 | 2 | 3 | 5 | 9 | 14 | 18 | 24 | 36 | 51 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 8 | 11 | 15 | 19 | 29 | 41 |
| Z | 14 | 14 | 25 | 41 | 72 | 98 | 161 | 282 | 426 | 556 | 711 | 1068 | 1508 |
| | 12 | 10 | 18 | 29 | 51 | 69 | 114 | 200 | 302 | 394 | 504 | 758 | 1070 |
| | 10 | 6 | 11 | 18 | 31 | 42 | 70 | 122 | 185 | 241 | 309 | 464 | 655 |
| | 8 | 4 | 7 | 11 | 20 | 27 | 44 | 77 | 117 | 153 | 195 | 293 | 414 |
| | 6 | 3 | 5 | 8 | 14 | 19 | 31 | 54 | 82 | 107 | 137 | 206 | 291 |
| | 4 | 1 | 3 | 5 | 9 | 13 | 21 | 37 | 56 | 74 | 94 | 142 | 200 |
| | 3 | 1 | 2 | 4 | 7 | 9 | 15 | 27 | 41 | 54 | 69 | 103 | 146 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 13 | 22 | 34 | 45 | 57 | 86 | 121 |
| 1 | 1 | 1 | 2 | 4 | 6 | 10 | 18 | 28 | 36 | 46 | 70 | 98 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 8 | 15 | 25 | 43 | 58 | 96 | 168 | 254 | 332 | 424 | 638 | 900 |
| | 12 | 6 | 11 | 19 | 33 | 45 | 74 | 129 | 195 | 255 | 326 | 490 | 691 |
| | 10 | 5 | 8 | 14 | 24 | 33 | 55 | 96 | 145 | 190 | 243 | 365 | 515 |
| | 8 | 2 | 5 | 8 | 13 | 18 | 30 | 53 | 81 | 105 | 135 | 203 | 286 |
| | 6 | 1 | 3 | 6 | 10 | 14 | 22 | 39 | 60 | 78 | 100 | 150 | 212 |
| | 4 | 1 | 2 | 4 | 7 | 10 | 16 | 28 | 43 | 56 | 72 | 109 | 153 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 14 | 24 | 36 | 48 | 61 | 92 | 130 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 | 20 | 31 | 40 | 51 | 77 | 109 |
| XHH, XHHW, XHHW-2 | 1 | 1 | 1 | 1 | 4 | 5 | 8 | 15 | 23 | 30 | 38 | 57 | 81 |
| | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 13 | 19 | 25 | 32 | 48 | 68 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 10 | 16 | 21 | 27 | 40 | 57 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 9 | 13 | 17 | 22 | 33 | 47 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 11 | 14 | 18 | 27 | 39 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 12 | 15 | 22 | 32 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 10 | 13 | 19 | 27 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 9 | 11 | 17 | 24 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 | 8 | 10 | 15 | 21 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 12 | 18 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 6 | 10 | 14 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | 12 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.1, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN ELECTRICAL NONMETALLIC TUBING

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | |
|---|----------------------|-----------------------|-----|----|-------|-------|-----|
| | | 1/8 | 1/4 | 1 | 1 1/4 | 1 1/2 | 2 |
| RHH, RHW, RHW-2 | 14 | 4 | 7 | 11 | 20 | 27 | 45 |
| | 12 | 3 | 5 | 9 | 16 | 22 | 37 |
| | 10 | 2 | 4 | 7 | 13 | 18 | 30 |
| | 8 | 1 | 2 | 4 | 7 | 9 | 15 |
| | 6 | 1 | 1 | 3 | 5 | 7 | 12 |
| | 4 | 1 | 1 | 2 | 4 | 6 | 10 |
| | 3 | 1 | 1 | 1 | 4 | 5 | 8 |
| | 2 | 1 | 1 | 1 | 3 | 4 | 7 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 5 |
| | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 |
| 500 | 0 | 0 | 0 | 0 | 1 | 1 | |
| 600 | 0 | 0 | 0 | 0 | 1 | 1 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | |
| TW, THHW, THW, THW-2 | 14 | 8 | 14 | 24 | 42 | 57 | 94 |
| | 12 | 6 | 11 | 18 | 32 | 44 | 72 |
| | 10 | 4 | 8 | 13 | 24 | 32 | 54 |
| | 8 | 2 | 4 | 7 | 13 | 18 | 30 |
| RHH*, RHW*, RHW-2* | 14 | 5 | 9 | 16 | 28 | 38 | 63 |
| | 12 | 4 | 8 | 13 | 22 | 30 | 50 |
| | 10 | 3 | 6 | 10 | 17 | 24 | 39 |
| | 8 | 1 | 3 | 6 | 10 | 14 | 23 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 2 | 4 | 8 | 11 | 18 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 13 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 11 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 |
| | 1 | 0 | 1 | 1 | 3 | 4 | 7 |
| | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 5 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 2 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 |
| THHN, THWN, THWN-2 | 14 | 11 | 21 | 34 | 60 | 82 | 135 |
| | 12 | 8 | 15 | 25 | 43 | 59 | 99 |
| | 10 | 5 | 9 | 15 | 27 | 37 | 62 |
| | 8 | 3 | 5 | 9 | 16 | 21 | 36 |
| | 6 | 1 | 4 | 6 | 11 | 15 | 26 |
| | 4 | 1 | 2 | 4 | 7 | 9 | 16 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 13 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 |
| 1 | 1 | 1 | 1 | 3 | 5 | 8 | |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN ELECTRICAL NONMETALLIC TUBING

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | |
|---------------------------------|----------------------|-----------------------|-----|----|-------|-------|-----|
| | | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 |
| THHN, THWN, THWN-2 | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 11 | 20 | 33 | 58 | 79 | 131 |
| | 12 | 8 | 15 | 24 | 42 | 58 | 96 |
| | 10 | 6 | 10 | 17 | 30 | 41 | 69 |
| | 8 | 3 | 6 | 10 | 17 | 24 | 39 |
| | 6 | 2 | 4 | 7 | 12 | 17 | 28 |
| | 4 | 1 | 3 | 5 | 8 | 12 | 19 |
| | 3 | 1 | 2 | 4 | 7 | 10 | 16 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 13 |
| PFA, PFAH, TFE | 1 | 1 | 1 | 2 | 4 | 5 | 9 |
| PFA, PFAH, TFE, Z | 1/0 | 1 | 1 | 1 | 3 | 4 | 8 |
| | 2/0 | 0 | 1 | 1 | 3 | 4 | 6 |
| | 3/0 | 0 | 1 | 1 | 2 | 3 | 5 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 |
| Z | 14 | 13 | 24 | 40 | 70 | 95 | 158 |
| | 12 | 9 | 17 | 28 | 49 | 68 | 112 |
| | 10 | 6 | 10 | 17 | 30 | 41 | 69 |
| | 8 | 3 | 6 | 11 | 19 | 26 | 43 |
| | 6 | 2 | 4 | 7 | 13 | 18 | 30 |
| | 4 | 1 | 3 | 5 | 9 | 12 | 21 |
| | 3 | 1 | 2 | 4 | 6 | 9 | 15 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 12 |
| 1 | 1 | 1 | 2 | 4 | 6 | 10 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 8 | 14 | 24 | 42 | 57 | 94 |
| | 12 | 6 | 11 | 18 | 32 | 44 | 72 |
| | 10 | 4 | 8 | 13 | 24 | 32 | 54 |
| | 8 | 2 | 4 | 7 | 13 | 18 | 30 |
| | 6 | 1 | 3 | 5 | 10 | 13 | 22 |
| | 4 | 1 | 2 | 4 | 7 | 9 | 16 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 13 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 |
| XHH, XHHW, XHHW-2 | 1 | 1 | 1 | 1 | 3 | 5 | 8 |
| | 1/0 | 0 | 1 | 1 | 3 | 4 | 7 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.2, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN RIGID PVC CONDUIT, SCHEDULE 40

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---|----------------------|-----------------------|-----|----|-------|-------|-----|-------|-----|-------|-----|-----|------|
| | | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 3 1/2 | 4 | 5 | 6 |
| RHH, RHW, RHW-2 | 14 | 4 | 7 | 11 | 20 | 27 | 45 | 64 | 99 | 133 | 171 | 269 | 390 |
| | 12 | 3 | 5 | 9 | 16 | 22 | 37 | 53 | 82 | 110 | 142 | 224 | 323 |
| | 10 | 2 | 4 | 7 | 13 | 18 | 30 | 43 | 66 | 89 | 115 | 181 | 261 |
| | 8 | 1 | 2 | 4 | 7 | 9 | 15 | 22 | 35 | 46 | 60 | 94 | 137 |
| | 6 | 1 | 1 | 3 | 5 | 7 | 12 | 18 | 28 | 37 | 48 | 76 | 109 |
| | 4 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 29 | 37 | 59 | 85 |
| | 3 | 1 | 1 | 1 | 4 | 5 | 8 | 12 | 19 | 25 | 33 | 52 | 75 |
| | 2 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 22 | 28 | 45 | 65 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 19 | 29 | 43 |
| | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 16 | 26 | 37 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 | 22 | 32 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 9 | 12 | 19 | 28 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 | 16 | 24 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 12 | 18 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 13 |
| 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 6 | 8 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 8 | |
| TW, THHW, THW, THW-2 | 14 | 8 | 14 | 24 | 42 | 57 | 94 | 135 | 209 | 280 | 361 | 568 | 822 |
| | 12 | 6 | 11 | 18 | 32 | 44 | 72 | 103 | 160 | 215 | 277 | 436 | 631 |
| | 10 | 4 | 8 | 13 | 24 | 32 | 54 | 77 | 119 | 160 | 206 | 325 | 470 |
| | 8 | 2 | 4 | 7 | 13 | 18 | 30 | 43 | 66 | 89 | 115 | 181 | 261 |
| RHH*, RHW*, RHW-2* | 14 | 5 | 9 | 16 | 28 | 38 | 63 | 90 | 139 | 186 | 240 | 378 | 546 |
| | 12 | 4 | 8 | 13 | 22 | 30 | 50 | 72 | 112 | 150 | 193 | 304 | 439 |
| | 10 | 3 | 6 | 10 | 17 | 24 | 39 | 56 | 87 | 117 | 150 | 237 | 343 |
| | 8 | 1 | 3 | 6 | 10 | 14 | 23 | 33 | 52 | 70 | 90 | 142 | 205 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 2 | 4 | 8 | 11 | 18 | 26 | 40 | 53 | 69 | 109 | 157 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 30 | 40 | 51 | 81 | 117 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 11 | 16 | 25 | 34 | 44 | 69 | 100 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 29 | 37 | 59 | 85 |
| | 1 | 0 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 20 | 26 | 41 | 60 |
| | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 17 | 22 | 35 | 51 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 19 | 30 | 43 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 | 25 | 36 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 10 | 13 | 21 | 30 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 25 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 21 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 12 | 17 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 10 | |
| THHN, THWN, THWN-2 | 14 | 11 | 21 | 34 | 60 | 82 | 135 | 193 | 299 | 401 | 517 | 815 | 1178 |
| | 12 | 8 | 15 | 25 | 43 | 59 | 99 | 141 | 218 | 293 | 377 | 594 | 859 |
| | 10 | 5 | 9 | 15 | 27 | 37 | 62 | 89 | 137 | 184 | 238 | 374 | 541 |
| | 8 | 3 | 5 | 9 | 16 | 21 | 36 | 51 | 79 | 106 | 137 | 216 | 312 |
| | 6 | 1 | 4 | 6 | 11 | 15 | 26 | 37 | 57 | 77 | 99 | 156 | 225 |
| | 4 | 1 | 2 | 4 | 7 | 9 | 16 | 22 | 35 | 47 | 61 | 96 | 138 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 30 | 40 | 51 | 81 | 117 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 | 16 | 25 | 33 | 43 | 68 | 98 |
| | 1 | 1 | 1 | 1 | 3 | 5 | 8 | 12 | 18 | 25 | 32 | 50 | 73 |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN RIGID PVC CONDUIT, SCHEDULE 40

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| THHN, THWN, THWN-2 | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 21 | 27 | 42 | 61 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 17 | 22 | 35 | 51 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 18 | 29 | 42 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 15 | 24 | 35 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 12 | 20 | 28 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 24 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 21 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 9 | 13 |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 11 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 11 | 20 | 33 | 58 | 79 | 131 | 188 | 290 | 389 | 502 | 790 | 1142 |
| | 12 | 8 | 15 | 24 | 42 | 58 | 96 | 137 | 212 | 284 | 366 | 577 | 834 |
| | 10 | 6 | 10 | 17 | 30 | 41 | 69 | 98 | 152 | 204 | 263 | 414 | 598 |
| | 8 | 3 | 6 | 10 | 17 | 24 | 39 | 56 | 87 | 117 | 150 | 237 | 343 |
| | 6 | 2 | 4 | 7 | 12 | 17 | 28 | 40 | 62 | 83 | 107 | 169 | 244 |
| | 4 | 1 | 3 | 5 | 8 | 12 | 19 | 28 | 43 | 58 | 75 | 118 | 170 |
| | 3 | 1 | 2 | 4 | 7 | 10 | 16 | 23 | 36 | 48 | 62 | 98 | 142 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 30 | 40 | 51 | 81 | 117 |
| PFA, PFAH, TFE | 1 | 1 | 1 | 2 | 4 | 5 | 9 | 13 | 20 | 28 | 36 | 56 | 81 |
| PFA, PFAH, TFE, Z | 1/0 | 1 | 1 | 1 | 3 | 4 | 8 | 11 | 17 | 23 | 30 | 47 | 68 |
| | 2/0 | 0 | 1 | 1 | 3 | 4 | 6 | 9 | 14 | 19 | 24 | 39 | 56 |
| | 3/0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 12 | 16 | 20 | 32 | 46 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 16 | 26 | 38 |
| Z | 14 | 13 | 24 | 40 | 70 | 95 | 158 | 226 | 350 | 469 | 605 | 952 | 1376 |
| | 12 | 9 | 17 | 28 | 49 | 68 | 112 | 160 | 248 | 333 | 429 | 675 | 976 |
| | 10 | 6 | 10 | 17 | 30 | 41 | 69 | 98 | 152 | 204 | 263 | 414 | 598 |
| | 8 | 3 | 6 | 11 | 19 | 26 | 43 | 62 | 96 | 129 | 166 | 261 | 378 |
| | 6 | 2 | 4 | 7 | 13 | 18 | 30 | 43 | 67 | 90 | 116 | 184 | 265 |
| | 4 | 1 | 3 | 5 | 9 | 12 | 21 | 30 | 46 | 62 | 80 | 126 | 183 |
| | 3 | 1 | 2 | 4 | 6 | 9 | 15 | 22 | 34 | 45 | 58 | 92 | 133 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 12 | 18 | 28 | 38 | 49 | 77 | 111 |
| XHH, XHHW, XHHW-2, ZW | 14 | 8 | 14 | 24 | 42 | 57 | 94 | 135 | 209 | 280 | 361 | 568 | 822 |
| | 12 | 6 | 11 | 18 | 32 | 44 | 72 | 103 | 160 | 215 | 277 | 436 | 631 |
| | 10 | 4 | 8 | 13 | 24 | 32 | 54 | 77 | 119 | 160 | 206 | 325 | 470 |
| | 8 | 2 | 4 | 7 | 13 | 18 | 30 | 43 | 66 | 89 | 115 | 181 | 261 |
| | 6 | 1 | 3 | 5 | 10 | 13 | 22 | 32 | 49 | 66 | 85 | 134 | 193 |
| | 4 | 1 | 2 | 4 | 7 | 9 | 16 | 23 | 35 | 48 | 61 | 97 | 140 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 30 | 40 | 52 | 82 | 118 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 | 16 | 25 | 34 | 44 | 69 | 99 |
| XHH, XHHW, XHHW-2 | 1 | 1 | 1 | 1 | 3 | 5 | 8 | 12 | 19 | 25 | 32 | 51 | 74 |
| | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 21 | 27 | 43 | 62 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 17 | 23 | 36 | 52 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 19 | 30 | 43 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 15 | 24 | 35 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 20 | 29 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 25 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 22 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 9 | 13 |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 11 | |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.11, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN RIGID PVC CONDUIT, SCHEDULE 80

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| RHH, RHW, RHW-2 | 14 | 3 | 5 | 9 | 17 | 23 | 39 | 56 | 88 | 118 | 153 | 243 | 349 |
| | 12 | 2 | 4 | 7 | 14 | 19 | 32 | 46 | 73 | 98 | 127 | 202 | 290 |
| | 10 | 1 | 3 | 6 | 11 | 15 | 26 | 37 | 59 | 79 | 103 | 163 | 234 |
| | 8 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 31 | 41 | 54 | 85 | 122 |
| | 6 | 1 | 1 | 2 | 4 | 6 | 11 | 16 | 24 | 33 | 43 | 68 | 98 |
| | 4 | 1 | 1 | 1 | 3 | 5 | 8 | 12 | 19 | 26 | 33 | 53 | 77 |
| | 3 | 0 | 1 | 1 | 3 | 4 | 7 | 11 | 17 | 23 | 29 | 47 | 67 |
| | 2 | 0 | 1 | 1 | 3 | 4 | 6 | 9 | 14 | 20 | 25 | 41 | 58 |
| | 1 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 17 | 27 | 38 |
| | 1/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 15 | 23 | 33 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 13 | 20 | 29 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 25 |
| | 4/0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 21 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 9 | 13 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 12 |
| 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 | |
| 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 6 | 8 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | |
| TW, THHW, THW, THW-2 | 14 | 6 | 11 | 19 | 35 | 49 | 82 | 118 | 185 | 250 | 324 | 514 | 736 |
| | 12 | 4 | 9 | 15 | 27 | 38 | 63 | 91 | 142 | 192 | 248 | 394 | 565 |
| | 10 | 3 | 6 | 11 | 20 | 28 | 47 | 68 | 106 | 143 | 185 | 294 | 421 |
| | 8 | 1 | 3 | 6 | 11 | 15 | 26 | 37 | 59 | 79 | 103 | 163 | 234 |
| RHH*, RHW*, RHW-2* | 14 | 4 | 8 | 13 | 23 | 32 | 55 | 79 | 123 | 166 | 215 | 341 | 490 |
| | 12 | 3 | 6 | 10 | 19 | 26 | 44 | 63 | 99 | 133 | 173 | 274 | 394 |
| | 10 | 2 | 5 | 8 | 15 | 20 | 34 | 49 | 77 | 104 | 135 | 214 | 307 |
| | 8 | 1 | 3 | 5 | 9 | 12 | 20 | 29 | 46 | 62 | 81 | 128 | 184 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 1 | 3 | 7 | 9 | 16 | 22 | 35 | 48 | 62 | 98 | 141 |
| | 4 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 35 | 46 | 73 | 105 |
| | 3 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 30 | 39 | 63 | 90 |
| | 2 | 1 | 1 | 1 | 3 | 5 | 8 | 12 | 19 | 26 | 33 | 53 | 77 |
| | 1 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 18 | 23 | 37 | 54 |
| | 1/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 20 | 32 | 46 |
| | 2/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 | 27 | 39 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 | 23 | 33 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 9 | 12 | 19 | 27 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 22 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 7 | 12 | 17 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 10 | 15 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 9 | 13 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 |
| | 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 |
| THHN, THWN, THWN-2 | 14 | 9 | 17 | 28 | 51 | 70 | 118 | 170 | 265 | 358 | 464 | 736 | 1055 |
| | 12 | 6 | 12 | 20 | 37 | 51 | 86 | 124 | 193 | 261 | 338 | 537 | 770 |
| | 10 | 4 | 7 | 13 | 23 | 32 | 54 | 78 | 122 | 164 | 213 | 338 | 485 |
| | 8 | 2 | 4 | 7 | 13 | 18 | 31 | 45 | 70 | 95 | 123 | 195 | 279 |
| | 6 | 1 | 3 | 5 | 9 | 13 | 22 | 32 | 51 | 68 | 89 | 141 | 202 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 42 | 54 | 86 | 124 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 35 | 46 | 73 | 105 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 30 | 39 | 61 | 88 |
| | 1 | 0 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 22 | 29 | 45 | 65 |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN RIGID PVC CONDUIT, SCHEDULE 80

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| THHN, THWN, THWN-2 | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 | 9 | 14 | 18 | 24 | 38 | 55 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 20 | 32 | 46 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 17 | 26 | 38 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 10 | 14 | 22 | 31 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 18 | 25 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 22 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 12 | 17 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 12 |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 9 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 8 | 16 | 27 | 49 | 68 | 115 | 164 | 257 | 347 | 450 | 714 | 1024 |
| | 12 | 6 | 12 | 20 | 36 | 50 | 84 | 120 | 188 | 253 | 328 | 521 | 747 |
| | 10 | 4 | 8 | 14 | 26 | 36 | 60 | 86 | 135 | 182 | 235 | 374 | 536 |
| | 8 | 2 | 5 | 8 | 15 | 20 | 34 | 49 | 77 | 104 | 135 | 214 | 307 |
| | 6 | 1 | 3 | 6 | 10 | 14 | 24 | 35 | 55 | 74 | 96 | 152 | 218 |
| | 4 | 1 | 2 | 4 | 7 | 10 | 17 | 24 | 38 | 52 | 67 | 106 | 153 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 32 | 43 | 56 | 89 | 127 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 35 | 46 | 73 | 105 |
| PFA, PFAH, TFE | 1 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 18 | 25 | 32 | 51 | 73 |
| PFA, PFAH, TFE, Z | 1/0 | 0 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 20 | 27 | 42 | 61 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 5 | 8 | 12 | 17 | 22 | 35 | 50 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 18 | 29 | 41 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 4 | 5 | 8 | 11 | 15 | 24 | 34 |
| Z | 14 | 10 | 19 | 33 | 59 | 82 | 138 | 198 | 310 | 418 | 542 | 860 | 1233 |
| | 12 | 7 | 14 | 23 | 42 | 58 | 98 | 141 | 220 | 297 | 385 | 610 | 875 |
| | 10 | 4 | 8 | 14 | 26 | 36 | 60 | 86 | 135 | 182 | 235 | 374 | 536 |
| | 8 | 3 | 5 | 9 | 16 | 22 | 38 | 54 | 85 | 115 | 149 | 236 | 339 |
| | 6 | 1 | 4 | 6 | 11 | 16 | 26 | 38 | 60 | 81 | 104 | 166 | 238 |
| | 4 | 1 | 2 | 4 | 8 | 11 | 18 | 26 | 41 | 55 | 72 | 114 | 164 |
| | 3 | 1 | 1 | 3 | 5 | 8 | 13 | 19 | 30 | 40 | 52 | 83 | 119 |
| | 2 | 1 | 1 | 2 | 5 | 6 | 11 | 16 | 25 | 33 | 43 | 69 | 99 |
| 1 | 1 | 1 | 1 | 4 | 5 | 9 | 13 | 20 | 27 | 35 | 56 | 80 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 6 | 11 | 19 | 35 | 49 | 82 | 118 | 185 | 250 | 324 | 514 | 736 |
| | 12 | 4 | 9 | 15 | 27 | 38 | 63 | 91 | 142 | 192 | 248 | 394 | 565 |
| | 10 | 3 | 6 | 11 | 20 | 28 | 47 | 68 | 106 | 143 | 185 | 294 | 421 |
| | 8 | 1 | 3 | 6 | 11 | 15 | 26 | 37 | 59 | 79 | 103 | 163 | 234 |
| | 6 | 1 | 2 | 4 | 8 | 11 | 19 | 28 | 43 | 59 | 76 | 121 | 173 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 42 | 55 | 87 | 125 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 36 | 47 | 74 | 106 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 30 | 39 | 62 | 89 |
| XHH, XHHW, XHHW-2 | 1 | 0 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 22 | 29 | 46 | 66 |
| | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 | 9 | 14 | 19 | 24 | 39 | 56 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 16 | 20 | 32 | 46 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 17 | 27 | 38 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 | 22 | 32 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 11 | 18 | 26 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 10 | 15 | 22 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 14 | 20 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 12 | 17 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.10, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN RIGID METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---|----------------------|-----------------------|----|----|----|----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| RHH, RHW, RHW-2 | 14 | 4 | 7 | 12 | 21 | 28 | 46 | 66 | 102 | 136 | 176 | 276 | 398 |
| | 12 | 3 | 6 | 10 | 17 | 23 | 38 | 55 | 85 | 113 | 146 | 229 | 330 |
| | 10 | 3 | 5 | 8 | 14 | 19 | 31 | 44 | 68 | 91 | 118 | 185 | 267 |
| | 8 | 1 | 2 | 4 | 7 | 10 | 16 | 23 | 36 | 48 | 61 | 97 | 139 |
| | 6 | 1 | 1 | 3 | 6 | 8 | 13 | 18 | 29 | 38 | 49 | 77 | 112 |
| | 4 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 30 | 38 | 60 | 87 |
| | 3 | 1 | 1 | 2 | 4 | 5 | 9 | 12 | 19 | 26 | 34 | 53 | 76 |
| | 2 | 1 | 1 | 1 | 3 | 4 | 7 | 11 | 17 | 23 | 29 | 46 | 66 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 19 | 30 | 44 |
| | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 | 26 | 38 |
| | 2/0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 8 | 11 | 14 | 23 | 33 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 12 | 20 | 28 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 24 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 13 | 18 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 6 | 10 | 15 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 13 |
| 500 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 6 | 9 | |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 3 | 6 | 8 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | 5 | 8 | |
| TW, THHW, THW, THW-2 | 14 | 9 | 15 | 25 | 44 | 59 | 98 | 140 | 215 | 288 | 370 | 581 | 839 |
| | 12 | 7 | 12 | 19 | 33 | 45 | 75 | 107 | 165 | 221 | 284 | 446 | 644 |
| | 10 | 5 | 9 | 14 | 25 | 34 | 56 | 80 | 123 | 164 | 212 | 332 | 480 |
| | 8 | 3 | 5 | 8 | 14 | 19 | 31 | 44 | 68 | 91 | 118 | 185 | 267 |
| RHH*, RHW*, RHW-2* | 14 | 6 | 10 | 17 | 29 | 39 | 65 | 93 | 143 | 191 | 246 | 387 | 558 |
| | 12 | 5 | 8 | 13 | 23 | 32 | 52 | 75 | 115 | 154 | 198 | 311 | 448 |
| | 10 | 3 | 6 | 10 | 18 | 25 | 41 | 58 | 90 | 120 | 154 | 242 | 350 |
| | 8 | 1 | 4 | 6 | 11 | 15 | 24 | 35 | 54 | 72 | 92 | 145 | 209 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 3 | 5 | 8 | 11 | 18 | 27 | 41 | 55 | 71 | 111 | 160 |
| | 4 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 41 | 53 | 83 | 120 |
| | 3 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 35 | 45 | 71 | 103 |
| | 2 | 1 | 1 | 2 | 4 | 6 | 10 | 14 | 22 | 30 | 38 | 60 | 87 |
| | 1 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 21 | 27 | 42 | 61 |
| | 1/0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 18 | 23 | 36 | 52 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 11 | 15 | 19 | 31 | 44 |
| | 3/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 16 | 26 | 37 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 10 | 14 | 21 | 31 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 25 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 15 | 22 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 | 13 | 19 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 | 12 | 17 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 | 10 | 14 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 12 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 7 | 10 |
| THHN, THWN, THWN-2 | 14 | 13 | 22 | 36 | 63 | 85 | 140 | 200 | 309 | 412 | 531 | 833 | 1202 |
| | 12 | 9 | 16 | 26 | 46 | 62 | 102 | 146 | 225 | 301 | 387 | 608 | 877 |
| | 10 | 6 | 10 | 17 | 29 | 39 | 64 | 92 | 142 | 189 | 244 | 383 | 552 |
| | 8 | 3 | 6 | 9 | 16 | 22 | 37 | 53 | 82 | 109 | 140 | 221 | 318 |
| | 6 | 2 | 4 | 7 | 12 | 16 | 27 | 38 | 59 | 79 | 101 | 159 | 230 |
| | 4 | 1 | 2 | 4 | 7 | 10 | 16 | 23 | 36 | 48 | 62 | 98 | 141 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 41 | 53 | 83 | 120 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 11 | 17 | 26 | 34 | 44 | 70 | 100 |
| 1 | 1 | 1 | 1 | 4 | 5 | 8 | 12 | 19 | 25 | 33 | 51 | 74 | |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN RIGID METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|----|----|----|-----|-----|-----|-----|-----|-----|-----|------|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | 5 | 6 |
| THHN, THWN, THWN-2 | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 21 | 27 | 43 | 63 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 18 | 23 | 36 | 52 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 19 | 30 | 43 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 | 25 | 36 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 20 | 29 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 | 17 | 25 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 10 | 15 | 22 |
| | 400 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 8 | 13 | 20 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 13 |
| 700 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 | |
| 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 11 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 12 | 22 | 35 | 61 | 83 | 136 | 194 | 300 | 400 | 515 | 808 | 1166 |
| | 12 | 9 | 16 | 26 | 44 | 60 | 99 | 142 | 219 | 292 | 376 | 590 | 851 |
| | 10 | 6 | 11 | 18 | 32 | 43 | 71 | 102 | 157 | 209 | 269 | 423 | 610 |
| | 8 | 3 | 6 | 10 | 18 | 25 | 41 | 58 | 90 | 120 | 154 | 242 | 350 |
| | 6 | 2 | 4 | 7 | 13 | 17 | 29 | 41 | 64 | 85 | 110 | 172 | 249 |
| | 4 | 1 | 3 | 5 | 9 | 12 | 20 | 29 | 44 | 59 | 77 | 120 | 174 |
| | 3 | 1 | 2 | 4 | 7 | 10 | 17 | 24 | 37 | 50 | 64 | 100 | 145 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 41 | 53 | 83 | 120 |
| PFA, PFAH, TFE | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 14 | 21 | 28 | 37 | 57 | 83 |
| PFA, PFAH, TFE, Z | 1/0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 18 | 24 | 30 | 48 | 69 |
| | 2/0 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 14 | 19 | 25 | 40 | 57 |
| | 3/0 | 0 | 1 | 1 | 2 | 3 | 5 | 8 | 12 | 16 | 21 | 33 | 47 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 | 27 | 39 |
| Z | 14 | 15 | 26 | 42 | 73 | 100 | 164 | 234 | 361 | 482 | 621 | 974 | 1405 |
| | 12 | 10 | 18 | 30 | 52 | 71 | 116 | 166 | 256 | 342 | 440 | 691 | 997 |
| | 10 | 6 | 11 | 18 | 32 | 43 | 71 | 102 | 157 | 209 | 269 | 423 | 610 |
| | 8 | 4 | 7 | 11 | 20 | 27 | 45 | 64 | 99 | 132 | 170 | 267 | 386 |
| | 6 | 3 | 5 | 8 | 14 | 19 | 31 | 45 | 69 | 93 | 120 | 188 | 271 |
| | 4 | 1 | 3 | 5 | 9 | 13 | 22 | 31 | 48 | 64 | 82 | 129 | 186 |
| | 3 | 1 | 2 | 4 | 7 | 9 | 16 | 22 | 35 | 47 | 60 | 94 | 136 |
| | 2 | 1 | 1 | 3 | 6 | 8 | 13 | 19 | 29 | 39 | 50 | 78 | 113 |
| 1 | 1 | 1 | 2 | 5 | 6 | 10 | 15 | 23 | 31 | 40 | 63 | 92 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 9 | 15 | 25 | 44 | 59 | 98 | 140 | 215 | 288 | 370 | 581 | 839 |
| | 12 | 7 | 12 | 19 | 33 | 45 | 75 | 107 | 165 | 221 | 284 | 446 | 644 |
| | 10 | 5 | 9 | 14 | 25 | 34 | 56 | 80 | 123 | 164 | 212 | 332 | 480 |
| | 8 | 3 | 5 | 8 | 14 | 19 | 31 | 44 | 68 | 91 | 118 | 185 | 267 |
| | 6 | 1 | 3 | 6 | 10 | 14 | 23 | 33 | 51 | 68 | 87 | 137 | 197 |
| | 4 | 1 | 2 | 4 | 7 | 10 | 16 | 24 | 37 | 49 | 63 | 99 | 143 |
| | 3 | 1 | 1 | 3 | 6 | 8 | 14 | 20 | 31 | 41 | 53 | 84 | 121 |
| | 2 | 1 | 1 | 3 | 5 | 7 | 12 | 17 | 26 | 35 | 45 | 70 | 101 |
| XHH, XHHW, XHHW-2 | 1 | 1 | 1 | 1 | 4 | 5 | 9 | 12 | 19 | 26 | 33 | 52 | 76 |
| | 1/0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 22 | 28 | 44 | 64 |
| | 2/0 | 0 | 1 | 1 | 2 | 3 | 6 | 9 | 13 | 18 | 23 | 37 | 53 |
| | 3/0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 15 | 19 | 30 | 44 |
| | 4/0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 | 25 | 36 |
| | 250 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 | 20 | 30 |
| | 300 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 11 | 18 | 25 |
| | 350 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 6 | 7 | 10 | 15 | 22 |
| | 400 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 | 14 | 20 |
| | 500 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 11 | 16 |
| | 600 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 13 |
| | 700 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | 8 | 11 |
| | 750 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 7 | 11 |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.9, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN FLEXIBLE METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | |
|---|----------------------|-----------------------|-----|-----|-----|-----|-----|-----|-------|-------|-----|-------|
| | | 1/8 | 1/4 | 3/8 | 1/2 | 5/8 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 |
| RHH, RHW, RHW-2 | 14 | 1 | 4 | 7 | 11 | 17 | 25 | 44 | 67 | 96 | 131 | 171 |
| | 12 | 1 | 3 | 6 | 9 | 14 | 21 | 37 | 55 | 80 | 109 | 142 |
| | 10 | 1 | 3 | 5 | 7 | 11 | 17 | 30 | 45 | 64 | 88 | 115 |
| | 8 | 0 | 1 | 2 | 4 | 6 | 9 | 15 | 23 | 34 | 46 | 60 |
| | 6 | 0 | 1 | 1 | 3 | 5 | 7 | 12 | 19 | 27 | 37 | 48 |
| | 4 | 0 | 1 | 1 | 2 | 4 | 5 | 10 | 14 | 21 | 29 | 37 |
| | 3 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 13 | 18 | 25 | 33 |
| | 2 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 11 | 16 | 22 | 28 |
| | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 5 | 7 | 10 | 14 | 19 |
| | 1/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 |
| | 3/0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 12 |
| | 4/0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 |
| | 250 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 |
| | 300 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 |
| | 350 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 |
| | 400 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 |
| 500 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | |
| 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | |
| TW, THHW, THW, THW-2 | 14 | 3 | 9 | 15 | 23 | 36 | 53 | 94 | 141 | 203 | 277 | 361 |
| | 12 | 2 | 7 | 11 | 18 | 28 | 41 | 72 | 108 | 156 | 212 | 277 |
| | 10 | 1 | 5 | 8 | 13 | 21 | 30 | 54 | 81 | 116 | 158 | 207 |
| | 8 | 1 | 3 | 5 | 7 | 11 | 17 | 30 | 45 | 64 | 88 | 115 |
| RHH*, RHW*, RHW-2* | 14 | 1 | 6 | 10 | 15 | 24 | 35 | 62 | 94 | 135 | 184 | 240 |
| | 12 | 1 | 5 | 8 | 12 | 19 | 28 | 50 | 75 | 108 | 148 | 193 |
| | 10 | 1 | 4 | 6 | 10 | 15 | 22 | 39 | 59 | 85 | 115 | 151 |
| | 8 | 1 | 1 | 4 | 6 | 9 | 13 | 23 | 35 | 51 | 69 | 90 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 1 | 3 | 4 | 7 | 10 | 18 | 27 | 39 | 53 | 69 |
| | 4 | 0 | 1 | 1 | 3 | 5 | 7 | 13 | 20 | 29 | 39 | 51 |
| | 3 | 0 | 1 | 1 | 3 | 4 | 6 | 11 | 17 | 25 | 34 | 44 |
| | 2 | 0 | 1 | 1 | 2 | 4 | 5 | 10 | 14 | 21 | 29 | 37 |
| | 1 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 10 | 15 | 20 | 26 |
| | 1/0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 12 | 17 | 22 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 14 | 19 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 |
| | 4/0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 |
| | 350 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 |
| | 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 |
| | 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 |
| | 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 |
| THHN, THWN, THWN-2 | 14 | 4 | 13 | 22 | 33 | 52 | 76 | 134 | 202 | 291 | 396 | 518 |
| | 12 | 3 | 9 | 16 | 24 | 38 | 56 | 98 | 147 | 212 | 289 | 378 |
| | 10 | 1 | 6 | 10 | 15 | 24 | 35 | 62 | 93 | 134 | 182 | 238 |
| | 8 | 1 | 3 | 6 | 9 | 14 | 20 | 35 | 53 | 77 | 105 | 137 |
| | 6 | 1 | 2 | 4 | 6 | 10 | 14 | 25 | 38 | 55 | 76 | 99 |
| | 4 | 0 | 1 | 2 | 4 | 6 | 9 | 16 | 24 | 34 | 46 | 61 |
| | 3 | 0 | 1 | 1 | 3 | 5 | 7 | 13 | 20 | 29 | 39 | 51 |
| | 2 | 0 | 1 | 1 | 3 | 4 | 6 | 11 | 17 | 24 | 33 | 43 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 4 | 8 | 12 | 18 | 24 | 32 |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN FLEXIBLE METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|----|----|----|----|----|-----|-----|-----|-----|-----|
| | | ½ | ¾ | 1 | 1¼ | 1½ | 2 | 2½ | 3 | 3½ | 4 | |
| THHN, THWN, THWN-2 | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 10 | 15 | 20 | 27 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 3 | 6 | 9 | 12 | 17 | 22 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 2 | 5 | 7 | 10 | 14 | 18 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 | 6 | 8 | 12 | 15 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 9 | 12 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 |
| | 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 4 | 12 | 21 | 32 | 51 | 74 | 130 | 196 | 282 | 385 | 502 |
| | 12 | 3 | 9 | 15 | 24 | 37 | 54 | 95 | 143 | 206 | 281 | 367 |
| | 10 | 2 | 6 | 11 | 17 | 26 | 39 | 68 | 103 | 148 | 201 | 263 |
| | 8 | 1 | 4 | 6 | 10 | 15 | 22 | 39 | 59 | 85 | 115 | 151 |
| | 6 | 1 | 2 | 4 | 7 | 11 | 16 | 28 | 42 | 60 | 82 | 107 |
| | 4 | 1 | 1 | 3 | 5 | 7 | 11 | 19 | 29 | 42 | 57 | 75 |
| | 3 | 0 | 1 | 2 | 4 | 6 | 9 | 16 | 24 | 35 | 48 | 62 |
| | 2 | 0 | 1 | 1 | 3 | 5 | 7 | 13 | 20 | 29 | 39 | 51 |
| PFA, PFAH, TFE | 1 | 0 | 1 | 1 | 2 | 3 | 5 | 9 | 14 | 20 | 27 | 36 |
| PFA, PFAH, TFE, Z | 1/0 | 0 | 1 | 1 | 1 | 3 | 4 | 8 | 11 | 17 | 23 | 30 |
| | 2/0 | 0 | 1 | 1 | 1 | 2 | 3 | 6 | 9 | 14 | 19 | 24 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 15 | 20 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 13 | 16 |
| Z | 14 | 5 | 15 | 25 | 39 | 61 | 89 | 157 | 236 | 340 | 463 | 605 |
| | 12 | 4 | 11 | 18 | 28 | 43 | 63 | 111 | 168 | 241 | 329 | 429 |
| | 10 | 2 | 6 | 11 | 17 | 26 | 39 | 68 | 103 | 148 | 201 | 263 |
| | 8 | 1 | 4 | 7 | 11 | 17 | 24 | 43 | 65 | 93 | 127 | 166 |
| | 6 | 1 | 3 | 5 | 7 | 12 | 17 | 30 | 45 | 65 | 89 | 117 |
| | 4 | 1 | 1 | 3 | 5 | 8 | 12 | 21 | 31 | 45 | 61 | 80 |
| | 3 | 0 | 1 | 2 | 4 | 6 | 8 | 15 | 23 | 33 | 45 | 58 |
| | 2 | 0 | 1 | 1 | 3 | 5 | 7 | 12 | 19 | 27 | 37 | 49 |
| 1 | 0 | 1 | 1 | 2 | 4 | 6 | 10 | 15 | 22 | 30 | 39 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 3 | 9 | 15 | 23 | 36 | 53 | 94 | 141 | 203 | 277 | 361 |
| | 12 | 2 | 7 | 11 | 18 | 28 | 41 | 72 | 108 | 156 | 212 | 277 |
| | 10 | 1 | 5 | 8 | 13 | 21 | 30 | 54 | 81 | 116 | 158 | 207 |
| | 8 | 1 | 3 | 5 | 7 | 11 | 17 | 30 | 45 | 64 | 88 | 115 |
| | 6 | 1 | 1 | 3 | 5 | 8 | 12 | 22 | 33 | 48 | 65 | 85 |
| | 4 | 0 | 1 | 2 | 4 | 6 | 9 | 16 | 24 | 34 | 47 | 61 |
| | 3 | 0 | 1 | 1 | 3 | 5 | 7 | 13 | 20 | 29 | 40 | 52 |
| | 2 | 0 | 1 | 1 | 3 | 4 | 6 | 11 | 17 | 24 | 33 | 44 |
| XHH, XHHW, XHHW-2 | 1 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 13 | 18 | 25 | 32 |
| | 1/0 | 0 | 1 | 1 | 1 | 2 | 4 | 7 | 10 | 15 | 21 | 27 |
| | 2/0 | 0 | 0 | 1 | 1 | 2 | 3 | 6 | 9 | 13 | 17 | 23 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 14 | 19 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 15 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 | 9 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | 7 |
| | 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 |
| 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 5 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.3, as modified.



MAXIMUM NUMBER OF CONDUCTORS IN LIQUIDTIGHT FLEXIBLE METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | |
|---|----------------------|-----------------------|-----|----|-------|-------|----|-------|-----|-------|-----|-----|
| | | 1/2 | 3/4 | 1 | 1 1/4 | 1 1/2 | 2 | 2 1/2 | 3 | 3 1/2 | 4 | |
| RHH, RHW, RHW-2 | 14 | 2 | 4 | 7 | 12 | 21 | 27 | 44 | 66 | 102 | 133 | 173 |
| | 12 | 1 | 3 | 6 | 10 | 17 | 22 | 36 | 55 | 84 | 110 | 144 |
| | 10 | 1 | 3 | 5 | 8 | 14 | 18 | 29 | 44 | 68 | 89 | 116 |
| | 8 | 1 | 1 | 2 | 4 | 7 | 9 | 15 | 23 | 36 | 46 | 61 |
| | 6 | 1 | 1 | 1 | 3 | 6 | 7 | 12 | 18 | 28 | 37 | 48 |
| | 4 | 0 | 1 | 1 | 2 | 4 | 6 | 9 | 14 | 22 | 29 | 38 |
| | 3 | 0 | 1 | 1 | 1 | 4 | 5 | 8 | 13 | 19 | 25 | 33 |
| | 2 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 11 | 17 | 22 | 29 |
| | 1 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 19 |
| | 1/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 16 |
| | 2/0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 8 | 11 | 14 |
| | 3/0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 9 | 12 |
| | 4/0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 8 | 10 |
| | 250 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 |
| | 300 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 |
| | 350 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 |
| 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 | |
| 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | |
| 600 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | |
| 700 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 3 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | |
| TW, THHW, THW, THW-2 | 14 | 5 | 9 | 15 | 25 | 44 | 57 | 93 | 140 | 215 | 280 | 365 |
| | 12 | 4 | 7 | 12 | 19 | 33 | 43 | 71 | 108 | 165 | 215 | 280 |
| | 10 | 3 | 5 | 9 | 14 | 25 | 32 | 53 | 80 | 123 | 160 | 209 |
| | 8 | 1 | 3 | 5 | 8 | 14 | 18 | 29 | 44 | 68 | 89 | 116 |
| RHH*, RHW*, RHW-2* | 14 | 3 | 6 | 10 | 16 | 29 | 38 | 62 | 93 | 143 | 186 | 243 |
| | 12 | 3 | 5 | 8 | 13 | 23 | 30 | 50 | 75 | 115 | 149 | 195 |
| | 10 | 1 | 3 | 6 | 10 | 18 | 23 | 39 | 58 | 89 | 117 | 152 |
| | 8 | 1 | 1 | 4 | 6 | 11 | 14 | 23 | 35 | 53 | 70 | 91 |
| RHH*, RHW*, RHW-2*, TW, THW, THHW, THW-2 | 6 | 1 | 1 | 3 | 5 | 8 | 11 | 18 | 27 | 41 | 53 | 70 |
| | 4 | 1 | 1 | 1 | 3 | 6 | 8 | 13 | 20 | 30 | 40 | 52 |
| | 3 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 17 | 26 | 34 | 44 |
| | 2 | 0 | 1 | 1 | 2 | 4 | 6 | 9 | 14 | 22 | 29 | 38 |
| | 1 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 15 | 20 | 26 |
| | 1/0 | 0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 17 | 23 |
| | 2/0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 7 | 11 | 15 | 19 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 |
| | 4/0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 8 | 10 | 13 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 |
| | 350 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 7 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 6 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 |
| | 700 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 |
| 750 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | |
| THHN, THWN, THWN-2 | 14 | 8 | 13 | 22 | 36 | 63 | 81 | 134 | 201 | 308 | 401 | 523 |
| | 12 | 5 | 9 | 16 | 26 | 46 | 59 | 97 | 146 | 225 | 292 | 381 |
| | 10 | 3 | 6 | 10 | 16 | 29 | 37 | 61 | 92 | 141 | 184 | 240 |
| | 8 | 1 | 3 | 6 | 9 | 16 | 21 | 35 | 53 | 81 | 106 | 138 |
| | 6 | 1 | 2 | 4 | 7 | 12 | 15 | 25 | 38 | 59 | 76 | 100 |
| | 4 | 1 | 1 | 2 | 4 | 7 | 9 | 15 | 23 | 36 | 47 | 61 |
| | 3 | 1 | 1 | 1 | 3 | 6 | 8 | 13 | 20 | 30 | 40 | 52 |
| | 2 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 17 | 26 | 33 | 44 |
| | 1 | 0 | 1 | 1 | 1 | 4 | 5 | 8 | 12 | 19 | 25 | 32 |

(continued on next page)



MAXIMUM NUMBER OF CONDUCTORS IN LIQUIDTIGHT FLEXIBLE METAL CONDUIT

| Type Letters | Cond. Size AWG/kcmil | Trade Sizes in Inches | | | | | | | | | | |
|---------------------------------|----------------------|-----------------------|-----|-----|----|-------|-------|-------|-------|-------|-----|-------|
| | | 3/8 | 1/2 | 5/8 | 1 | 1 1/8 | 1 1/4 | 1 3/8 | 1 1/2 | 1 5/8 | 2 | 2 1/2 |
| THHN, THWN, THWN-2 | 1/0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 21 | 27 |
| | 2/0 | 0 | 0 | 1 | 1 | 2 | 3 | 6 | 8 | 13 | 17 | 23 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 19 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 15 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 12 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 9 |
| | 400 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 6 | 8 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 |
| 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 | |
| 750 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 3 | 5 | |
| FEP, FEPB, PFA, PFAH, TFE | 14 | 7 | 12 | 21 | 35 | 61 | 79 | 130 | 195 | 299 | 389 | 507 |
| | 12 | 5 | 9 | 15 | 25 | 44 | 58 | 94 | 142 | 218 | 284 | 370 |
| | 10 | 4 | 6 | 11 | 18 | 32 | 41 | 68 | 102 | 156 | 203 | 266 |
| | 8 | 1 | 3 | 6 | 10 | 18 | 23 | 39 | 58 | 89 | 117 | 152 |
| | 6 | 1 | 2 | 4 | 7 | 13 | 17 | 27 | 41 | 64 | 83 | 108 |
| | 4 | 1 | 1 | 3 | 5 | 9 | 12 | 19 | 29 | 44 | 58 | 75 |
| | 3 | 1 | 1 | 2 | 4 | 7 | 10 | 16 | 24 | 37 | 48 | 63 |
| | 2 | 1 | 1 | 1 | 3 | 6 | 8 | 13 | 20 | 30 | 40 | 52 |
| PFA, PFAH, TFE | 1 | 0 | 1 | 1 | 2 | 4 | 5 | 9 | 14 | 21 | 28 | 36 |
| PFA, PFAH, TFE, Z | 1/0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 11 | 18 | 23 | 30 |
| | 2/0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 9 | 14 | 19 | 25 |
| | 3/0 | 0 | 0 | 1 | 1 | 2 | 3 | 5 | 8 | 12 | 16 | 20 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 10 | 13 | 17 |
| Z | 14 | 9 | 15 | 26 | 42 | 73 | 95 | 156 | 235 | 360 | 469 | 611 |
| | 12 | 6 | 10 | 18 | 30 | 52 | 67 | 111 | 167 | 255 | 332 | 434 |
| | 10 | 4 | 6 | 11 | 18 | 32 | 41 | 68 | 102 | 156 | 203 | 266 |
| | 8 | 2 | 4 | 7 | 11 | 20 | 26 | 43 | 64 | 99 | 129 | 168 |
| | 6 | 1 | 3 | 5 | 8 | 14 | 18 | 30 | 45 | 69 | 90 | 118 |
| | 4 | 1 | 1 | 3 | 5 | 9 | 12 | 20 | 31 | 48 | 62 | 81 |
| | 3 | 1 | 1 | 2 | 4 | 7 | 9 | 15 | 23 | 35 | 45 | 59 |
| | 2 | 1 | 1 | 1 | 3 | 6 | 7 | 12 | 19 | 29 | 38 | 49 |
| 1 | 1 | 1 | 1 | 2 | 5 | 6 | 10 | 15 | 23 | 30 | 40 | |
| XHH, XHHW, XHHW-2, ZW | 14 | 5 | 9 | 15 | 25 | 44 | 57 | 93 | 140 | 215 | 280 | 365 |
| | 12 | 4 | 7 | 12 | 19 | 33 | 43 | 71 | 108 | 165 | 215 | 280 |
| | 10 | 3 | 5 | 9 | 14 | 25 | 32 | 53 | 80 | 123 | 160 | 209 |
| | 8 | 1 | 3 | 5 | 8 | 14 | 18 | 29 | 44 | 68 | 89 | 116 |
| | 6 | 1 | 1 | 3 | 6 | 10 | 13 | 22 | 33 | 50 | 66 | 86 |
| | 4 | 1 | 1 | 2 | 4 | 7 | 9 | 16 | 24 | 36 | 48 | 62 |
| | 3 | 1 | 1 | 1 | 3 | 6 | 8 | 13 | 20 | 31 | 40 | 52 |
| | 2 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 17 | 26 | 34 | 44 |
| XHH, XHHW, XHHW-2 | 1 | 0 | 1 | 1 | 1 | 4 | 5 | 8 | 12 | 19 | 25 | 33 |
| | 1/0 | 0 | 1 | 1 | 1 | 3 | 4 | 7 | 10 | 16 | 21 | 28 |
| | 2/0 | 0 | 0 | 1 | 1 | 2 | 3 | 6 | 9 | 13 | 17 | 23 |
| | 3/0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 11 | 14 | 19 |
| | 4/0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 6 | 9 | 12 | 16 |
| | 250 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 5 | 7 | 10 | 13 |
| | 300 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 4 | 6 | 8 | 11 |
| | 350 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 5 | 7 | 10 |
| | 400 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 5 | 6 | 8 |
| | 500 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 4 | 5 | 7 |
| | 600 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 6 |
| | 700 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 3 | 4 | 5 |
| | 750 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 3 | 5 |

*Types RHH, RHW, and RHW-2 without outer covering.

See *Ugly's* page 141 for Trade Size/Metric Designator conversion.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Annex C, Table C.8, as modified.



DIMENSIONS OF INSULATED CONDUCTORS AND FIXTURE WIRES

| Type | Size | Approx. Area Sq. In. | Type | Size | Approx. Area Sq. In. |
|---------------------|------|-------------------------|--------------------|------|-------------------------|
| RFH-2 | 18 | 0.0145 | RHH*, RHW*, XF | 10 | 0.0333 |
| FFH-2, RFHH-2 | 16 | 0.0172 | RHW-2*, XFF | | |
| RHW-2, RHH | 14 | 0.0293 | RHH*, RHW*, RHW-2* | 8 | 0.0556 |
| RHW | 12 | 0.0353 | TW, THW | 6 | 0.0726 |
| | 10 | 0.0437 | THHW | 4 | 0.0973 |
| | 8 | 0.0835 | THW-2 | 3 | 0.1134 |
| | 6 | 0.1041 | RHH* | 2 | 0.1333 |
| | 4 | 0.1333 | RHW* | 1 | 0.1901 |
| | 3 | 0.1521 | RHW-2* | 1/0 | 0.2223 |
| | 2 | 0.1750 | | 2/0 | 0.2624 |
| | 1 | 0.2660 | | 3/0 | 0.3117 |
| | 1/0 | 0.3039 | | 4/0 | 0.3718 |
| | 2/0 | 0.3505 | | 250 | 0.4596 |
| | 3/0 | 0.4072 | | 300 | 0.5281 |
| | 4/0 | 0.4754 | | 350 | 0.5958 |
| | 250 | 0.6291 | | 400 | 0.6619 |
| | 300 | 0.7088 | | 500 | 0.7901 |
| | 350 | 0.7870 | | 600 | 0.9729 |
| | 400 | 0.8626 | | 700 | 1.1010 |
| | 500 | 1.0082 | | 750 | 1.1652 |
| | 600 | 1.2135 | | 800 | 1.2272 |
| | 700 | 1.3561 | | 900 | 1.3561 |
| | 750 | 1.4272 | | 1000 | 1.4784 |
| | 800 | 1.4957 | | 1250 | 1.8602 |
| | 900 | 1.6377 | | 1500 | 2.1695 |
| | 1000 | 1.7719 | | 1750 | 2.4773 |
| | 1250 | 2.3479 | | 2000 | 2.7818 |
| | 1500 | 2.6938 | TFN | 18 | 0.0055 |
| | 1750 | 3.0357 | TFFN | 16 | 0.0072 |
| | 2000 | 3.3719 | THHN | 14 | 0.0097 |
| SF-2, SFF-2 | 18 | 0.0115 | THWN | 12 | 0.0133 |
| | 16 | 0.0139 | THWN-2 | 10 | 0.0211 |
| | 14 | 0.0172 | | 8 | 0.0366 |
| SF-1, SFF-1 | 18 | 0.0065 | | 6 | 0.0507 |
| RFH-1, XF, XFF | 18 | 0.0088 | | 4 | 0.0824 |
| TF, TFF, XF, XFF | 16 | 0.0109 | | 3 | 0.0973 |
| TW, XF, XFF, | 14 | 0.0139 | | 2 | 0.1158 |
| THHW, THW, THW-2 | | | | 1 | 0.1562 |
| TW, THHW, | 12 | 0.0181 | | 1/0 | 0.1855 |
| THW, THW-2 | 10 | 0.0243 | | 2/0 | 0.2223 |
| | 8 | 0.0437 | | 3/0 | 0.2679 |
| RHH*, RHW*, RHW-2* | 14 | 0.0209 | | 4/0 | 0.3237 |
| RHH*, RHW*, RHW-2*, | 12 | 0.0260 | | 250 | 0.3970 |
| XF, XFF | | | | 300 | 0.4608 |
| | | | | 350 | 0.5242 |
| | | | | 400 | 0.5863 |
| | | | | 500 | 0.7073 |
| | | | | 600 | 0.8676 |
| | | | | 700 | 0.9887 |



DIMENSIONS OF INSULATED CONDUCTORS AND FIXTURE WIRES

| Type | Size | Approx. Area Sq. In. | Type | Size | Approx. Area Sq. In. |
|--|--------|-------------------------|--------|--------|-------------------------|
| THHN | 750 | 1.0496 | XHHW | 300 | 0.4536 |
| THWN | 800 | 1.1085 | XHHW-2 | 350 | 0.5166 |
| THWN-2 | 900 | 1.2311 | XHH | 400 | 0.5782 |
| | 1000 | 1.3478 | | 500 | 0.6984 |
| PF, PGFF, PGF, PFF, PTF, PAF, PTFF, PAFF | 18 | 0.0058 | | 600 | 0.8709 |
| | 16 | 0.0075 | | 700 | 0.9923 |
| PF, PGFF, PGF, PFF, PTF, PAF, PTFF, PAFF TFE, FEP, PFA FEPB, PFAH | 14 | 0.0100 | | 750 | 1.0532 |
| | | | | 800 | 1.1122 |
| TFE, FEP, PFA, FEPB, PFAH | 12 | 0.0137 | | 900 | 1.2351 |
| | 10 | 0.0191 | | 1000 | 1.3519 |
| | 8 | 0.0333 | 1250 | 1.7180 | |
| | 6 | 0.0468 | 1500 | 2.0157 | |
| | 4 | 0.0670 | 1750 | 2.3127 | |
| | 3 | 0.0804 | 2000 | 2.6073 | |
| | 2 | 0.0973 | | | |
| TFE, PFAH | 1 | 0.1399 | KF-2 | 18 | 0.0031 |
| TFE, PFA, PFAH, Z | 1/0 | 0.1676 | KFF-2 | 16 | 0.0044 |
| | 2/0 | 0.2027 | | 14 | 0.0064 |
| | 3/0 | 0.2463 | | 12 | 0.0093 |
| | 4/0 | 0.3000 | | 10 | 0.0139 |
| ZF, ZFF | 18 | 0.0045 | | KF-1 | 18 |
| | 16 | 0.0061 | KFF-1 | 16 | 0.0037 |
| Z, ZF, ZFF | 14 | 0.0083 | | 14 | 0.0055 |
| | Z | 12 | | 0.0117 | 12 |
| 10 | | 0.0191 | | 10 | 0.0127 |
| 8 | | 0.0302 | | | |
| 6 | | 0.0430 | | | |
| 4 | | 0.0625 | | | |
| 3 | | 0.0855 | | | |
| 2 | | 0.1029 | | | |
| 1 | | 0.1269 | | | |
| XHHW, ZW | 14 | 0.0139 | | | |
| XHHW-2 | 12 | 0.0181 | | | |
| XHH | 10 | 0.0243 | | | |
| | 8 | 0.0437 | | | |
| | 6 | 0.0590 | | | |
| | 4 | 0.0814 | | | |
| | 3 | 0.0962 | | | |
| | 2 | 0.1146 | | | |
| | XHHW | 1 | 0.1534 | | |
| | XHHW-2 | 1/0 | 0.1825 | | |
| XHH | 2/0 | 0.2190 | | | |
| | 3/0 | 0.2642 | | | |
| | 4/0 | 0.3197 | | | |
| | 250 | 0.3904 | | | |

*Types RHH, RHW, and RHW-2 without outer covering

See *Ugly's* page 139 for conversion of square inches to square millimeters

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Chapter 9, Table 5, as modified.



COMPACT (STRANDED TYPE) COPPER AND ALUMINUM BUILDING WIRE NOMINAL DIMENSIONS* AND AREAS

| Size AWG or kcmil | Bare Conductor | | Types THW and THHW | | Type THHN | | Type XHHW | | Size AWG or kcmil |
|-------------------------|-----------------|----------------------------|----------------------------|-------------------------------|----------------------------|-------------------------------|----------------------------|-------------------------------|-------------------------|
| | Diam. Inches | Approx. Diam. Inches | Approx. Diam. Inches | Approx. Area Sq. Inches | Approx. Diam. Inches | Approx. Area Sq. Inches | Approx. Diam. Inches | Approx. Area Sq. Inches | |
| 8 | 0.134 | 0.255 | 0.0510 | — | — | — | 0.224 | 0.0394 | 8 |
| 6 | 0.169 | 0.290 | 0.0660 | 0.240 | 0.0452 | 0.0530 | 0.260 | 0.0530 | 6 |
| 4 | 0.213 | 0.335 | 0.0881 | 0.305 | 0.0730 | 0.0730 | 0.305 | 0.0730 | 4 |
| 2 | 0.268 | 0.390 | 0.1194 | 0.360 | 0.1017 | 0.1017 | 0.360 | 0.1017 | 2 |
| 1 | 0.299 | 0.465 | 0.1698 | 0.415 | 0.1352 | 0.1352 | 0.415 | 0.1352 | 1 |
| 1/0 | 0.336 | 0.500 | 0.1963 | 0.450 | 0.1590 | 0.1590 | 0.450 | 0.1590 | 1/0 |
| 2/0 | 0.376 | 0.545 | 0.2332 | 0.495 | 0.1924 | 0.1885 | 0.490 | 0.1885 | 2/0 |
| 3/0 | 0.423 | 0.590 | 0.2733 | 0.540 | 0.2290 | 0.2290 | 0.540 | 0.2290 | 3/0 |
| 4/0 | 0.475 | 0.645 | 0.3267 | 0.595 | 0.2780 | 0.2733 | 0.590 | 0.2733 | 4/0 |
| 250 | 0.520 | 0.725 | 0.4128 | 0.670 | 0.3525 | 0.3421 | 0.660 | 0.3421 | 250 |
| 300 | 0.570 | 0.775 | 0.4717 | 0.720 | 0.4071 | 0.4015 | 0.715 | 0.4015 | 300 |
| 350 | 0.616 | 0.820 | 0.5281 | 0.770 | 0.4656 | 0.4536 | 0.760 | 0.4536 | 350 |
| 400 | 0.659 | 0.865 | 0.5876 | 0.815 | 0.5216 | 0.5026 | 0.800 | 0.5026 | 400 |
| 500 | 0.736 | 0.940 | 0.6939 | 0.885 | 0.6151 | 0.6082 | 0.880 | 0.6082 | 500 |
| 600 | 0.813 | 1.050 | 0.8659 | 0.985 | 0.7620 | 0.7542 | 0.980 | 0.7542 | 600 |
| 700 | 0.877 | 1.110 | 0.9676 | 1.050 | 0.8659 | 0.8659 | 1.050 | 0.8659 | 700 |
| 750 | 0.908 | 1.150 | 1.0386 | 1.075 | 0.9076 | 0.9331 | 1.090 | 0.9331 | 750 |
| 900 | 0.999 | 1.224 | 1.1766 | 1.194 | 1.1196 | 1.0733 | 1.169 | 1.0733 | 900 |
| 1000 | 1.060 | 1.285 | 1.2968 | 1.255 | 1.2370 | 1.1882 | 1.230 | 1.1882 | 1000 |

*Dimensions are from industry sources.

See *Ugly's* pages 139-140 for metric conversions.



DIMENSIONS AND PERCENT AREA OF CONDUIT AND TUBING

(For the combinations of wires permitted in Chapter 9, Table 1, *NEC*[®])
(See *Ugly's* pages 139–140 for metric conversions.)

| Trade Size Inches | Internal Diameter Inches | Total Area 100% Sq. Inches | 2 Wires 31% Sq. Inches | Over 2 Wires 40% Sq. Inches | 1 Wire 53% Sq. Inches | (Nipple ¹) 60% Sq. Inches |
|--|--------------------------|----------------------------|------------------------|-----------------------------|-----------------------|---------------------------------------|
| Electrical Metallic Tubing (EMT) | | | | | | |
| ½ | 0.622 | 0.304 | 0.094 | 0.122 | 0.161 | 0.182 |
| ¾ | 0.824 | 0.533 | 0.165 | 0.213 | 0.283 | 0.320 |
| 1 | 1.049 | 0.864 | 0.268 | 0.346 | 0.458 | 0.519 |
| 1¼ | 1.380 | 1.496 | 0.464 | 0.598 | 0.793 | 0.897 |
| 1½ | 1.610 | 2.036 | 0.631 | 0.814 | 1.079 | 1.221 |
| 2 | 2.067 | 3.356 | 1.040 | 1.342 | 1.778 | 2.013 |
| 2½ | 2.731 | 5.858 | 1.816 | 2.343 | 3.105 | 3.515 |
| 3 | 3.356 | 8.846 | 2.742 | 3.538 | 4.688 | 5.307 |
| 3½ | 3.834 | 11.545 | 3.579 | 4.618 | 6.119 | 6.927 |
| 4 | 4.334 | 14.753 | 4.573 | 5.901 | 7.819 | 8.852 |
| 5 | 5.073 | 20.212 | 6.266 | 8.085 | 10.713 | 12.127 |
| 6 | 6.093 | 29.158 | 9.039 | 11.663 | 15.454 | 17.495 |
| Electrical Nonmetallic Tubing (ENT) | | | | | | |
| ½ | 0.602 | 0.285 | 0.088 | 0.114 | 0.151 | 0.171 |
| ¾ | 0.804 | 0.508 | 0.157 | 0.203 | 0.269 | 0.305 |
| 1 | 1.029 | 0.832 | 0.258 | 0.333 | 0.441 | 0.499 |
| 1¼ | 1.36 | 1.453 | 0.450 | 0.581 | 0.770 | 0.872 |
| 1½ | 1.59 | 1.986 | 0.616 | 0.794 | 1.052 | 1.191 |
| 2 | 2.047 | 3.291 | 1.020 | 1.316 | 1.744 | 1.975 |
| 2½ | — | — | — | — | — | — |
| 3 | — | — | — | — | — | — |
| 3½ | — | — | — | — | — | — |
| 4 | — | — | — | — | — | — |
| Flexible Metal Conduit (FMC) | | | | | | |
| ½ | 0.384 | 0.116 | 0.036 | 0.046 | 0.061 | 0.069 |
| ¾ | 0.635 | 0.317 | 0.098 | 0.127 | 0.168 | 0.190 |
| 1 | 0.824 | 0.533 | 0.165 | 0.213 | 0.283 | 0.320 |
| 1¼ | 1.020 | 0.817 | 0.253 | 0.327 | 0.433 | 0.490 |
| 1½ | 1.275 | 1.277 | 0.396 | 0.511 | 0.677 | 0.766 |
| 2 | 1.538 | 1.858 | 0.576 | 0.743 | 0.985 | 1.115 |
| 2½ | 2.040 | 3.269 | 1.013 | 1.307 | 1.732 | 1.961 |
| 3 | 2.500 | 4.909 | 1.522 | 1.963 | 2.602 | 2.945 |
| 3½ | 3.000 | 7.069 | 2.191 | 2.827 | 3.746 | 4.241 |
| 4 | 3.500 | 9.621 | 2.983 | 3.848 | 5.099 | 5.773 |
| 4 | 4.000 | 12.566 | 3.896 | 5.027 | 6.660 | 7.540 |
| Intermediate Metal Conduit (IMC) | | | | | | |
| ½ | — | — | — | — | — | — |
| ¾ | 0.660 | 0.342 | 0.106 | 0.137 | 0.181 | 0.205 |
| 1 | 0.864 | 0.586 | 0.182 | 0.235 | 0.311 | 0.352 |
| 1¼ | 1.105 | 0.959 | 0.297 | 0.384 | 0.508 | 0.575 |
| 1½ | 1.448 | 1.647 | 0.510 | 0.659 | 0.873 | 0.988 |
| 2 | 1.683 | 2.225 | 0.690 | 0.890 | 1.179 | 1.335 |
| 2½ | 2.150 | 3.630 | 1.125 | 1.452 | 1.924 | 2.178 |
| 3 | 2.557 | 5.135 | 1.592 | 2.054 | 2.722 | 3.081 |
| 3½ | 3.176 | 7.922 | 2.456 | 3.169 | 4.199 | 4.753 |
| 4 | 3.671 | 10.584 | 3.281 | 4.234 | 5.610 | 6.351 |
| 5 | 4.166 | 13.631 | 4.226 | 5.452 | 7.224 | 8.179 |
| 6 | 5.210 | 21.32 | 6.610 | 8.528 | 11.30 | 12.792 |
| 6 | 6.258 | 30.76 | 9.536 | 12.304 | 16.302 | 18.456 |

(continued on the next page)



DIMENSIONS AND PERCENT AREA OF CONDUIT AND TUBING

(For the combinations of wires permitted in Chapter 9, Table 1, *NEC*[®])
(See *Ugly's* pages 139–140 for metric conversions.)

| Trade Size Inches | Internal Diameter Inches | Total Area 100% Sq. Inches | 2 Wires 31% Sq. Inches | Over 2 Wires 40% Sq. Inches | 1 Wire 53% Sq. Inches | (Nipple ¹) 60% Sq. Inches |
|--|--------------------------|----------------------------|------------------------|-----------------------------|-----------------------|---------------------------------------|
| Liquidtight Flexible Nonmetallic Conduit (LFNC-A*) | | | | | | |
| 3/8 | 0.495 | 0.192 | 0.060 | 0.077 | 0.102 | 0.115 |
| 1/2 | 0.630 | 0.312 | 0.097 | 0.125 | 0.165 | 0.187 |
| 3/4 | 0.825 | 0.535 | 0.166 | 0.214 | 0.283 | 0.321 |
| 1 | 1.043 | 0.854 | 0.265 | 0.342 | 0.453 | 0.513 |
| 1 1/4 | 1.383 | 1.502 | 0.466 | 0.601 | 0.796 | 0.901 |
| 1 1/2 | 1.603 | 2.018 | 0.626 | 0.807 | 1.070 | 1.211 |
| 2 | 2.063 | 3.343 | 1.036 | 1.337 | 1.772 | 2.006 |
| *Corresponds to Article 100, Conduit, Liquidtight Flexible Nonmetallic (LFNC) list item (1). | | | | | | |
| Liquidtight Flexible Nonmetallic Conduit (LFNC-B*) | | | | | | |
| 3/8 | 0.494 | 0.192 | 0.059 | 0.077 | 0.102 | 0.115 |
| 1/2 | 0.632 | 0.314 | 0.097 | 0.125 | 0.166 | 0.188 |
| 3/4 | 0.830 | 0.541 | 0.168 | 0.216 | 0.287 | 0.325 |
| 1 | 1.054 | 0.873 | 0.270 | 0.349 | 0.462 | 0.524 |
| 1 1/4 | 1.395 | 1.528 | 0.474 | 0.611 | 0.810 | 0.917 |
| 1 1/2 | 1.588 | 1.981 | 0.614 | 0.792 | 1.050 | 1.188 |
| 2 | 2.033 | 3.246 | 1.006 | 1.298 | 1.720 | 1.948 |
| *Corresponds to Article 100, Conduit, Liquidtight Flexible Nonmetallic (LFNC) list item (2). | | | | | | |
| Liquidtight Flexible Metal Conduit (LFMC) | | | | | | |
| 3/8 | 0.494 | 0.192 | 0.059 | 0.077 | 0.102 | 0.115 |
| 1/2 | 0.632 | 0.314 | 0.097 | 0.125 | 0.166 | 0.188 |
| 3/4 | 0.830 | 0.541 | 0.168 | 0.216 | 0.287 | 0.325 |
| 1 | 1.054 | 0.873 | 0.270 | 0.349 | 0.462 | 0.524 |
| 1 1/4 | 1.395 | 1.528 | 0.474 | 0.611 | 0.810 | 0.917 |
| 1 1/2 | 1.588 | 1.981 | 0.614 | 0.792 | 1.050 | 1.188 |
| 2 | 2.033 | 3.246 | 1.006 | 1.298 | 1.720 | 1.948 |
| 2 1/2 | 2.493 | 4.881 | 1.513 | 1.953 | 2.587 | 2.929 |
| 3 | 3.085 | 7.475 | 2.317 | 2.990 | 3.962 | 4.485 |
| 3 1/2 | 3.520 | 9.731 | 3.017 | 3.893 | 5.158 | 5.839 |
| 4 | 4.020 | 12.692 | 3.935 | 5.077 | 6.727 | 7.615 |
| Rigid Metal Conduit (RMC) | | | | | | |
| 3/8 | — | — | — | — | — | — |
| 1/2 | 0.632 | 0.314 | 0.097 | 0.125 | 0.166 | 0.188 |
| 3/4 | 0.836 | 0.549 | 0.170 | 0.220 | 0.291 | 0.329 |
| 1 | 1.063 | 0.887 | 0.275 | 0.355 | 0.470 | 0.532 |
| 1 1/4 | 1.394 | 1.526 | 0.473 | 0.610 | 0.809 | 0.916 |
| 1 1/2 | 1.624 | 2.071 | 0.642 | 0.829 | 1.098 | 1.243 |
| 2 | 2.083 | 3.408 | 1.056 | 1.363 | 1.806 | 2.045 |
| 2 1/2 | 2.489 | 4.866 | 1.508 | 1.946 | 2.579 | 2.919 |
| 3 | 3.090 | 7.499 | 2.325 | 3.000 | 3.974 | 4.499 |
| 3 1/2 | 3.570 | 10.010 | 3.103 | 4.004 | 5.305 | 6.006 |
| 4 | 4.050 | 12.882 | 3.994 | 5.153 | 6.828 | 7.729 |
| 5 | 5.073 | 20.212 | 6.266 | 8.085 | 10.713 | 12.127 |
| 6 | 6.093 | 29.158 | 9.039 | 11.663 | 15.454 | 17.495 |



DIMENSIONS AND PERCENT AREA OF CONDUIT AND TUBING

(For the combinations of wires permitted in Chapter 9, Table 1, *NEC*[®])
(See *Ugly's* pages 139–140 for metric conversions.)

| Trade Size Inches | Internal Diameter Inches | Total Area 100% Sq. Inches | 2 Wires 31% Sq. Inches | Over 2 Wires 40% Sq. Inches | 1 Wire 53% Sq. Inches | (Nipple ¹) 60% Sq. Inches |
|---|--------------------------|----------------------------|------------------------|-----------------------------|-----------------------|---------------------------------------|
| Rigid PVC Conduit (PVC), Schedule 80 | | | | | | |
| ½ | 0.526 | 0.217 | 0.067 | 0.087 | 0.115 | 0.130 |
| ¾ | 0.722 | 0.409 | 0.127 | 0.164 | 0.217 | 0.246 |
| 1 | 0.936 | 0.688 | 0.213 | 0.275 | 0.365 | 0.413 |
| 1¼ | 1.255 | 1.237 | 0.383 | 0.495 | 0.656 | 0.742 |
| 1½ | 1.476 | 1.711 | 0.530 | 0.684 | 0.907 | 1.027 |
| 2 | 1.913 | 2.874 | 0.891 | 1.150 | 1.523 | 1.725 |
| 2½ | 2.290 | 4.119 | 1.277 | 1.647 | 2.183 | 2.471 |
| 3 | 2.864 | 6.442 | 1.997 | 2.577 | 3.414 | 3.865 |
| 3½ | 3.326 | 8.688 | 2.693 | 3.475 | 4.605 | 5.213 |
| 4 | 3.786 | 11.258 | 3.490 | 4.503 | 5.967 | 6.755 |
| 5 | 4.768 | 17.855 | 5.535 | 7.142 | 9.463 | 10.713 |
| 6 | 5.709 | 25.598 | 7.935 | 10.239 | 13.567 | 15.359 |
| Rigid PVC Conduit (PVC), Schedule 40 & HDPE Conduit (HDPE) | | | | | | |
| ½ | 0.602 | 0.285 | 0.088 | 0.114 | 0.151 | 0.171 |
| ¾ | 0.804 | 0.508 | 0.157 | 0.203 | 0.269 | 0.305 |
| 1 | 1.029 | 0.832 | 0.258 | 0.333 | 0.441 | 0.499 |
| 1¼ | 1.360 | 1.453 | 0.450 | 0.581 | 0.770 | 0.872 |
| 1½ | 1.590 | 1.986 | 0.616 | 0.794 | 1.052 | 1.191 |
| 2 | 2.047 | 3.291 | 1.020 | 1.316 | 1.744 | 1.975 |
| 2½ | 2.445 | 4.695 | 1.455 | 1.878 | 2.488 | 2.817 |
| 3 | 3.042 | 7.268 | 2.253 | 2.907 | 3.852 | 4.361 |
| 3½ | 3.521 | 9.737 | 3.018 | 3.895 | 5.161 | 5.842 |
| 4 | 3.998 | 12.554 | 3.892 | 5.022 | 6.654 | 7.532 |
| 5 | 5.016 | 19.761 | 6.126 | 7.904 | 10.473 | 11.856 |
| 6 | 6.031 | 28.567 | 8.856 | 11.427 | 15.141 | 17.140 |
| Type A, Rigid PVC Conduit (PVC) | | | | | | |
| ½ | 0.700 | 0.385 | 0.119 | 0.154 | 0.204 | 0.231 |
| ¾ | 0.910 | 0.650 | 0.202 | 0.260 | 0.345 | 0.390 |
| 1 | 1.175 | 1.084 | 0.336 | 0.434 | 0.575 | 0.651 |
| 1¼ | 1.500 | 1.767 | 0.548 | 0.707 | 0.937 | 1.060 |
| 1½ | 1.720 | 2.324 | 0.720 | 0.929 | 1.231 | 1.394 |
| 2 | 2.155 | 3.647 | 1.131 | 1.459 | 1.933 | 2.188 |
| 2½ | 2.635 | 5.453 | 1.690 | 2.181 | 2.890 | 3.272 |
| 3 | 3.230 | 8.194 | 2.540 | 3.278 | 4.343 | 4.916 |
| 3½ | 3.690 | 10.694 | 3.315 | 4.278 | 5.668 | 6.416 |
| 4 | 4.180 | 13.723 | 4.254 | 5.489 | 7.273 | 8.234 |
| Type EB, PVC Conduit (PVC) | | | | | | |
| 2 | 2.221 | 3.874 | 1.201 | 1.550 | 2.053 | 2.325 |
| 2½ | — | — | — | — | — | — |
| 3 | 3.330 | 8.709 | 2.700 | 3.484 | 4.616 | 5.226 |
| 3½ | 3.804 | 11.365 | 3.523 | 4.546 | 6.023 | 6.819 |
| 4 | 4.289 | 14.448 | 4.479 | 5.779 | 7.657 | 8.669 |
| 5 | 5.316 | 22.195 | 6.881 | 8.878 | 11.763 | 13.317 |
| 6 | 6.336 | 31.530 | 9.774 | 12.612 | 16.711 | 18.918 |

¹Nipples must be 24 inches or less.

Source: NFPA 70[®], *National Electrical Code*[®], 2026 edition, NFPA, Quincy, MA, 2025, Chapter 9, Table 4, as modified.



THREAD DIMENSIONS AND TAP DRILL SIZES

| Nominal Size | Coarse Thread Series | | | Fine Thread Series | | | |
|--------------|----------------------|-----------|-----------------|--------------------|-----------------|-----------|-----------------|
| | Threads per In. | Tap Drill | Clearance Drill | Nominal Size | Threads per In. | Tap Drill | Clearance Drill |
| 5/64" | 48 | 47 | 36 | 0 | 80 | 3/64" | 51 |
| 1/8 | 40 | 38 | 29 | 1 | 72 | 53 | 47 |
| 6 | 32 | 36 | 25 | 2 | 64 | 50 | 42 |
| 8 | 32 | 29 | 16 | 3 | 56 | 45 | 36 |
| 10 | 24 | 25 | 13/64" | 4 | 48 | 42 | 31 |
| 12 | 24 | 16 | 7/32" | 1/8" | 44 | 37 | 29 |
| 1/4" | 20 | 7 | 17/64" | 6 | 40 | 33 | 25 |
| 5/16" | 18 | F | 21/64" | 8 | 36 | 29 | 16 |
| 3/8" | 16 | 5/16" | 25/64" | 10 | 32 | 21 | 13/64" |
| 7/16" | 14 | U | 29/64" | 12 | 28 | 14 | 7/32" |
| 1/2" | 13 | 27/64" | 33/64" | 1/4" | 28 | 3 | 17/64" |
| 9/16" | 12 | 31/64" | 37/64" | 5/16" | 24 | 1 | 21/64" |
| 5/8" | 11 | 17/32" | 41/64" | 3/8" | 24 | 0 | 25/64" |
| 3/4" | 10 | 21/32" | 49/64" | 7/16" | 20 | 25/64" | 29/64" |
| 7/8" | 9 | 49/64" | 57/64" | 1/2" | 20 | 29/64" | 33/64" |
| 1" | 8 | 7/8" | 1-1/64" | 9/16" | 18 | 33/64" | 37/64" |
| 1-1/4" | 7 | 1-11/64" | 1-17/64" | 5/8" | 18 | 37/64" | 41/64" |
| 1-3/8" | 6 | 1-19/64" | 1-25/64" | 3/4" | 16 | 11/16" | 49/64" |
| 1-1/2" | 6 | 1-27/64" | 1-33/64" | 7/8" | 14 | 13/16" | 57/64" |
| 2" | 4-1/2" | 1-25/32" | 2-1/32" | 1 | 14 | 15/16" | 1-1/64" |

HOLE SAW CHART *

| Trade Size | Rigid Conduit | E. M. I. Conduit | Green-Field | L. I. Flex. | Trade Size | Rigid Conduit | E. M. I. Conduit | Green-Field |
|------------|---------------|------------------|-------------|-------------|------------|---------------|------------------|-------------|
| 1/2" | 7/8" | 3/4" | 1" | 1-1/8" | 2-1/2" | 3" | 2-7/8" | 2-7/8" |
| 3/4 | 1-1/8" | 1" | 1-1/8" | 1-1/4" | 3" | 3-5/8" | 3-1/2" | 3-5/8" |
| 1" | 1-3/8" | 1-1/4" | 1-1/2" | 1-1/2" | 3-1/2" | 4-1/8" | 4" | 4-1/8" |
| 1-1/4" | 1-3/4" | 1-5/8" | 1-3/4" | 1-7/8" | 4" | 4-5/8" | 4-1/2" | 4-5/8" |
| 1-1/2" | 2" | 1-7/8" | 2" | 2-1/8" | 5" | 5-3/4" | | |
| 2" | 2-1/2" | 2-1/8" | 2-1/2" | 2-3/4" | 6" | 6-3/4" | | |

Note: For oil-type push button station, use size 1-7/32" knock-out punch.

* For connectors (male connectors and adapters), use Rigid Table.



METAL BOXES

| Box Dimension, Inches Trade Size, or Type | Min. Cu. In. Capacity | Maximum Number of Conductors* | | | | | | | |
|--|-----------------------------|-------------------------------|--------|--------|--------|--------|-------|-------|--|
| | | No. 18 | No. 16 | No. 14 | No. 12 | No. 10 | No. 8 | No. 6 | |
| 4 x 1-1/4 Round or Octagonal | 12.5 | 8 | 7 | 6 | 5 | 5 | 4 | 2 | |
| 4 x 1-1/2 Round or Octagonal | 15.5 | 10 | 8 | 7 | 6 | 6 | 5 | 3 | |
| 4 x 2-1/8 Round or Octagonal | 21.5 | 14 | 12 | 10 | 9 | 8 | 7 | 4 | |
| 4 x 1-1/4 Square | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 | |
| 4 x 1-1/2 Square | 21.0 | 14 | 12 | 10 | 9 | 8 | 7 | 4 | |
| 4 x 2-1/8 Square | 30.3 | 20 | 17 | 15 | 13 | 12 | 10 | 6 | |
| 4-11/16 x 1-1/4 Square | 25.5 | 17 | 14 | 12 | 11 | 10 | 8 | 5 | |
| 4-11/16 x 1-1/2 Square | 29.5 | 19 | 16 | 14 | 13 | 11 | 9 | 5 | |
| 4-11/16 x 2-1/8 Square | 42.0 | 28 | 24 | 21 | 18 | 16 | 14 | 8 | |
| 3 x 2 x 1-1/2 Device | 7.5 | 5 | 4 | 3 | 3 | 3 | 2 | 1 | |
| 3 x 2 x 2 Device | 10.0 | 6 | 5 | 5 | 4 | 4 | 3 | 2 | |
| 3 x 2 x 2-1/4 Device | 10.5 | 7 | 6 | 5 | 4 | 4 | 3 | 2 | |
| 3 x 2 x 2-1/2 Device | 12.5 | 8 | 7 | 6 | 5 | 5 | 4 | 2 | |
| 3 x 2 x 2-3/4 Device | 14.0 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | |
| 3 x 2 x 3-1/2 Device | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 | |
| 4 x 2-1/8 x 1-1/2 Device | 10.3 | 6 | 5 | 5 | 4 | 4 | 3 | 2 | |
| 4 x 2-1/8 x 1-7/8 Device | 13.0 | 8 | 7 | 6 | 5 | 5 | 4 | 2 | |
| 4 x 2-1/8 x 2-1/8 Device | 14.5 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | |
| 3-3/4 x 2 x 2-1/2 Masonry Box/Gang | 14.0 | 9 | 8 | 7 | 6 | 5 | 4 | 2 | |
| 3-3/4 x 2 x 3-1/2 Masonry Box/Gang | 21.0 | 14 | 12 | 10 | 9 | 8 | 7 | 4 | |
| FS-Minimum Internal Depth 1-3/4 Single cover/Gang | 13.5 | 9 | 7 | 6 | 6 | 5 | 4 | 2 | |
| FD-Minimum Internal Depth 2-3/8 Single Cover/Gang | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 | |
| FS-Minimum Internal Depth 1-3/4 Multiple Cover/Gang | 18.0 | 12 | 10 | 9 | 8 | 7 | 6 | 3 | |
| FD-Minimum Internal Depth 2-3/8 Multiple Cover/Gang | 24.0 | 16 | 13 | 12 | 10 | 9 | 8 | 4 | |

*Where no volume allowances are required by 314.16(B)(2) through 314.16(B)(6).

Source: NFPA 70®, National Electrical Code®, 2026 edition, NFPA, Quincy, MA, 2025, Table 314.16(A), as modified.



MINIMUM COVER REQUIREMENTS, 0 TO 1000 VOLTS ac, 1500 VOLTS dc, NOMINAL

Cover is defined as the distance between the top surface of direct burial cable, conduit, or other raceways and the finished surface.

| Wiring Method | Minimum Burial (Inches) |
|---|-------------------------|
| Direct burial cables | 24* |
| Rigid metal conduit or Intermediate metal conduit | 6* |
| Electrical metallic tubing | 18* |
| Rigid nonmetallic conduit (Approved for direct burial without concrete encasement) | 18* |

*For most locations, for complete details, refer to *NEC*® Table 300.7(A) for exceptions such as highways, dwellings, airports, driveways, and parking lots.

Source: Data from NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 300.7(A).



VOLUME REQUIRED PER CONDUCTOR

| Size of Conductor | Free Space Within Box for Each Conductor |
|-------------------|--|
| No. 18 | 1.5 cubic inches |
| No. 16 | 1.75 cubic inches |
| No. 14 | 2 cubic inches |
| No. 12 | 2.25 cubic inches |
| No. 10 | 2.5 cubic inches |
| No. 8 | 3 cubic inches |
| No. 6 | 5 cubic inches |

For complete details see *NEC* 314.16(B)(4).

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 314.16(B)(4), as modified.



SUPPORTING CONDUCTORS IN VERTICAL RACEWAYS – SPACINGS FOR CONDUCTOR SUPPORTS

| Conductor Size | Support of Conductors in Vertical Raceways | Conductors | |
|----------------------------------|--|------------|----------------------------------|
| | | Copper | Aluminum or Copper-Clad Aluminum |
| 18 AWG through 8 AWG | Not greater than | 100 feet | 100 feet |
| 6 AWG through 1/0 AWG | Not greater than | 100 feet | 200 feet |
| 2/0 AWG through 4/0 AWG | Not greater than | 80 feet | 180 feet |
| Over 4/0 AWG through 350 kcmil | Not greater than | 60 feet | 135 feet |
| Over 350 kcmil through 500 kcmil | Not greater than | 50 feet | 120 feet |
| Over 500 kcmil through 750 kcmil | Not greater than | 40 feet | 95 feet |
| Over 750 kcmil | Not greater than | 35 feet | 85 feet |

For SI units: 1 foot = 0.3048 meter.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 300.21(A), as modified.



MINIMUM DEPTH OF CLEAR WORKING SPACE AT ELECTRICAL EQUIPMENT

| Nominal ac Voltage to Ground | Conditions | | |
|------------------------------|-----------------------------|----|----|
| | 1 | 2 | 3 |
| | Minimum Clear Distance (ft) | | |
| 0–150 V | 3 | 3 | 3 |
| 151–600 V | 3 | 3½ | 4 |
| 601–2500 V | 3 | 4 | 5 |
| 2501–9000 V | 4 | 5 | 6 |
| 9001–25000 V | 5 | 6 | 9 |
| 25001 V–75 kV | 6 | 8 | 10 |
| Above 75 kV | 8 | 10 | 12 |

Notes:

1. For SI units, 1 foot = 0.3048 meter.
2. Where the conditions are as follows:
Condition 1—Exposed or enclosed live parts on one side of the working space and no exposed or enclosed live or grounded parts on the other side of the working space, or exposed or enclosed live parts on both sides of the working space that are effectively guarded by insulating materials.
Condition 2—Exposed or enclosed live parts on one side of the working space and grounded parts on the other side of the working space. Concrete, brick, or tile walls shall be considered as grounded.
Condition 3—Exposed or enclosed live parts on both sides of the working space.

See *Ugly's* pages 139–140 for metric conversions. Where equipment rated 800 amperes or more that contains OCPDs, switching devices, or control devices is installed and there are personnel doors intended for entrance to and egress from the working space less than 25 ft from the nearest edge of the working space, NEC 110.26(C)(3) states the doors shall open at least 90 degrees in the direction of egress and be equipped with listed panic hardware or listed fire exit hardware. Entrances to rooms and other guarded locations that contain exposed live parts shall comply with 110.27(C) and shall be marked with conspicuous warning signs forbidding unqualified persons to enter; the marking shall comply with 110.21(B).

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Tables 110.26(A)(1) and 110.34(A), as modified.



MINIMUM CLEARANCE OF LIVE PARTS, OVER 1000 VOLTS ac, 1500 VOLTS dc, NOMINAL

| Nominal Voltage Rating (kV) | Impulse Withstand (BIL) (kV) | | Minimum Clearance of Live Parts, Inches* | | | |
|-----------------------------|------------------------------|----------|--|----------|-----------------|----------|
| | Indoors | Outdoors | Phase-to-Phase | | Phase-to-Ground | |
| | | | Indoors | Outdoors | Indoors | Outdoors |
| 2.4–4.16 | 60 | 95 | 4.5 | 7 | 3.0 | 6 |
| 7.2 | 75 | 95 | 5.5 | 7 | 4.0 | 6 |
| 13.8 | 95 | 110 | 7.5 | 12 | 5.0 | 7 |
| 14.4 | 110 | 110 | 9.0 | 12 | 6.5 | 7 |
| 23 | 125 | 150 | 10.5 | 15 | 7.5 | 10 |
| 34.5 | 150 | 150 | 12.5 | 15 | 9.5 | 10 |
| | 200 | 200 | 18.0 | 18 | 13.0 | 13 |
| 46 | | 200 | | 18 | | 13 |
| | | 250 | | 21 | | 17 |
| 69 | | 250 | | 21 | | 17 |
| | | 350 | | 31 | | 25 |
| 115 | | 550 | | 53 | | 42 |
| 138 | | 550 | | 53 | | 42 |
| | | 650 | | 63 | | 50 |
| 161 | | 650 | | 63 | | 50 |
| | | 750 | | 72 | | 58 |
| 230 | | 750 | | 72 | | 58 |
| | | 900 | | 89 | | 71 |
| | | 1050 | | 105 | | 83 |

* For SI units: 1 inch = 25.4 millimeters.

The values given are the minimum clearance for rigid parts and bare conductors under favorable service conditions. They shall be increased for conductor movement or under unfavorable service conditions, or wherever space limitations permit. The selection of the associated impulse withstand voltage for a particular system voltage is determined by the characteristics of the overvoltage (surge) protective equipment.

See *Ugly's* pages 139–140 for metric conversions.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 495.24, as modified.



MINIMUM SIZE EQUIPMENT GROUNDING CONDUCTORS (EGCs) FOR GROUNDING RACEWAY AND EQUIPMENT

| Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, Etc., Not Exceeding (Amperes) | Size (AWG or kcmil) | |
|---|---------------------|-----------------------------------|
| | Copper | Aluminum or Copper-Clad Aluminum* |
| 15 | 14 | 12 |
| 20 | 12 | 10 |
| 60 | 10 | 8 |
| 100 | 8 | 6 |
| 200 | 6 | 4 |
| 300 | 4 | 2 |
| 400 | 3 | 1 |
| 500 | 2 | 1/0 |
| 600 | 1 | 2/0 |
| 800 | 1/0 | 3/0 |
| 1000 | 2/0 | 4/0 |
| 1200 | 3/0 | 250 |
| 1600 | 4/0 | 350 |
| 2000 | 250 | 400 |
| 2500 | 350 | 600 |
| 3000 | 400 | 600 |
| 4000 | 500 | 750 |
| 5000 | 700 | 1250 |
| 6000 | 800 | 1250 |

Note: Where necessary to comply with *NEC* 250.4(A)(5) or 250.4(B)(4), the equipment grounding conductor EGC shall be sized larger than given in this table.

* See installation requirements in *NEC* 250.120.



GROUNDING ELECTRODE CONDUCTOR FOR ALTERNATING-CURRENT SYSTEMS

| Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) | | Size of Grounding Electrode Conductor (AWG/kcmil) | |
|---|----------------------------------|---|----------------------------------|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum |
| 2 or Smaller | 1/0 or Smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | 3/0 | 250 |

Notes:

1. If multiple sets of service-entrance conductors connect directly to a service drop, set of overhead service conductors, set of underground service conductors, or service lateral, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set.
2. If there are no service-entrance conductors, the grounding electrode conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.
3. See installation requirements in *NEC* 250.64.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 250.66, as modified.



GROUNDING CONDUCTOR, MAIN BONDING JUMPER, SYSTEM BONDING JUMPER, AND SUPPLY-SIDE BONDING JUMPER FOR ALTERNATING-CURRENT SYSTEMS

| Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil) | | Size of Grounded Conductor or Bonding Jumper (AWG/kcmil) | |
|---|----------------------------------|--|----------------------------------|
| Copper | Aluminum or Copper-Clad Aluminum | Copper | Aluminum or Copper-Clad Aluminum |
| 2 or Smaller | 1/0 or Smaller | 8 | 6 |
| 1 or 1/0 | 2/0 or 3/0 | 6 | 4 |
| 2/0 or 3/0 | 4/0 or 250 | 4 | 2 |
| Over 3/0 through 350 | Over 250 through 500 | 2 | 1/0 |
| Over 350 through 600 | Over 500 through 900 | 1/0 | 3/0 |
| Over 600 through 1100 | Over 900 through 1750 | 2/0 | 4/0 |
| Over 1100 | Over 1750 | See Notes 1 and 2. | |

Notes:

1. If the circular mil area of ungrounded supply conductors that are connected in parallel is larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12½% of the area of the largest ungrounded supply conductor or equivalent area for parallel supply conductors. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.
2. The grounded conductor or bonding jumper shall not be required to be larger than the largest ungrounded conductor or set of ungrounded conductors.
3. If the circular mil area of ungrounded supply conductors that are connected in parallel is larger than 1100 kcmil copper or 1750 kcmil aluminum and if the ungrounded supply conductors and the bonding jumper are of different materials (copper, aluminum, or copper-clad aluminum), the minimum size of the grounded conductor or bonding jumper shall be based on the assumed use of ungrounded supply conductors of the same material as the grounded conductor or bonding jumper that has an ampacity equivalent to that of the installed ungrounded supply conductors.
4. If there are no service-entrance conductors, the supply conductor size shall be determined by the equivalent size of the largest service-entrance conductor required for the load to be served.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 250.102(C)(1), as modified.



GENERAL LIGHTING LOADS BY NON-DWELLING OCCUPANCY

| Type of Occupancy | Volt-Amperes/ Square Foot | Type of Occupancy | Volt-Amperes/ Square Foot |
|---|------------------------------|-----------------------------|------------------------------|
| Automotive facility | 1.5 | Museum | 1.6 |
| Convention center | 1.4 | Office ⁴ | 1.3 |
| Courthouse | 1.4 | Parking garage ⁵ | 0.3 |
| Dormitory | 1.5 | Penitentiary | 1.2 |
| Exercise center | 1.4 | Performing arts theater | 1.5 |
| Fire station | 1.3 | Police station | 1.3 |
| Gymnasium ¹ | 1.7 | Post office | 1.6 |
| Health care clinic | 1.6 | Religious facility | 2.2 |
| Hospital | 1.6 | Restaurant ⁶ | 1.5 |
| Hotel or motels, or apartment houses without provisions for cooking by tenants ² | 1.7 | Retail ^{7, 8} | 1.9 |
| Library | 1.5 | School/university | 1.5 |
| Manufacturing facility ³ | 2.2 | Sports arena | 1.5 |
| Motion picture theater | 1.6 | Town hall | 1.4 |
| | | Transportation | 1.2 |
| | | Warehouse | 1.2 |
| | | Workshop | 1.7 |

See NEC 120.41 for dwelling units.

See NEC 120.14(J) for receptacle outlets in office buildings.

¹Armories and auditoriums are considered gymnasium-type occupancies.

²Lodge rooms are similar to hotels and motels.

³Industrial commercial loft buildings are considered manufacturing-type occupancies.

⁴Banks are office-type occupancies.

⁵Commercial (storage) garages are considered parking garage occupancies.

⁶Clubs are considered restaurant occupancies.

⁷Barber shops and beauty parlors are considered retail occupancies.

⁸Stores are considered retail occupancies.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 120.42(A), as modified.



LIGHTING LOAD DEMAND FACTORS

| Type of Occupancy | Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes) | Demand Factor (%) |
|---|--|-------------------|
| Dwelling units | First 3000 | 100 |
| | From 3001 to 120000 at | 35 |
| | Remainder over 120000 at | 25 |
| Hotels and motels, including apartment houses without provision for cooking by tenants* | First 20000 or less at | 60 |
| | From 20001 to 100000 at | 50 |
| | Remainder over 100000 at | 35 |
| Warehouses (storage) | First 12500 or less at | 100 |
| | Remainder over 12500 at | 50 |
| All others | Total volt-amperes | 100 |

* The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hotels and motels where the entire lighting is likely to be used at one time, as in ballrooms or dining rooms.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 120.45, as modified.



DEMAND FACTORS FOR RECEPTACLE LOADS—OTHER THAN DWELLING UNITS

| Portion of Receptacle Load to Which Demand Factor Applies (Volt-Amperes) | Demand Factor (%) |
|--|-------------------|
| First 10 kVA or less at | 100 |
| Remainder over 10 kVA at | 50 |

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 120.47, as modified.



DEMAND FACTORS FOR HOUSEHOLD ELECTRIC CLOTHES DRYERS

| Number of Dryers | Demand Factor (%) |
|------------------|--|
| 1–2 | 100 |
| 3–5 | 80 |
| 6 | 75 |
| 7 | 65 |
| 8 | 60 |
| 9 | 55 |
| 10 | 50 |
| 11 | 47 |
| 12–23 | 47 minus 1 for each dryer exceeding 11 |
| 24–42 | 35 minus 0.5 for each dryer exceeding 23 |
| 43 and over | 25 |

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 120.54, as modified.



DEMAND FACTORS FOR INSTANTANEOUS WATER HEATERS AND KITCHEN EQUIPMENT—OTHER THAN DWELLING UNIT(S)

| Number of Units of Equipment | Demand Factor (%) |
|------------------------------|-------------------|
| 1 | 100 |
| 2 | 100 |
| 3 | 90 |
| 4 | 80 |
| 5 | 70 |
| 6 and over | 65 |

Note: In no case shall the feeder or service calculated load be less than the sum of the largest two kitchen equipment loads.

Source: NFPA 70®, *National Electrical Code*®, 2026 edition, NFPA, Quincy, MA, 2025, Table 120.56, as modified.



DEMAND LOADS FOR HOUSEHOLD ELECTRIC RANGES, WALL-MOUNTED OVENS, COUNTER-MOUNTED COOKING UNITS, AND OTHER HOUSEHOLD COOKING APPLIANCES OVER 1 $\frac{3}{4}$ KW RATING

(Column C to be used in all cases except as otherwise permitted in Note 3)

| Number of Appliances | Demand Factor (%) (See Notes) | | Column C Maximum Demand (kW) (See Notes) (Not over 12 kW Rating) |
|----------------------|---|--|---|
| | Column A (Less than 3 $\frac{1}{2}$ kW Rating) | Column B (3 $\frac{1}{2}$ kW Through 8 $\frac{1}{2}$ kW Rating) | |
| 1 | 80 | 80 | 8 |
| 2 | 75 | 65 | 11 |
| 3 | 70 | 55 | 14 |
| 4 | 66 | 50 | 17 |
| 5 | 62 | 45 | 20 |
| 6 | 59 | 43 | 21 |
| 7 | 56 | 40 | 22 |
| 8 | 53 | 36 | 23 |
| 9 | 51 | 35 | 24 |
| 10 | 49 | 34 | 25 |
| 11 | 47 | 32 | 26 |
| 12 | 45 | 32 | 27 |
| 13 | 43 | 32 | 28 |
| 14 | 41 | 32 | 29 |
| 15 | 40 | 32 | 30 |
| 16 | 39 | 28 | 31 |
| 17 | 38 | 28 | 32 |
| 18 | 37 | 28 | 33 |
| 19 | 36 | 28 | 34 |
| 20 | 35 | 28 | 35 |
| 21 | 34 | 26 | 36 |
| 22 | 33 | 26 | 37 |
| 23 | 32 | 26 | 38 |
| 24 | 31 | 26 | 39 |
| 25 | 30 | 26 | 40 |
| 26-30 | 30 | 24 | 15 kW + 1 kW for each range |
| 31-40 | 30 | 22 | |
| 41-50 | 30 | 20 | 25 kW + 3/4 kW for each range |
| 51-60 | 30 | 18 | |
| 61 and over | 30 | 16 | |

(continued on next page)



DEMAND LOADS FOR HOUSEHOLD ELECTRIC RANGES, WALL-MOUNTED OVENS, COUNTER-MOUNTED COOKING UNITS, AND OTHER HOUSEHOLD COOKING APPLIANCES OVER 1³/₄ KW RATING

Notes:

1. Over 12 kW through 27 kW ranges all of same rating. For ranges individually rated more than 12 kW but not more than 27 kW, the maximum demand in Column C shall be increased by 5% for each additional kilowatt of rating or major fraction thereof by which the rating of individual ranges exceeds 12 kW.
2. Over 8³/₄ kW through 27 kW ranges of unequal ratings. For ranges individually rated more than 8³/₄ kW and of different ratings, but none exceeding 27 kW, an average value of rating shall be computed by adding together the ratings of all ranges to obtain the total connected load (using 12 kW for any range rated less than 12 kW) and dividing the total number of ranges. Then the maximum demand in Column C shall be increased by 5% for each kilowatt or major fraction thereof by which this average value exceeds 12 kW.
3. Over 1³/₄ kW through 8³/₄ kW. In lieu of the method provided in Column C, adding the nameplate ratings of all household cooking appliances rated more than 1³/₄ kW but not more than 8³/₄ kW and multiplying the sum by the demand factors specified in Column A or B for the given number of appliances shall be permitted. Where the rating of cooking appliances falls under both Column A and Column B, the demand factors for each column shall be applied to the appliances for that column and the results are added together.
4. Calculating the branch-circuit load for one range in accordance with Table 120.55 shall be permitted.
5. The branch-circuit load for one wall-mounted oven or one counter-mounted cooking unit shall be the nameplate rating of the appliance.
6. The branch-circuit load for a counter-mounted cooking unit and not more than two wall-mounted ovens, all supplied from a single branch circuit and located in the same room, shall be computed by adding the nameplate rating of the individual appliances and treating this total as equivalent to one range.
7. This table also applies to household cooking appliances rated over 1³/₄ kW and used in instructional programs.

NFPA 70®, National Electrical Code®, 2026 edition, NFPA, Quincy, MA, 2025. Table 120.55, as modified.



CALCULATING COST OF OPERATING AN ELECTRICAL APPLIANCE

What is the monthly cost of operating a 240-volt, 5-kilowatt (kW) central electric heater that operates 12 hours per day when the cost is 15 cents per kilowatt-hour (kWhr)?

$$\text{Cost} = \text{Watts} \times \text{Hours Used} \times \text{Rate per kWhr}/1000$$

$$5 \text{ kW} = 5000 \text{ Watts}$$

$$\text{Hours} = 12 \text{ Hours} \times 30 \text{ Days} = 360 \text{ Hours per Month}$$

$$= 5000 \times 360 \times 0.15/1000$$

$$= 270000/1000 = \text{\$270 Monthly Cost}$$

The above example is for a resistive load. Air-conditioning loads are primarily inductive loads. However, if ampere and voltage values are known, this method will give an approximate cost. Kilowatt-hour rates vary for different power companies, and for residential use, graduated-rate scales are usually used (the more power used, the lower the rate). Commercial and industrial rates are generally based on kilowatt usage, maximum demand and power factor. Other costs are often added such as fuel cost adjustments.



CHANGING INCANDESCENT LAMP TO ENERGY-SAVING LAMP

A 100-watt incandescent lamp is to be replaced with a 15-watt, energy-saving lamp that has the same light output (lumens). If the cost per kilowatt-hour (kWhr) is 15 cents, how many hours would the new lamp need to operate to pay for itself?

Lamp cost is 4 dollars. Energy saved is 85 watts.

$$\text{Hours} = \text{Lamp Cost} \times 1000/\text{Watts Saved} \times \text{kWhr}$$

$$(4 \times 1000)/(85 \times 0.15) = 4000/12.75 = 313.73 \text{ hours}$$

The energy-saving lamp will pay for itself with 313.73 hours of operation. The comparative operating cost of these two lamps based on 313.73 hours is found by:

$$\text{Cost} = \text{Watts} \times \text{Hours Used} \times \text{Rate per kWhr}/1000$$

$$100\text{-watt incandescent lamp} = \$4.71 \text{ for } 313.73 \text{ hours of operation}$$

$$15\text{-watt energy saving lamp} = \$0.71 \text{ for } 313.73 \text{ hours of operation}$$



PARTIAL 2026 NATIONAL ELECTRICAL CODE SUMMARY

The 2026 edition of the National Electrical Code (NEC) contains 13 new articles and several relocated articles. Six existing articles were deleted, but the requirements from these deleted articles were moved into other new and existing articles. Article 220 was relocated to Chapter 1 and is now Article 120. Article 235 was deleted and separated into four new articles. Article 750 was renamed, and the rules for energy management systems were moved to Article 130. The requirements found in Article 395 for outdoor overhead conductors over 1000 volts were relocated to Article 267. The requirements for fire-resistive cable systems, which were found in the now-deleted Article 728, have been moved to Article 772.

Article 120—Branch-Circuit, Feeder, and Service Load Calculations (Moved)

Article 120 provides requirements for calculating branch-circuit, feeder, and service loads. This article was revised and relocated from Article 220 in the 2023 NEC to Article 120 in the 2026 NEC.

Article 130—Energy Management Systems (Moved)

Article 130 applies to the installation and operation of energy management systems. The requirements found in Article 130 were previously located in Article 750 in the 2023 NEC.

Article 206—Non-Power-Limited Remote-Control and Signaling Circuits (New)

Article 206 covers the general requirements for non-power-limited remote-control and signaling circuits. This new article contains new content as well as existing rules that were previously found in Article 300 of the 2023 NEC.

Article 265—Branch Circuits Over 1000 Volts ac, 1500 Volts dc, Nominal (New)

Article 235 in the 2023 NEC, which covered branch circuits, feeders, and services over 1000 volts ac, and 1500 volts dc was deleted and broken down into four separate articles for the 2026 NEC. The first



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of these four new articles is Article 265 which solely covers branch circuits over 1000 volts ac and 1500 volts dc nominal.

Article 266—Feeders Over 1000 Volts ac, 1500 Volts dc, Nominal (New)

Article 266 is the second new article that contains requirements from the deleted Article 235 found in the 2023 NEC. Article 266 contains the rules for feeders over 1000 volts ac and 1500 volts dc.

Article 267—Outside Branch Circuits and Feeders Over 1000 Volts ac, 1500 Volts dc, Nominal (New)

Article 267 covers outside branch circuits and feeders over 1000 volts ac and 1500 volts dc. This article is the third of four new articles relocated from the 2023 NEC Article 235.

Article 268—Services Over 1000 Volts ac, 1500 Volts dc, Nominal (New)

The fourth article relocated from Article 235 in the 2023 NEC is Article 268. This article covers services over 1000 volts ac and 1500 volts dc, nominal.

Article 270—Grounding and Bonding of Systems Over 1000 Volts ac, 1500 Volts dc, Nominal (New)

Article 270 provides the requirements for grounding and bonding of systems over 1000 volts ac and 1500 volts dc. This new article contains text that was previously found in Part X of Article 250 in the 2023 NEC.

Article 624—Electric Self-Propelled Vehicle Power Transfer Systems (ESVSEs) (New)

Article 624 contains new requirements and existing requirements for conductors and equipment connecting an electric self-propelled vehicle to premises wiring for the purposes of charging, power export, or bidirectional current flow. Many of the sections contained in Article 624 were relocated from Article 625 in the 2023 NEC and several new sections were added.



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Article 720—General Requirements for Limited-Energy System Wiring Methods and Materials (New)

Article 720 covers the wiring methods and materials for Class 1 power-limited circuits, Class 2, 3, and 4 circuits, as well as optical fiber systems, communications systems, antenna systems, CATV systems, network-powered broadband communications systems, premises-powered broadband communications systems, and power-limited fire alarm systems.

Article 721—Power Sources for Limited-Energy Systems (New)

Article 721 provides rules for power sources for limited-energy circuits.

Article 722—Limited-Energy Cables for Power-Limited Circuits, Fault-Managed-Power Circuits, Optical Fiber Circuits, and Communications Circuits (New)

Article 722 received a new title for the 2026 NEC and now covers the general requirements for the installation of single- and multiple-conductor cables used in Class 2, 3, and 4 circuits, power-limited fire alarm circuits, optical fiber cables, and communications systems power-limited, remote-control, and signaling circuits that are not an integral part of a device or utilization equipment installed inside of buildings.

Article 723—Raceways, Cable-Routing Assemblies, and Cable Trays for Limited-Energy Systems (New)

Article 723 provides the requirements for raceways and cable assemblies for limited-energy systems.

Article 742—Overvoltage Protection of Limited-Energy Systems (New)

Article 742 covers the overvoltage protection requirements for Class 1 power-limited circuits, Class 2, 3, and 4 circuits, optical fiber systems, communications systems, antenna systems, community antenna systems, network-powered broadband communications systems, premises-powered broadband communications systems, and power-limited fire alarm systems.



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Article 750—Grounding and Bonding of Limited-Energy Systems (New)

Article 750 covers the grounding and bonding for Class 1 power-limited circuits, Class 2, 3, and 4 circuits, optical fiber systems, communications systems, antenna systems, community antenna systems, network-powered broadband communications systems, premises-powered broadband communications systems, and power-limited fire alarm systems.

Article 772—Fire-Resistive Cable Systems (Moved)

Article 772 provides the requirements for the installation of fire-resistive cables, conductors, and other system components used for survivability of critical circuits to ensure continued operation during a specified time under fire conditions as required by the NEC. These rules were relocated from Article 728 in the 2023 NEC.

Code Arrangement [90.3]

Chapter 8 is no longer a “stand-alone” chapter. In previous editions of the NEC, Chapter 8 was not subject to the requirements found in Chapters 1 through 7. In the 2026 NEC, revised Figure 90.3 shows that Chapter 8 supplements or modifies Chapters 1 through 8 and is subject to the rules found in Chapters 1 through 8.

Definitions [Article 100]

A new definition of “Limited-Energy Cable” has been added. A limited-energy cable is defined as a factory assembly of one or more conductors or optical fibers used for Class 2, 3, or 4 circuits, optical fiber systems, communications circuits, CATV circuits, network-powered broadband low-power communications circuits, premises communications circuits, and power-limited fire alarm circuits.

Arc-Flash Hazard Marking [110.16]

In other than dwelling units, a permanent arc flash marking is now required to be field or factory applied to service equipment and feeder-supplied equipment such as switchboards, switchgear, enclosed



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panelboards, industrial control panels, meter socket enclosures, and motor-control centers. In previous editions of the NEC, this rule simply required a label warning of the potential of an arc flash. The 2026 edition of the NEC requires permanent markings showing the nominal system voltage, the arc flash boundary, the available incident energy or minimum required level of PPE, and the date the assessment was completed.

GFCI Protection for Personnel [210.8]

201.8(F) requires GFCI protection for all outdoor outlets at dwelling units supplied by single-phase branch circuits rated 150 volts or less to ground and 60 amperes or less. Effective September 1, 2026, GFCI or SPGFCI protection shall be provided for listed HVAC equipment. This section was added to the 2020 NEC and requires GFCI protection for all specified outlets located outdoors at dwelling units but was modified in the 2026 NEC by raising the current limit from 50 amperes to 60 amperes. By definition, listed HVAC equipment is an outlet and GFCI or SPGFCI protection is required. There are a few limited exceptions to this rule including most lighting outlets and electric snow-melting and deicing equipment. The requirement for protecting listed HVAC equipment has been postdated to September 1, 2026.

10-Ampere Branch Circuits [210.23(A)]

10-ampere branch circuits were introduced in the 2023 NEC with limited use. This section has been revised and now allows 10-ampere branch circuits to be used for lighting outlets and dwelling unit exhaust fans on bathroom and laundry room lighting circuits only. Section 310.5(A) has also been revised for the 2026 NEC and now allows 16 AWG copper, 14 AWG copper-clad aluminum, and 12 AWG aluminum conductors to be used on 10-ampere branch circuits.

Dwelling Unit Receptacle Outlets [210.52]

210.52(C)(4) states that required and permitted receptacle outlets in dwelling unit kitchens, pantries, breakfast rooms, dining rooms, and similar areas installed in a location that is accessible outside cabinets or wall surfaces that are below countertop and work surfaces shall not



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be installed on adjacent walls within 24 inches of the base cabinets. If installed beneath countertops, the receptacle outlets shall not be located within 24 inches of the countertop or work surface. Previous editions of the NEC allowed receptacle outlets to be installed on the sides of island and peninsular countertop spaces within this zone. This new section prohibits receptacle outlets from being installed below the countertops in kitchens, dining rooms, and similar areas of dwelling units if located within 24 inches of the countertop or base cabinets.

Minimum Size of Conductors [310.5(A)]

Since 10-ampere branch circuits are now permitted when complying with 210.23(A), the minimum size of conductors has also been revised. The minimum size of conductors for voltage ratings up to and including 2000 volts shall be 16 AWG copper, 14 AWG copper-clad aluminum, or 12 AWG aluminum, except as permitted elsewhere in the NEC.

Wiring Devices [Article 406]

The title of Article 406 has changed “Receptacles, Cord Connectors, and Attachment Plugs (Caps)” to “Wiring Devices”. The revised title illustrates that this article no longer solely covers receptacle outlets but now includes requirements for switches and other wiring devices. Much of the text in Article 404 in the 2023 NEC, related to switches, has been moved to Article 406 in the 2026 NEC.

Annex L—Proposed Organization of the 2029 National Electrical Code

Annex L was added to the 2026 NEC and gives us a look at what is being proposed for the structure of the 2029 edition. The NEC has contained 9 chapters for many decades. The 2029 edition is poised to undergo vast changes and will potentially contain 30 chapters. Annex L gives a preview of this proposed reorganization and allows for Public Input to be submitted during that stage of the NFPA Standards Development Process. For more information, please visit www.nfpa.org/70next. Public Input for the 2029 NEC must be submitted by April 9, 2026.



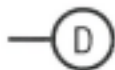

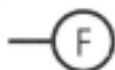



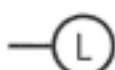



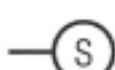

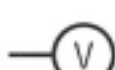

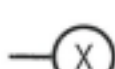

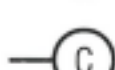



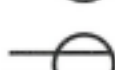

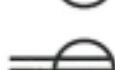
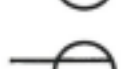






FIELD TERMS VERSUS *NEC* TERMS

- BX Armored cable (*NEC* 320)
- Romex Nonmetallic sheathed cable (*NEC* 334)
- Green field Flexible metal conduit (*NEC* 348)
- Thin wall Electrical metallic tubing (*NEC* 358)
- Smurf tube Electrical nonmetallic tubing (*NEC* 362)
- 1900 box 4-inch square box (*NEC* 314)
- 333 box Device box (*NEC* 314)
- EYS Explosion proof seal off (*NEC* 500)
- Neutral** Grounded conductor (*NEC* 200)**
- Ground wire Equipment grounding conductor (*NEC* 250.118)
- Ground wire Grounding electrode conductor (*NEC* 250.66)
- Hot, live Ungrounded conductor (*NEC* 100)

** Some systems do not have a neutral, and the grounded conductor may be a phase conductor. (See *NEC* Article 100 definition of *neutral conductor*.)

ELECTRICAL SYMBOLS

| Wall | Ceiling | | Switch Outlets |
|---|---|---------------------------------|---|
|  |  | Outlet | S Single-Pole Switch |
|  |  | Drop Card | S_2 Double-Pole Switch |
|  |  | Fan Outlet | S_3 Three-Way Switch |
|  |  | Junction Box | S_4 Four-Way Switch |
|  |  | Lampholder | S_D Door Switch |
|  |  | Lampholder With Pull Switch | S_E Electrolier Switch |
|  |  | Pull Switch | S_P Switch and Pilot Lamp |
|  |  | Vapor Discharge Lamp Outlet | S_K Key-Operated Switch |
|  |  | Exit Outlet | S_{CB} Circuit Breaker |
|  |  | Clock Outlet | S_{WCB} Weather-Proof Circuit Breaker |
|  |  | Blanked Outlet | S_{MC} Momentary-Contact Switch |
|  | | Duplex Convenience Outlet | S_{RC} Remote-Control Switch |
|  | | Single, Triplex, etc. | S_{WP} Weather-Proof Switch |
|  | | Range Outlet | S_F Fused Switch |
|  | | Duplex Receptacle and Switch | S_{WPF} Weather-Proof Fused Switch |
|  | | Special Purpose Outlet |  Lighting Switch |
|  | | Floor Outlet |  Power Panel |



ELECTRICAL SYMBOLS

| Transformers | | | | | ac motors | | | | | | | | |
|-------------------------------|-------------------------------|----------------------------|------------------------|---------------|-----------------|-------------------------|----------------|-----------------------|-----------|----------------------|--------------------|--------------------------|---------|
| Auto | Iron core | Air core | Current | Dual voltage | Single phase | 3 phase sq. cage | 2 phase 4 wire | Wound rotor | | | | | |
| | | | | | | | | | | | | | |
| dc motors | | | | Wiring | | | | | | | | | |
| Armature | Shunt field | Series field | Comm or compens. field | Not connected | Not connected | Connected | Power | Control | Home run* | Undergrnd. | Concealed in floor | Number of conductors (4) | Exposed |
| | | | | | | | | | | | | | |
| Resistors | | | Capacitors | | Wiring terminal | | | Ground | | | Connections | | |
| Fixed | Adj. by fixed taps | Rheostat. pot. or adj. tap | Fixed | Adj. | | | Mechanical | | | Mechanical interlock | | | |
| | | | | | | | | | | | | | |
| Heating element | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Supplementary contact | | | | | | Miscellaneous | | | | | | | |
| SPST.N.O. | SPST.N.C. | SPDT | | Annunciator | Bell | Buzzer | | | | | | | |
| Single break | Double break | Single break | Double break | Single break | Double break | Single break | Double break | | | | | | |
| | | | | | | | | | | | | | |
| DPST, 2 N.O. | DPST, 2 N.C. | DPDT | | Horn siren | Meter | Meter shunt | | | | | | | |
| Single break | Double break | Single break | Double break | Single break | Double break | Single break | Double break | | | | | | |
| | | | | | | | | | | | | | |
| Terms | | | | | | Miscellaneous | | | | | | | |
| SPST—Single pole single throw | DPDT—Double pole double throw | | Half wave | | | Indicate type by letter | | Fuse power or control | | Thermo-couple | | | |
| SPDT—Single pole double throw | N.O.—Normally open | | | | | | | | | | | | |
| DPST—Double pole single throw | N.C.—Normally closed | | Battery | | | | | | | | | | |
| | | | | | | | | | | | | | |



ELECTRICAL SYMBOLS

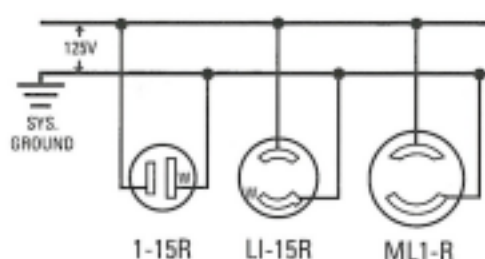
| Switches | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|--------------------------------|------------------------------------|-------------------------------------|---|-------------------|-------------|---|-------------------|----|--|---|--|--|---|--|------------|---|------------|----|------------|--|------------|----|------|--|-----------|--|------|--|-----------|--|-----|--|---|--|--|--|--|--|-----|--|--|---|---|---|--|---|
| Disconnect | Circuit breaker | Circuit breaker w/thermal O.L. | Circuit breaker w/magnetic O.L. | Circuit breaker w/thermal and magnetic O.L. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Limit switches | | Foot switches | Pressure and vacuum SW. | Liquid level switch | Temp. act. switch | Flow switch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| N.O. | N.C. | N.O. | N.O. | N.O. | N.O. | N.O. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Held closed | Held open | N.C. | N.C. | N.C. | N.C. | N.C. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Speed (plugging) | | Anti-plug | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Selectors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 position* | | | 3 position* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1" style="display: inline-table; border-collapse: collapse;"> <tr><td></td><td>J</td><td>K</td></tr> <tr><td>A1</td><td>•</td><td></td></tr> <tr><td>A2</td><td></td><td>•</td></tr> </table> | | | | J | K | A1 | • | | A2 | | • | <table border="1" style="display: inline-table; border-collapse: collapse;"> <tr><td></td><td>J</td><td>K</td><td>L</td></tr> <tr><td>A1</td><td>•</td><td></td><td></td></tr> <tr><td>A2</td><td></td><td></td><td>•</td></tr> </table> | | | | J | K | L | A1 | • | | | A2 | | | • | | | | | | | | | | | | | | | | | | | | | |
| | J | K | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A1 | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A2 | | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | J | K | L | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A1 | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A2 | | | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 position select push button* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><th colspan="2" rowspan="2">Contacts</th><th colspan="4">Selector position</th></tr> <tr><th colspan="2">A</th><th colspan="2">B</th></tr> <tr><th colspan="2">Button is:</th><th colspan="2">Button is:</th><th colspan="2">Button is:</th><th colspan="2">Button is:</th></tr> <tr><th colspan="2">Free</th><th colspan="2">Depressed</th><th colspan="2">Free</th><th colspan="2">Depressed</th></tr> <tr><td colspan="2">1-2</td><td>•</td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td colspan="2">3-4</td><td></td><td>•</td><td>•</td><td>•</td><td></td><td>•</td></tr> </table> | | | | | | Contacts | | Selector position | | | | A | | B | | Button is: | | Button is: | | Button is: | | Button is: | | Free | | Depressed | | Free | | Depressed | | 1-2 | | • | | | | | | 3-4 | | | • | • | • | | • |
| Contacts | | Selector position | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | A | | B | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Button is: | | Button is: | | Button is: | | Button is: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Free | | Depressed | | Free | | Depressed | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1-2 | | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3-4 | | | • | • | • | | • | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| * • = Contact closed | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Push buttons momentary contact | | Maintained contact | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Single N.O. | Double N.O. and N.C. | Mushroom Head | Wobble Stick | Illuminated | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Two single CKT. | | One double CKT. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pilot lights indicate color by letter | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Non-push-to-test | | | Push-to-test | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Coils | | Overload relays | | Contacts | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Shunt | Series | Thermal | Magnetic | N.O. | N.C. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note: N.O. = normally open; N.C. = normally closed

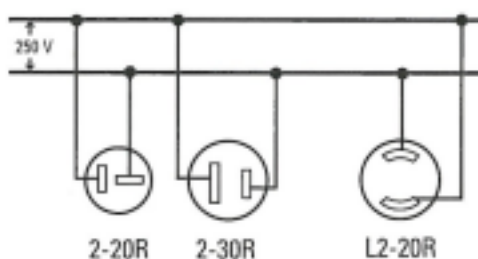


WIRING DIAGRAMS FOR NEMA CONFIGURATIONS

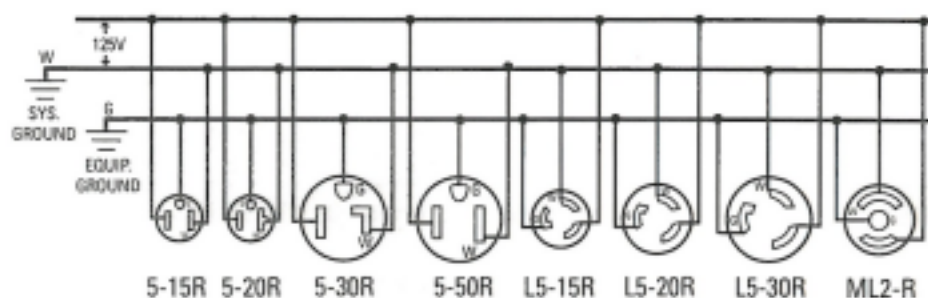
2 Pole, 2 Wire
Nongrounding
125V



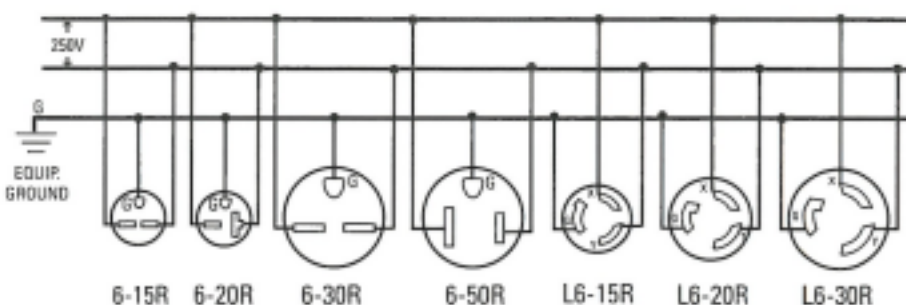
2 Pole, 2 Wire
Nongrounding
250V



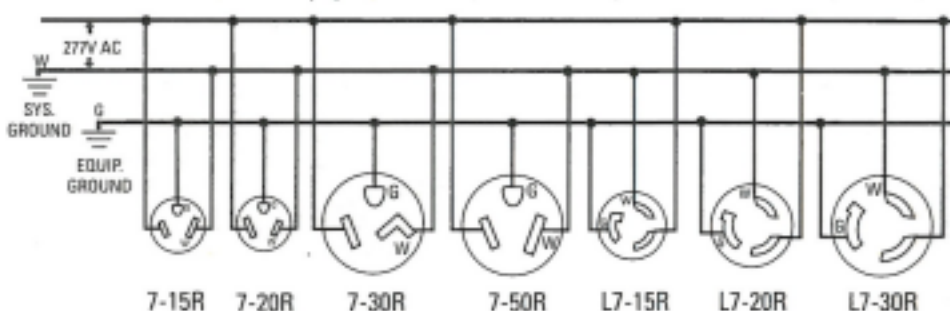
2 Pole, 3 Wire
Grounding
125V



2 Pole, 3 Wire
Grounding
250V



2 Pole, 3 Wire
Grounding
277V ac

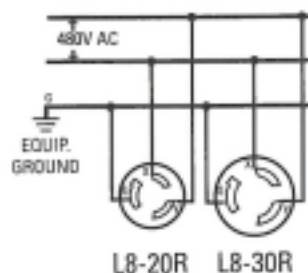


Courtesy of
COOPER Wiring Devices
The New Power in Wiring Devices

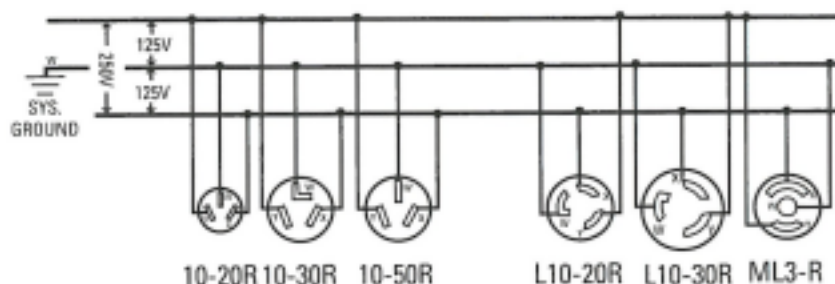


WIRING DIAGRAMS FOR NEMA CONFIGURATIONS

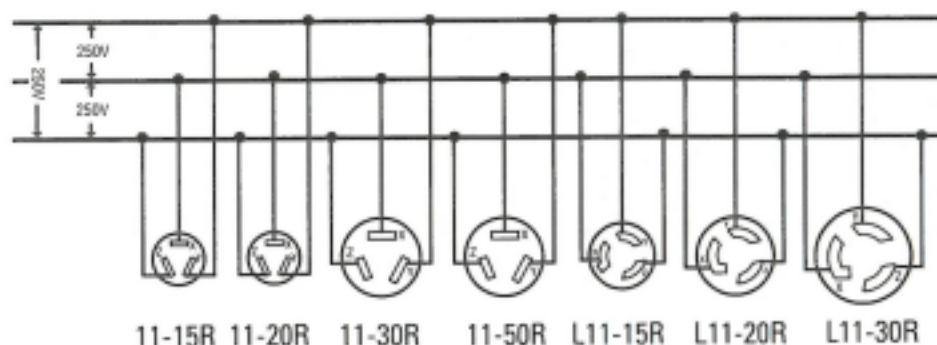
2 Pole, 3 Wire
Grounding
480V ac



3 Pole, 3 Wire
Nongrounding
125/250V



3 Pole, 3 Wire
Nongrounding
3ø 250V



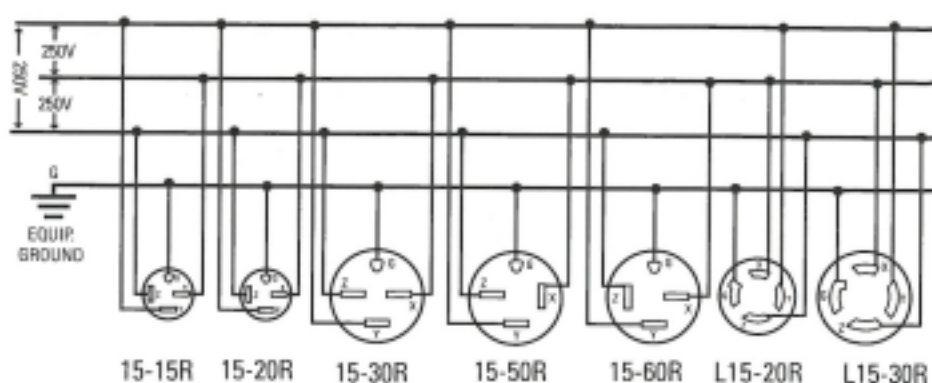
3 Pole, 4 Wire
Grounding
125/250V



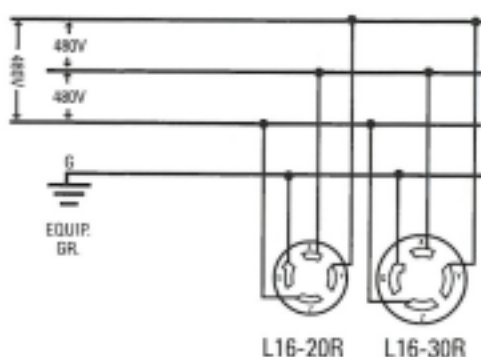


WIRING DIAGRAMS FOR NEMA CONFIGURATIONS

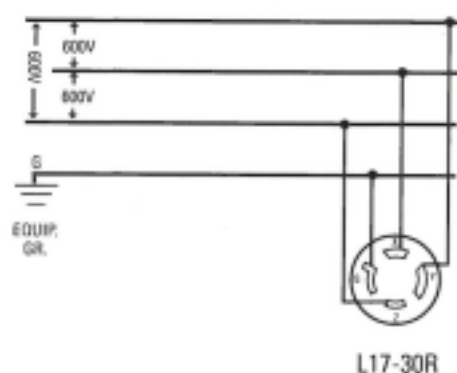
3 Pole, 4 Wire
Grounding
3Ø 250V



3 Pole, 4 Wire
Grounding
3Ø 480V



3 Pole, 4 Wire
Grounding
3Ø 600V

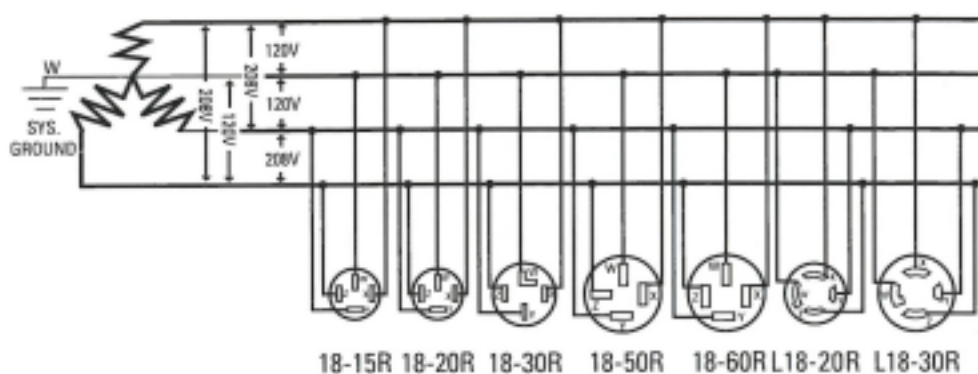


Courtesy of
COOPER Wiring Devices
The New Power in Wiring Devices

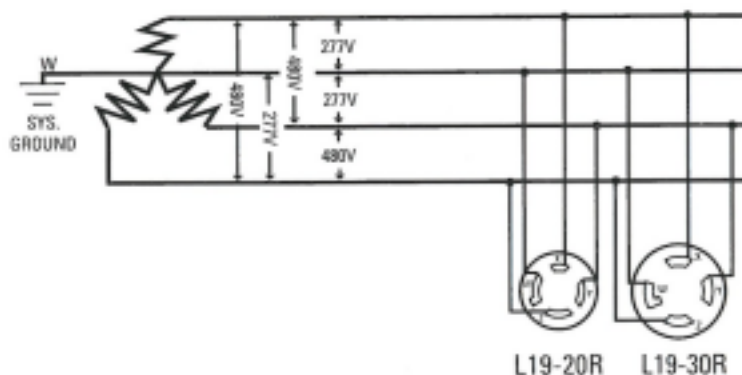


WIRING DIAGRAMS FOR NEMA CONFIGURATIONS

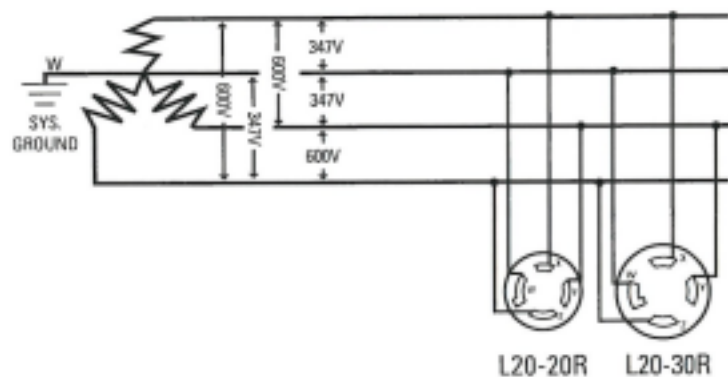
4 Pole, 4 Wire
Nongrounding
3 ϕ 120/208V



4 Pole, 4 Wire
Nongrounding
3 ϕ 277/480V



4 Pole, 4 Wire
Nongrounding
3 ϕ 347/600V

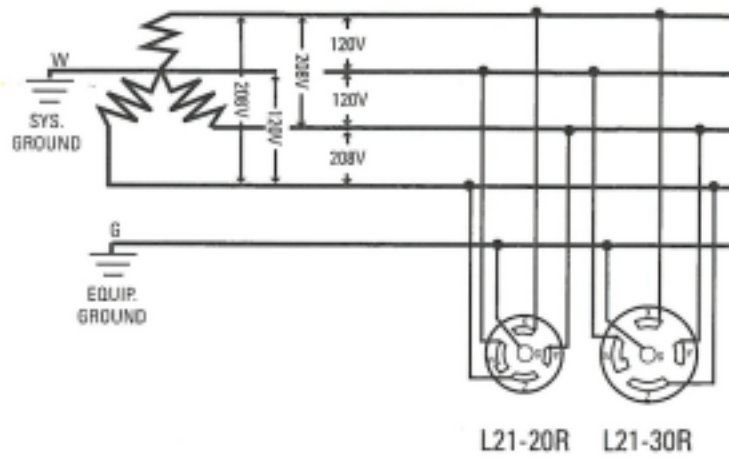


Courtesy of
COOPER Wiring Devices
The New Power In Wiring Devices

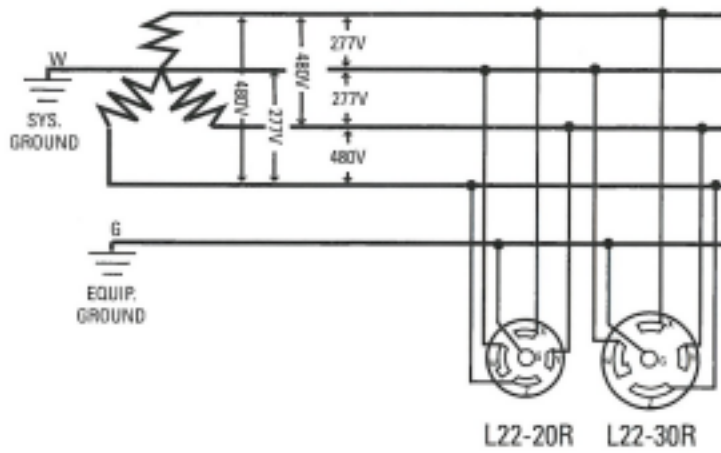


WIRING DIAGRAMS FOR NEMA CONFIGURATIONS

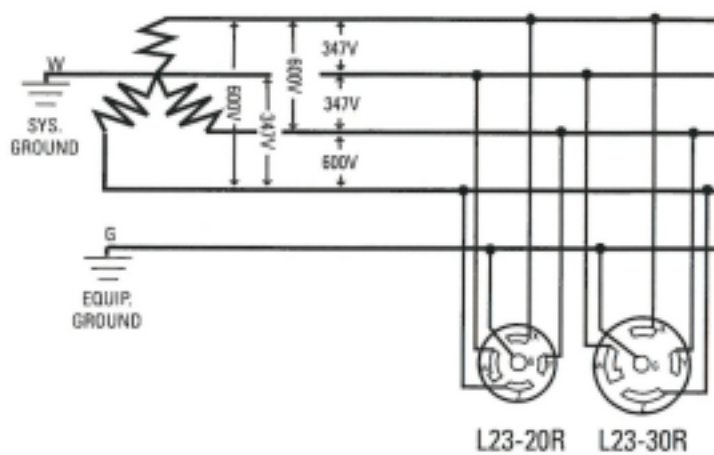
4 Pole, 5 Wire
Grounding
3Ø 120/208V



4 Pole, 5 Wire
Grounding
3Ø 277/480V



4 Pole, 5 Wire
Grounding
3Ø 347/600V



Courtesy of

COOPER Wiring Devices
The New Power in Wiring Devices

NEMA ENCLOSURE TYPES

The specific enclosure types, their applications, and the environmental conditions they are designed to provide a degree of protection against are as follows:

Type 1—Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts and to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt).

Type 2—Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 3—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.

Type 3R—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and that will be undamaged by the external formation of ice on the enclosure.

Type 3S—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown



NEMA ENCLOSURE TYPES

dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); and for which the external mechanism(s) remain(s) operable when ice laden.

Type 3X—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an increased level of protection against corrosion and that will be undamaged by the external formation of ice on the enclosure.

Type 3RX—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that will be undamaged by the external formation of ice on the enclosure that provides an increased level of protection against corrosion.

Type 3SX—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow); that provides an increased level of protection against corrosion; and for which the external mechanism(s) remain(s) operable when ice laden.

Type 4—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt

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NEMA ENCLOSURE TYPES

and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water); and that will be undamaged by the external formation of ice on the enclosure.

Type 4X—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and windblown dust); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow, splashing water, and hose-directed water); that provides an increased level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.

Type 5—Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and settling airborne dust, lint, fibers, and flyings); and to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing).

Type 6—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose-directed water and the entry of water during occasional temporary submersion at a limited depth); and that will be undamaged by the external formation of ice on the enclosure.

Type 6P—Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the

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NEMA ENCLOSURE TYPES

enclosure against ingress of solid foreign objects (falling dirt); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (hose-directed water and the entry of water during prolonged submersion at a limited depth); that provides an increased level of protection against corrosion; and that will be undamaged by the external formation of ice on the enclosure.

Type 12—Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against light splashing and seepage of oil and non-corrosive coolants.

Type 12K—Enclosures constructed (with knockouts) for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against light splashing and seepage of oil and non-corrosive coolants.

Type 13—Enclosures constructed for indoor use to provide a degree of protection to personnel against access to hazardous parts; to provide a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt and circulating dust, lint, fibers, and flyings); to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of water (dripping and light splashing); and to provide a degree of protection against the spraying, splashing, and seepage of oil and non-corrosive coolants.

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U.S. WEIGHTS AND MEASURES

Linear Measures

| | | |
|------------|-------------|---------------------|
| | 1 Inch | = 2.540 Centimeters |
| 12 Inches | = 1 Foot | = 3.048 Decimeters |
| 3 Feet | = 1 Yard | = 9.144 Decimeters |
| 5.5 Yards | = 1 Rod | = 5.029 Meters |
| 40 Rods | = 1 Furlong | = 2.018 Hectometers |
| 8 Furlongs | = 1 Mile | = 1.609 Kilometers |

Mile Measurements

| | |
|-----------------|--------------|
| 1 Statute Mile | = 5280 Feet |
| 1 Scots Mile | = 5952 Feet |
| 1 Irish Mile | = 6720 Feet |
| 1 Russian Verst | = 3504 Feet |
| 1 Italian Mile | = 4401 Feet |
| 1 Spanish Mile | = 15084 Feet |

Other Linear Measurements

| | |
|--------------------|-----------------------|
| 1 Hand = 4 Inches | 1 Link = 7.92 Inches |
| 1 Span = 9 Inches | 1 Fathom = 6 Feet |
| 1 Chain = 22 Yards | 1 Furlong = 10 Chains |
| | 1 Cable = 608 Feet |

Square Measures

| | |
|-------------------|-----------------|
| 144 Square Inches | = 1 Square Foot |
| 9 Square Feet | = 1 Square Yard |
| 30¼ Square Yards | = 1 Square Rod |
| 40 Rods | = 1 Rood |
| 4 Roods | = 1 Acre |
| 640 Acres | = 1 Square Mile |
| 1 Square Mile | = 1 Section |
| 36 Sections | = 1 Township |

Cubic or Solid Measures

| | |
|---------------------|------------------------------|
| 1 Cubic Foot | = 1728 Cubic Inches |
| 1 Cubic Yard | = 27 Cubic Feet |
| 1 Cubic Foot | = 7.48 Gallons |
| 1 Gallon (Water) | = 8.34 Pounds |
| 1 Gallon (U.S.) | = 231 Cubic Inches of Water |
| 1 Gallon (Imperial) | = 277¼ Cubic Inches of Water |



U.S. WEIGHTS AND MEASURES

Liquid Measurements

| | | |
|----------|---|-------------------------------------|
| 1 Pint | = | 4 Gills |
| 1 Quart | = | 2 Pints |
| 1 Gallon | = | 4 Quarts |
| 1 Firkin | = | 9 Gallons (Ale or Beer) |
| 1 Barrel | = | 42 Gallons (Petroleum or Crude Oil) |

Dry Measure

| | | |
|----------|---|----------|
| 1 Quart | = | 2 Pints |
| 1 Peck | = | 8 Quarts |
| 1 Bushel | = | 4 Pecks |

Weight Measurement (Mass)

A. Avoirdupois Weight

| | | |
|-----------------|---|-------------|
| 1 Ounce | = | 16 Drams |
| 1 Pound | = | 16 Ounces |
| 1 Hundredweight | = | 100 Pounds |
| 1 Ton | = | 2000 Pounds |

B. Troy Weight

| | | |
|---------------------------|---|---|
| 1 Carat | = | 3.17 Grains |
| 1 Pennyweight | = | 20 Grains |
| 1 Ounce | = | 20 Pennyweights |
| 1 Pound | = | 12 Ounces |
| 1 Long Hundred- Weight | = | 112 Pounds |
| 1 Long Ton | = | 20 Long Hundredweights = 2240 Pounds |

C. Apothecaries Weight

| | | | | |
|-----------|---|------------|---|----------------|
| 1 Scruple | = | 20 Grains | = | 1.296 Grams |
| 1 Dram | = | 3 Scruples | = | 3.888 Grams |
| 1 Ounce | = | 8 Drams | = | 31.1035 Grams |
| 1 Pound | = | 12 Ounces | = | 373.2420 Grams |

D. Kitchen Weights and Measures

| | | |
|----------------|---|---|
| 1 U.S. Pint | = | 16 Fluid Ounces |
| 1 Standard Cup | = | 8 Fluid Ounces |
| 1 Tablespoon | = | 0.5 Fluid Ounces (15 Cubic Centimeters) |
| 1 Teaspoon | = | 0.16 Fluid Ounces (5 Cubic Centimeters) |



METRIC SYSTEM

Prefixes

| | | | |
|----------|-----------|----------|------------|
| A. Mega | = 1000000 | E. Deci | = 0.1 |
| B. Kilo | = 1000 | F. Centi | = 0.01 |
| C. Hecto | = 100 | G. Milli | = 0.001 |
| D. Deka | = 10 | H. Micro | = 0.000001 |

Linear Measure

(The Unit is the Meter = 39.37 Inches)

| | | | | |
|--------------|---------|-------------|-------------|--------|
| 1 Centimeter | = 10 | Millimeters | = 0.3937011 | Inch |
| 1 Decimeter | = 10 | Centimeters | = 3.9370113 | Inches |
| 1 Meter | = 10 | Decimeters | = 1.0936143 | Yards |
| | | | = 3.2808429 | Feet |
| 1 Dekameter | = 10 | Meters | = 10.936143 | Yards |
| 1 Hectometer | = 10 | Dekameters | = 109.36143 | Yards |
| 1 Kilometer | = 10 | Hectometers | = 0.62137 | Mile |
| 1 Myriameter | = 10000 | Meters | | |

Square Measure

(The Unit is the Square Meter = 1549.9969 SQ. Inches)

| | | | |
|------------------|-----------------------|-----------|---------------|
| 1 SQ. Centimeter | = 100 SQ. Millimeters | = 0.1550 | Square Inch |
| 1 SQ. Decimeter | = 100 SQ. Centimeters | = 15.550 | Square Inches |
| 1 SQ. Meter | = 100 SQ. Decimeters | = 10.7639 | Square Feet |
| 1 SQ. Dekameter | = 100 SQ. Meters | = 119.60 | Square Yards |
| 1 SQ. Hectometer | = 100 SQ. Dekameters | | |
| 1 SQ. Kilometer | = 100 SQ. Hectometers | | |

(The Unit is the "Are" = 100 SQ. Meters)

| | | | | |
|-----------------|-------|-----------|------------|--------------|
| 1 Centiare | = 10 | Milliares | = 10.7643 | Square Feet |
| 1 Deciare | = 10 | Centiares | = 11.96033 | Square Yards |
| 1 Are | = 10 | Deciares | = 119.6033 | Square Yards |
| 1 Decare | = 10 | Ares | = 0.247110 | Acres |
| 1 Hectare | = 10 | Decares | = 2.471098 | Acres |
| 1 SQ. Kilometer | = 100 | Hectares | = 0.38611 | Square Mile |

Cubic Measure

(The Unit is the "Stere" = 61025.38659 CU. INs.)

| | | | |
|-------------|------------------|------------|-------------|
| 1 Decistere | = 10 Centisteres | = 3.531562 | Cubic Foot |
| 1 Stere | = 10 Decisteres | = 1.307986 | Cubic Yards |
| 1 Dekastere | = 10 Steres | = 13.07986 | Cubic Yards |

METRIC SYSTEM

Cubic Measure *(continued)*

(The Unit is the Meter = 39.37 Inches)

| | | |
|------------------------------|------------------------|-------------------------|
| 1 CU. Centimeter | = 1000 CU. Millimeters | = 0.06102 Cubic Inches |
| 1 CU. Decimeter | = 1000 CU. Centimeters | = 61.02374 Cubic Inches |
| 1 CU. Meter | = 1000 CU. Decimeters | = 35.31467 Cubic Feet |
| | = 1 Stere | = 1.30795 Cubic Yards |
| 1 CU. Centimeter (Water) | | = 1 Gram |
| 1000 CU. Centimeters (Water) | = 1 Liter | = 1 Kilogram |
| 1 CU. Meter (1000 Liters) | | = 1 Metric Ton |

Measures of Weight

(The Unit is the Gram = 0.035274 Ounces)

| | | | |
|--------------|-----------------|------------------|------------------------|
| 1 Milligram | = | = | 0.015432 Grains |
| 1 Centigram | = 10 Milligrams | = | 0.15432 Grains |
| 1 Decigram | = 10 Centigrams | = | 1.5432 Grains |
| 1 Gram | = 10 Decigrams | = | 15.4323 Grains |
| 1 Dekagram | = 10 Grams | = | 5.6438 Drams |
| 1 Hectogram | = 10 Dekagrams | = | 3.5274 Ounces |
| 1 Kilogram | = 10 Hectograms | = | 2.2046223 Pounds |
| 1 Myriagram | = 10 Kilograms | = | 22.046223 Pounds |
| 1 Quintal | = 10 Myriagrams | = | 1.986412 Hundredweight |
| 1 Metric Ton | = 10 Quintal | = | 22045.622 Pounds |
| 1 Gram | = | 0.56438 Drams | |
| 1 Dram | = | 1.77186 Grams | |
| | = | 27.3438 Grains | |
| 1 Metric Ton | = | 2204.6223 Pounds | |

Measures of Capacity

(The Unit is the Liter = 1.0567 Liquid Quarts)

| | | |
|--------------|------------------|----------------------|
| 1 Centiliter | = 10 Milliliters | = 0.338 Fluid Ounces |
| 1 Deciliter | = 10 Centiliters | = 3.38 Fluid Ounces |
| 1 Liter | = 10 Deciliters | = 33.8 Fluid Ounces |
| 1 Dekaliter | = 10 Liters | = 0.284 Bushel |
| 1 Hectoliter | = 10 Dekaliters | = 2.84 Bushels |
| 1 Kiloliter | = 10 Hectoliters | = 264.2 Gallons |

Note: $\frac{\text{Kilometers}}{8} \times 5 = \text{Miles}$ or $\frac{\text{Miles}}{5} \times 8 = \text{Kilometers}$

METRIC SYSTEM

Metric Designator and Trade Sizes

Metric Designator

| | | | | | | | | | | | | |
|---------------|---------------|---------------|----|----------------|----------------|----|----------------|----|----------------|-----|-----|-----|
| 12 | 16 | 21 | 27 | 35 | 41 | 53 | 63 | 78 | 91 | 103 | 129 | 155 |
| $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ | 4 | 5 | 6 |

Trade Size

Source: NFPA 70, *National Electrical Code*®, NFPA, Quincy, MA, 2023, Table 300.1(C), as modified.

U.S. Weights and Measures/Metric Equivalent Chart

| | In. | Ft | Yd. | Mile | mm | cm | m | km |
|----------|--------|-----------|-------------------------|-------------------------|---------|----------|----------|------------------------|
| 1 Inch = | 1 | .0833 | .0278 | 1.578×10^{-5} | 25.4 | 2.54 | .0254 | 2.54×10^{-9} |
| 1 Foot = | 12 | 1 | .333 | 1.894×10^{-4} | 304.8 | 30.48 | .3048 | 3.048×10^{-4} |
| 1 Yard = | 36 | 3 | 1 | 5.6818×10^{-4} | 914.4 | 91.44 | .9144 | 9.144×10^{-4} |
| 1 Mile = | 63360 | 5280 | 1760 | 1 | 1609344 | 160934.4 | 1609.344 | 1609344 |
| 1 mm = | .03937 | .00032808 | 1.0936×10^{-3} | 6.2137×10^{-7} | 1 | 0.1 | 0.001 | 0.000001 |
| 1 cm = | .3937 | .0328084 | .0109361 | 6.2137×10^{-6} | 10 | 1 | 0.01 | 0.00001 |
| 1 m = | 39.37 | 3.280.84 | 1.093.61 | 6.2137×10^{-4} | 1000 | 100 | 1 | 0.001 |
| 1 km = | 39370 | 3280.84 | 1093.61 | 0.62137 | 1000000 | 100000 | 1000 | 1 |

In. = inches Ft = foot Yd. = yard mm = millimeter cm = centimeter m = meter km = kilometer

Explanation of Scientific Notation

Scientific notation (powers of 10) is simply a way of expressing very large or very small numbers in a more compact format. Any number can be expressed as a number between 1 and 10, multiplied by a power of 10 (which indicates the correct position of the decimal point in the original number). Numbers greater than 10 have positive powers of 10, and numbers less than 1 have negative powers of 10.

Example: $186000 = 1.86 \times 10^5$ $0.000524 = 5.24 \times 10^{-4}$

Useful Conversions/Equivalents

| | |
|--------------------------|----------------------------|
| 1 BTU | Raises 1 lb of water 1°F |
| 1 Gram Calorie | Raises 1 gram of water 1°C |
| 1 Circular Mil | Equals 0.7854 sq. mil |
| 1 SQ. Mil | Equals 1.2732 cir. mils |
| 1 Mil | Equals 0.001 in. |

To determine circular mil (cmil) of a conductor:

Round Conductor cmil = (Diameter in mils)²

Rectangle Bus Bar cmil = $\frac{\text{Width} \times \text{Thickness} \times 1,000,000}{0.7854}$

Notes: 1 millimeter = 39.37 mils 1 cir. millimeter = 1550 cir. mils
1 sq. millimeter = 1974 cir. mils



DECIMAL EQUIVALENTS

| Fraction | | | | | Decimal | Fraction | | | | | Decimal |
|----------|-------|------|-----|-----|---------|----------|-------|-------|-----|-----|---------|
| 1/64 | | | | | .0156 | 33/64 | | | | | .5156 |
| 2/64 | 1/32 | | | | .0313 | 34/64 | 17/32 | | | | .5313 |
| 3/64 | | | | | .0469 | 35/64 | | | | | .5469 |
| 4/64 | 2/32 | 1/16 | | | .0625 | 36/64 | 18/32 | 9/16 | | | .5625 |
| 5/64 | | | | | .0781 | 37/64 | | | | | .5781 |
| 6/64 | 3/32 | | | | .0938 | 38/64 | 19/32 | | | | .5938 |
| 7/64 | | | | | .1094 | 39/64 | | | | | .6094 |
| 8/64 | 4/32 | 2/16 | 1/8 | | .125 | 40/64 | 20/32 | 10/16 | 5/8 | | .625 |
| 9/64 | | | | | .1406 | 41/64 | | | | | .6406 |
| 10/64 | 5/32 | | | | .1563 | 42/64 | 21/32 | | | | .6563 |
| 11/64 | | | | | .1719 | 43/64 | | | | | .6719 |
| 12/64 | 6/32 | 3/16 | | | .1875 | 44/64 | 22/32 | 11/16 | | | .6875 |
| 13/64 | | | | | .2031 | 45/64 | | | | | .7031 |
| 14/64 | 7/32 | | | | .2188 | 46/64 | 23/32 | | | | .7188 |
| 15/64 | | | | | .2344 | 47/64 | | | | | .7344 |
| 16/64 | 8/32 | 4/16 | 2/8 | 1/4 | .25 | 48/64 | 24/32 | 12/16 | 6/8 | 3/4 | .75 |
| 17/64 | | | | | .2656 | 49/64 | | | | | .7656 |
| 18/64 | 9/32 | | | | .2813 | 50/64 | 25/32 | | | | .7813 |
| 19/64 | | | | | .2969 | 51/64 | | | | | .7969 |
| 20/64 | 10/32 | 5/16 | | | .3125 | 52/64 | 26/32 | 13/16 | | | .8125 |
| 21/64 | | | | | .3281 | 53/64 | | | | | .8281 |
| 22/64 | 11/32 | | | | .3438 | 54/64 | 27/32 | | | | .8438 |
| 23/64 | | | | | .3594 | 55/64 | | | | | .8594 |
| 24/64 | 12/32 | 6/16 | 3/8 | | .375 | 56/64 | 28/32 | 14/16 | 7/8 | | .875 |
| 25/64 | | | | | .3906 | 57/64 | | | | | .8906 |
| 26/64 | 13/32 | | | | .4063 | 58/64 | 29/32 | | | | .9063 |
| 27/64 | | | | | .4219 | 59/64 | | | | | .9219 |
| 28/64 | 14/32 | 7/16 | | | .4375 | 60/64 | 30/32 | 15/16 | | | .9375 |
| 29/64 | | | | | .4531 | 61/64 | | | | | .9531 |
| 30/64 | 15/32 | | | | .4688 | 62/64 | 31/32 | | | | .9688 |
| 31/64 | | | | | .4844 | 63/64 | | | | | .9844 |
| 32/64 | 16/32 | 8/16 | 4/8 | 2/4 | .5 | 64/64 | 32/32 | 16/16 | 8/8 | 4/4 | 1.000 |

Decimals are rounded to the nearest 10000th.



TWO-WAY CONVERSION TABLE

To convert from the unit of measure in Column B to the unit of measure in Column C, multiply the number of units in Column B by the multiplier in Column A. To convert from Column C to B, use the multiplier in Column D.

Example: To convert 1000 BTUs to Calories, find the "BTU - Calorie" combination in Columns B and C. "BTU" is in Column B and "Calorie" is in Column C; so we are converting from B to C. Therefore, we use Column A multiplier. $1000 \text{ BTUs} \times 251.996 = 251996 \text{ Calories}$.

To convert 251996 Calories to BTUs, use the same "BTU - Calorie" combination. But this time you are converting from C to B. Therefore, use Column D multiplier. $251996 \text{ Calories} \times 0.0039683 = 1000 \text{ BTUs}$.

$$A \times B = C$$

&

$$D \times C = B$$

To Convert from B to C,
Multiply B x A:

To Convert from C to B,
Multiply C x D:

| A | B | C | D |
|--------------------------|--------------------|--------------------------|--------------------------|
| 43560 | Acre | Sq. foot | 2.2956×10^{-5} |
| 1.5625×10^{-3} | Acre | Sq. mile | 640 |
| 6.4516 | Ampere per sq. cm. | Ampere per sq. in. | 0.155003 |
| 1.256637 | Ampere (turn) | Gilberts | 0.79578 |
| 33.89854 | Atmosphere | Foot of H ₂ O | 0.029499 |
| 29.92125 | Atmosphere | Inch of Hg | 0.033421 |
| 14.69595 | Atmosphere | Pound force/sq. in. | 0.06804 |
| 251.996 | BTU | Calorie | 3.96832×10^{-3} |
| 778.169 | BTU | Foot pound force | 1.28507×10^{-3} |
| 3.93015×10^{-1} | BTU | Horsepower hour | 2544.43 |
| 1055.056 | BTU | Joule | 9.47817×10^{-1} |
| 2.9307×10^{-4} | BTU | Kilowatt hour | 3412.14 |
| 3.93015×10^{-1} | BTU/hour | Horsepower | 2544.43 |
| 2.93071×10^{-4} | BTU/hour | Kilowatt | 3412.1412 |
| 0.293071 | BTU/hour | Watt | 3.41214 |
| 4.19993 | BTU/minute | Calorie/second | 0.23809 |
| 0.0235809 | BTU/minute | Horsepower | 42.4072 |
| 17.5843 | BTU/minute | Watt | 0.0568 |

(continued on next page)



TWO-WAY CONVERSION TABLE

To Convert from B to C,
Multiply B x A:

To Convert from C to B,
Multiply C x D:

| A | B | C | D |
|--------------------------|--------------------------|------------------|------------------------|
| 4.1868 | Calorie | Joule | 0.238846 |
| 0.0328084 | Centimeter | Foot | 30.48 |
| 0.3937 | Centimeter | Inch | 2.54 |
| 0.00001 | Centimeter | Kilometer | 100000 |
| 0.01 | Centimeter | Meter | 100 |
| 6.2137×10^{-6} | Centimeter | Mile | 160934.4 |
| 10 | Centimeter | Millimeter | 0.1 |
| 0.010936 | Centimeter | Yard | 91.44 |
| 7.85398×10^{-7} | Circular mil | Sq. inch | 1.273239×10^5 |
| 0.000507 | Circular mil | Sq. millimeter | 1973.525 |
| 0.06102374 | Cubic centimeter | Cubic inch | 16.387065 |
| 0.028317 | Cubic foot | Cubic meter | 35.31467 |
| 1.0197×10^{-3} | Dyne | Gram force | 980.665 |
| 1×10^{-5} | Dyne | Newton | 100000 |
| 1 | Dyne centimeter | Erg | 1 |
| 7.376×10^{-4} | Erg | Foot pound force | 1.355818×10^7 |
| 2.777×10^{-14} | Erg | Kilowatt hour | 3.6×10^{13} |
| 1.0×10^{-7} | Erg/second | Watt | 1.0×10^7 |
| 12 | Foot | Inch | 0.0833 |
| 3.048×10^{-4} | Foot | Kilometer | 3280.84 |
| 0.3048 | Foot | Meter | 3.28084 |
| 1.894×10^{-4} | Foot | Mile | 5280 |
| 304.8 | Foot | Millimeter | 0.00328 |
| 0.333 | Foot | Yard | 3 |
| 10.7639 | Foot candle | Lux | 0.0929 |
| 0.882671 | Foot of H ₂ O | Inch of Hg | 1.13292 |
| 5.0505×10^{-7} | Foot pound force | Horsepower hour | 1.98×10^6 |
| 1.35582 | Foot pound force | Joule | 0.737562 |
| 3.76616×10^{-7} | Foot pound force | Kilowatt hour | 2.655223×10^6 |
| 3.76616×10^{-4} | Foot pound force | Watt hour | 2655.22 |
| 3.76616×10^{-7} | Foot pound force/hour | Kilowatt | 2.6552×10^6 |
| 3.0303×10^{-5} | Foot pound force/minute | Horsepower | 33000 |



TWO-WAY CONVERSION TABLE

To Convert from B to C,
Multiply B x A:

To Convert from C to B,
Multiply C x D:

| A | B | C | D |
|-----------------------------|--------------------------|---------------|---------------------------|
| 2.2597 x 10 ⁻³ | Foot pnd. force/minute | Kilowatt | 44253.7 |
| 0.022597 | Foot pnd. force/minute | Watt | 44.2537 |
| 1.81818 x 10 ⁻³ | Foot pnd. force/second | Horsepower | 550 |
| 1.355818 x 10 ⁻³ | Foot pnd. force/second | Kilowatt | 737.562 |
| 0.7457 | Horsepower | Kilowatt | 1.34102 |
| 745.7 | Horsepower | Watt | 0.00134 |
| 0.0022046 | Gram | Pound mass | 453.592 |
| 2.54 x 10 ⁻⁵ | Inch | Kilometer | 39370 |
| 0.0254 | Inch | Meter | 39.37 |
| 1.578 x 10 ⁻⁵ | Inch | Mile | 63360 |
| 25.4 | Inch | Millimeter | 0.03937 |
| 0.0278 | Inch | Yard | 36 |
| 0.07355 | Inch of H ₂ O | Inch of Hg | 13.5951 |
| 2.7777x10 ⁻⁷ | Joule | Kilowatt hour | 3.6 X 10 ⁹ |
| 2.7777x10 ⁻⁴ | Joule | Watt hour | 3600 |
| 1 | Joule | Watt second | 1 |
| 1000 | Kilometer | Meter | 0.001 |
| 0.62137 | Kilometer | Mile | 1.609344 |
| 1000000 | Kilometer | Millimeter | 0.000001 |
| 1093.61 | Kilometer | Yard | 9.144 x 10 ⁻⁴ |
| 0.000621 | Meter | Mile | 1609.344 |
| 1000 | Meter | Millimeter | 0.001 |
| 1.0936 | Meter | Yard | 0.9144 |
| 1609344 | Mile | Millimeter | 6.2137 x 10 ⁻⁷ |
| 1760 | Mile | Yard | 5.681 x 10 ⁻⁴ |
| 1.0936 x 10 ⁻³ | Millimeter | Yard | 914.4 |
| 0.224809 | Newton | Pound force | 4.44822 |
| 0.03108 | Pound | Slug | 32.174 |
| 0.0005 | Pound | Ton (short) | 2000 |
| 0.155 | Sq. centimeter | Sq. inch | 6.4516 |
| 0.092903 | Sq. foot | Sq. meter | 10.76391 |
| 0.386102 | Sq. kilometer | Sq. mile | 2.589988 |

| Metal | Symb. | Spec. Grav. | Melt Point | | Elec. Cond. % Copper | Pounds/Cu In |
|----------------|-------|-------------|------------|-----------|----------------------|--------------|
| | | | °C | °F | | |
| Aluminum | Al | 2.71 | 660 | 1220 | 64.9 | .0978 |
| Antimony | Sb | 6.62 | 630 | 1167 | 4.42 | .2390 |
| Arsenic | As | 5.73 | — | — | 4.9 | .2070 |
| Beryllium | Be | 1.83 | 1280 | 2336 | 9.32 | .0660 |
| Bismuth | Bi | 9.80 | 271 | 520 | 1.50 | .3540 |
| Brass (70-30) | | 8.51 | 900 | 1652 | 28.0 | .3070 |
| Bronze (5% SN) | | 8.87 | 1000 | 1832 | 18.0 | .3200 |
| Cadmium | Cd | 8.65 | 321 | 610 | 22.7 | .3120 |
| Calcium | Ca | 1.55 | 850 | 1562 | 50.1 | .0560 |
| Cobalt | Co | 8.90 | 1495 | 2723 | 17.8 | .3210 |
| Copper | Cu | | | | | |
| Rolled | | 8.89 | 1083 | 1981 | 100.0 | .3210 |
| Tubing | | 8.95 | — | — | 100.0 | .3230 |
| Gold | Au | 19.30 | 1063 | 1945 | 71.2 | .6970 |
| Graphite | | 2.25 | 3500 | 6332 | 10 ⁻³ | .0812 |
| Indium | In | 7.30 | 156 | 311 | 20.6 | .2640 |
| Iridium | Ir | 22.40 | 2450 | 4442 | 32.5 | .8090 |
| Iron | Fe | 7.20 | 1200–1400 | 2192–2552 | 17.6 | .2600 |
| Malleable | | 7.20 | 1500–1600 | 2732–2912 | 10 | .2600 |
| Wrought | | 7.70 | 1500–1600 | 2732–2912 | 10 | .2780 |
| Lead | Pb | 11.40 | 327 | 621 | 8.35 | .4120 |
| Magnesium | Mg | 1.74 | 651 | 1204 | 38.7 | .0628 |

| Metal | Symb. | Spec. Grav. | Melt Point | | Elec. Cond. % Copper | Pounds/Cu In |
|----------------|-------|-------------|------------|-----------|----------------------|--------------|
| | | | °C | °F | | |
| Manganese | Mn | 7.20 | 1245 | 2273 | 0.9 | .2600 |
| Mercury | Hg | 13.65 | -38.9 | -37.7 | 1.80 | .4930 |
| Molybdenum | Mo | 10.20 | 2620 | 4748 | 36.1 | .3680 |
| Monel (63-37) | | 8.87 | 1300 | 2372 | 3.0 | .3200 |
| Nickel | Ni | 8.90 | 1452 | 2646 | 25.0 | .3210 |
| Phosphorous | P | 1.82 | 44.1 | 111.4 | 10 ⁻¹⁷ | .0657 |
| Platinum | Pt | 21.46 | 1773 | 3221 | 17.5 | .7750 |
| Potassium | K | 0.860 | 62.3 | 144.1 | 28 | .0310 |
| Selenium | Se | 4.81 | 220 | 428 | 14.4 | .1740 |
| Silicon | Si | 2.40 | 1420 | 2588 | 10 ⁻⁵ | .0866 |
| Silver | Ag | 10.50 | 960 | 1760 | 106 | .3790 |
| Steel (Carbon) | | 7.84 | 1330-1380 | 2436-2516 | 10 | .2830 |
| Stainless | | | | | | |
| (18-8) | | 7.92 | 1500 | 2732 | 2.5 | .2860 |
| (13-CR) | | 7.78 | 1520 | 2768 | 3.5 | .2810 |
| Tantalum | Ta | 16.60 | 2900 | 5414 | 13.9 | .599 |
| Tellurium | Te | 6.20 | 450 | 846 | 10 ⁻⁵ | .224 |
| Thorium | Th | 11.70 | 1845 | 3353 | 9.10 | .422 |
| Tin | Sn | 7.30 | 232 | 449 | 15.00 | .264 |
| Titanium | Ti | 4.50 | 1800 | 3272 | 2.10 | .162 |
| Tungsten | W | 19.30 | 3410 | — | 31.50 | .697 |
| Uranium | U | 18.70 | 1130 | 2066 | 2.80 | .675 |
| Vanadium | V | 5.96 | 1710 | 3110 | 6.63 | .215 |
| Zinc | Zn | 7.14 | 419 | 786 | 29.10 | .258 |
| Zirconium | Zr | 6.40 | 1700 | 3092 | 4.20 | .231 |

Specific Resistance (K)

The specific resistance (K) of a material is the resistance offered by a wire of this material that is 1 foot long with a diameter of 1 mil.

| Material | K | Material | K |
|-------------------|------|----------|------|
| Brass | 43.0 | Aluminum | 17.0 |
| Constantan | 295 | Monel | 253 |
| Copper | 10.8 | Nichrome | 600 |
| German silver 18% | 200 | Nickel | 947 |
| Gold | 14.7 | Tantalum | 93.3 |
| Iron (pure) | 60.0 | Tin | 69.0 |
| Magnesium | 276 | Tungsten | 34.0 |
| Manganin | 265 | Silver | 9.7 |

Note: 1. The resistance of a wire is directly proportional to the specific resistance of the material.

2. "K" = Specific Resistance

3. Resistance varies with temperature. See *NEC* Chapter 9, Table 8, Note 1.



CENTIGRADE AND FAHRENHEIT THERMOMETER SCALES

| °C | °F | °C | °F | °C | °F | °C | °F |
|----|------|----|-------|----|-------|-----|-------|
| 0 | 32 | | | | | | |
| 1 | 33.8 | 26 | 78.8 | 51 | 123.8 | 76 | 168.8 |
| 2 | 35.6 | 27 | 80.6 | 52 | 125.6 | 77 | 170.6 |
| 3 | 37.4 | 28 | 82.4 | 53 | 127.4 | 78 | 172.4 |
| 4 | 39.2 | 29 | 84.2 | 54 | 129.2 | 79 | 174.2 |
| 5 | 41 | 30 | 86 | 55 | 131 | 80 | 176 |
| 6 | 42.8 | 31 | 87.8 | 56 | 132.8 | 81 | 177.8 |
| 7 | 44.6 | 32 | 89.6 | 57 | 134.6 | 82 | 179.6 |
| 8 | 46.4 | 33 | 91.4 | 58 | 136.4 | 83 | 181.4 |
| 9 | 48.2 | 34 | 93.2 | 59 | 138.2 | 84 | 183.2 |
| 10 | 50 | 35 | 95 | 60 | 140 | 85 | 185 |
| 11 | 51.8 | 36 | 96.8 | 61 | 141.8 | 86 | 186.8 |
| 12 | 53.6 | 37 | 98.6 | 62 | 143.6 | 87 | 188.6 |
| 13 | 55.4 | 38 | 100.4 | 63 | 145.4 | 88 | 190.4 |
| 14 | 57.2 | 39 | 102.2 | 64 | 147.2 | 89 | 192.2 |
| 15 | 59 | 40 | 104 | 65 | 149 | 90 | 194 |
| 16 | 60.8 | 41 | 105.8 | 66 | 150.8 | 91 | 195.8 |
| 17 | 62.6 | 42 | 107.6 | 67 | 152.6 | 92 | 197.6 |
| 18 | 64.4 | 43 | 109.4 | 68 | 154.4 | 93 | 199.4 |
| 19 | 66.2 | 44 | 111.2 | 69 | 156.2 | 94 | 201.2 |
| 20 | 68 | 45 | 113 | 70 | 158 | 95 | 203 |
| 21 | 69.8 | 46 | 114.8 | 71 | 159.8 | 96 | 204.8 |
| 22 | 71.6 | 47 | 116.6 | 72 | 161.6 | 97 | 206.6 |
| 23 | 73.4 | 48 | 118.4 | 73 | 163.4 | 98 | 208.4 |
| 24 | 75.2 | 49 | 120.2 | 74 | 165.2 | 99 | 210.2 |
| 25 | 77 | 50 | 122 | 75 | 167 | 100 | 212 |

1. Temp. °C = $\frac{5}{9} \times (\text{Temp. } ^\circ\text{F} - 32)$

2. Temp. °F = $(\frac{9}{5} \times \text{Temp. } ^\circ\text{C}) + 32$

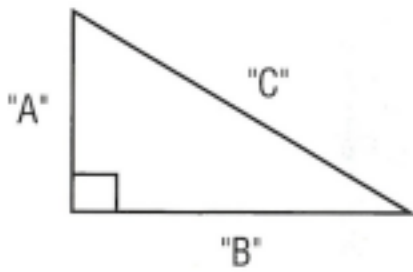
3. Ambient temperature is the temperature of the surrounding cooling medium.

4. Rated temperature rise is the permissible rise in temperature above ambient when operating under load.



USEFUL MATH FORMULAS

Right triangle



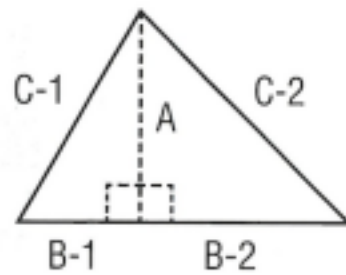
$$A = \sqrt{C^2 - B^2}$$

$$B = \sqrt{C^2 - A^2}$$

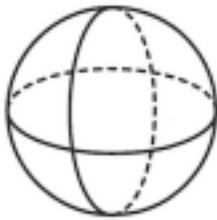
$$C = \sqrt{A^2 + B^2}$$

$$\text{Area} = 0.5 \times (A \times B)$$

Oblique triangle



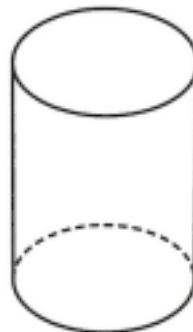
Solve as two right triangles



Sphere

$$\text{Surface Area} = D^2 \times 3.1416$$

$$\text{Volume} = D^3 \times 0.5236$$



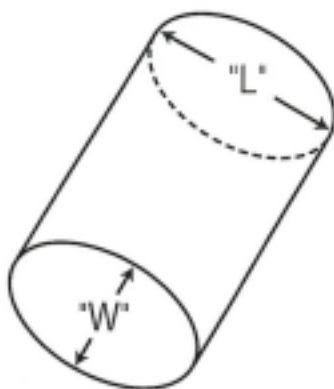
Cylindrical

$$\text{Volume} = \text{Area of end} \times \text{height}$$



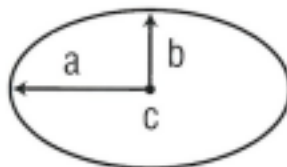
Cone

$$\text{Volume} = \text{Area of end} \times \text{height} \div 3$$



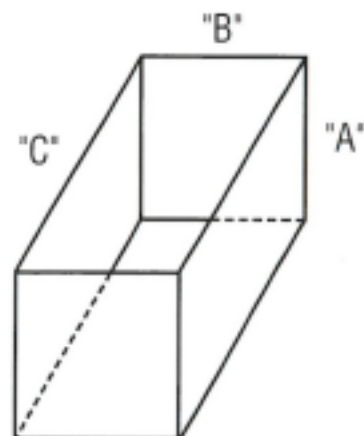
Elliptical

Solve the same as cylindrical



Ellipse

$$\text{Area} = a \times b \times 3.1416 \text{ (assuming } c \text{ is center)}$$



Rectangular prism

$$\text{Volume} = A \times B \times C$$
$$\text{Area} = 2(AB + AC + BC)$$

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 = $3.1416 \times 2 \times \text{radius}$

Area of a Circle = $3.1416 \times \text{radius}^2$

ARC Length = Degrees in arc \times radius \times 0.01745

Radius Length = One-half length of diameter

Sector Area = One-half length of arc \times radius

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

Segment Area = Sector area minus triangle area

Note:

$3.1416 \times 2 \times R = 360^\circ$,
or $0.0087266 \times 2 \times R = 1^\circ$, or
 $0.01745 \times R = 1^\circ$

This gives us the arc formula.

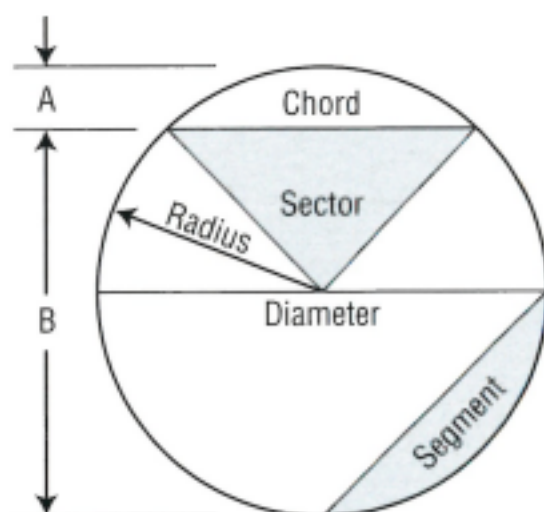
Degrees \times Radius \times 0.01745 =
Developed Length

Example:

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

$90 \times 17.25 \times 0.01745 =$
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:**

$$(1.) \quad \frac{1}{2} \begin{array}{l} \xrightarrow{\text{Numerator}} \\ \xrightarrow{\text{Denominator}} \end{array} = \frac{\text{Numerator}}{\text{Denominator}} = \text{Fraction}$$

$$(2.) \quad \text{Numerator} \xrightarrow{\quad} \frac{1}{2} \xleftarrow{\quad} \text{Denominator}$$

To Add or Subtract

To solve: $\frac{1}{2} - \frac{2}{3} + \frac{3}{4} - \frac{5}{6} + \frac{7}{12} = ?$

- 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:

| <u>Common Denominator</u> Denominator of Fraction | x | Numerator of Fraction |
|--|---|-----------------------|
| (1.) $12/2 \times 1 = 6 \times 1 = 6$ | | $1/2$ becomes $6/12$ |
| (2.) $12/3 \times 2 = 4 \times 2 = 8$ | | $2/3$ becomes $8/12$ |
| (3.) $12/4 \times 3 = 3 \times 3 = 9$ | | $3/4$ becomes $9/12$ |
| (4.) $12/6 \times 5 = 2 \times 5 = 10$ | | $5/6$ 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.

$$\frac{1}{2} - \frac{2}{3} + \frac{3}{4} - \frac{5}{6} + \frac{7}{12} = \text{Original form}$$

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

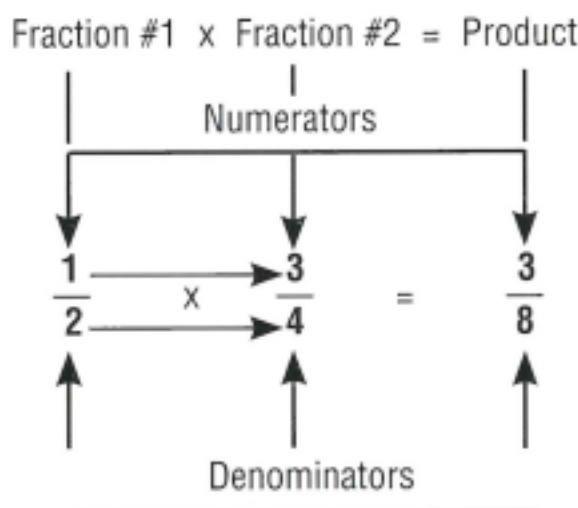
$$\frac{4}{12} = \frac{1}{3} \quad \text{Reduced to lowest form}$$

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

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

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:**



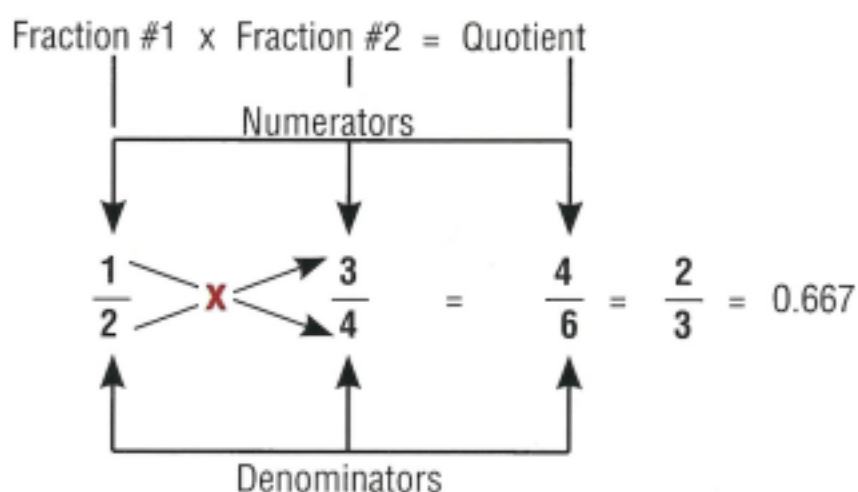
Note: To change $\frac{3}{8}$ to decimal form, divide 3 by 8 = 0.375



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 $\frac{4}{3}$

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



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:

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

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:

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

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:

$$\begin{aligned} (+3) \times (-2) &= -6 \\ (-3) \times (+2) &= -6 \\ (+3) \times (+2) &= +6 \\ (-3) \times (-2) &= +6 \end{aligned}$$

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:

$$\begin{aligned} \frac{+6}{-2} &= -3 & \frac{+6}{+2} &= +3 \\ \frac{-6}{+2} &= -3 & \frac{-6}{-2} &= +3 \end{aligned}$$



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° .

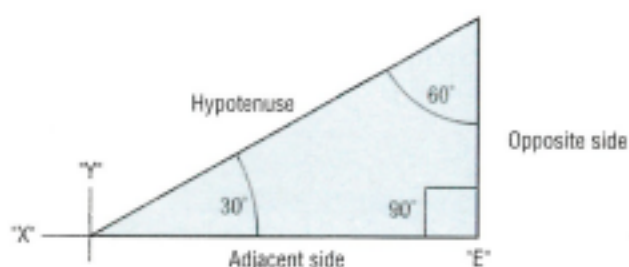
To help you remember the six trigonometric functions, memorize:

“Oh Hell Another Hour of Andy”

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

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

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



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

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

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

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

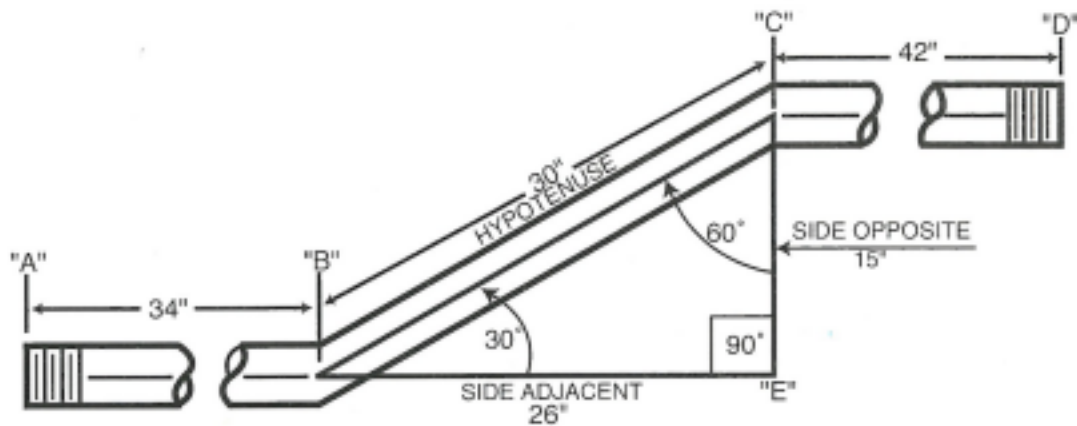
Always place the angle to be solved at the vertex (where “X” and “Y” cross).

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".

$$(40 \times 6")/60 = 4"$$

"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

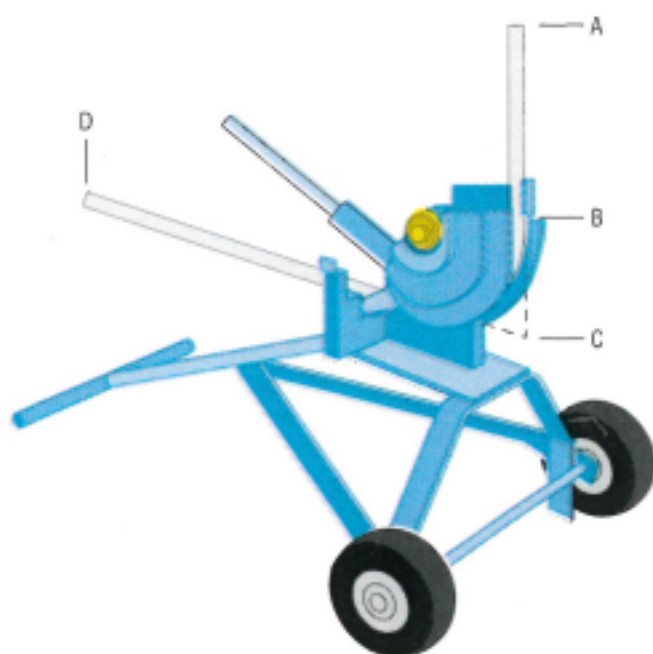
"C" = Bottom of Conduit

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."

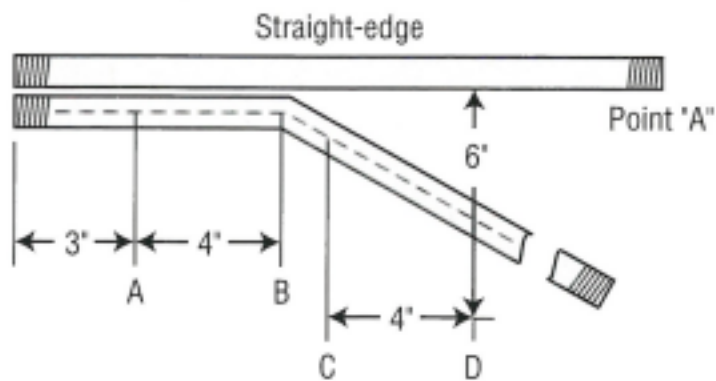


3. Place conduit in bender. Mark at edge of shoe, "B."
4. Level conduit. Bend ninety, and count number of pumps. Be sure to keep notes on each size conduit used.
5. After bending ninety:
 - A. Distance between "B" and "C" is the take-up.
 - B. Original measurement of the scrap piece of conduit subtracted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

$$\text{Radius of Conduit \#1} = 8 \times 2" + 1.25" = 17.25"$$

$$\text{Radius of Conduit \#2} = \text{RADIUS \#1} + 6" = 23.25"$$

$$\text{Radius of Conduit \#3} = \text{RADIUS \#2} + 6" = 29.25"$$

- B. To Determine Developed Length (DL):

$$\text{Radius} \times 1.57 = \text{DL}$$

$$\text{DL of Conduit \#1} = R \times 1.57 = 17.25" \times 1.57 = 27"$$

$$\text{DL of Conduit \#2} = R \times 1.57 = 23.25" \times 1.57 = 36.5"$$

$$\text{DL of Conduit \#3} = R \times 1.57 = 29.25" \times 1.57 = 46"$$

- C. To Determine Length of Nipple:

$$\begin{aligned} \text{Length of Nipple, Conduit \#1} &= L + H + \text{DL} - 2R \\ &= 48" + 36" + 27" - 34.5" \\ &= 76.5" \end{aligned}$$

$$\begin{aligned} \text{Length of Nipple, Conduit \#2} &= L + H + \text{DL} - 2R \\ &= 54" + 42" + 36.5" - 46.5" \\ &= 86" \end{aligned}$$

$$\begin{aligned} \text{Length of Nipple, Conduit \#3} &= L + H + \text{DL} - 2R \\ &= 60" + 48" + 46" - 58.5" \\ &= 95.5" \end{aligned}$$

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



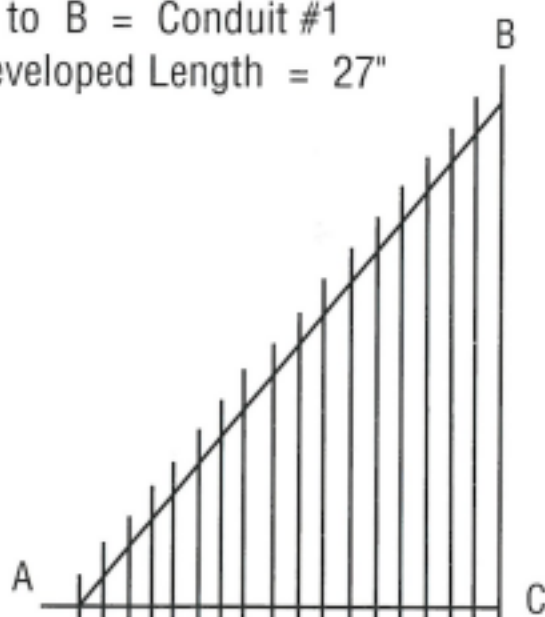
MULTI-SHOT: 90° CONDUIT BENDING

Layout and Bending:

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

A to B = Conduit #1

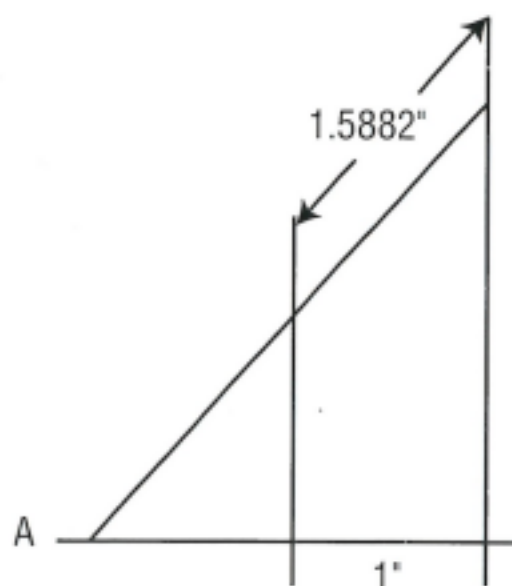
Developed Length = 27"



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.



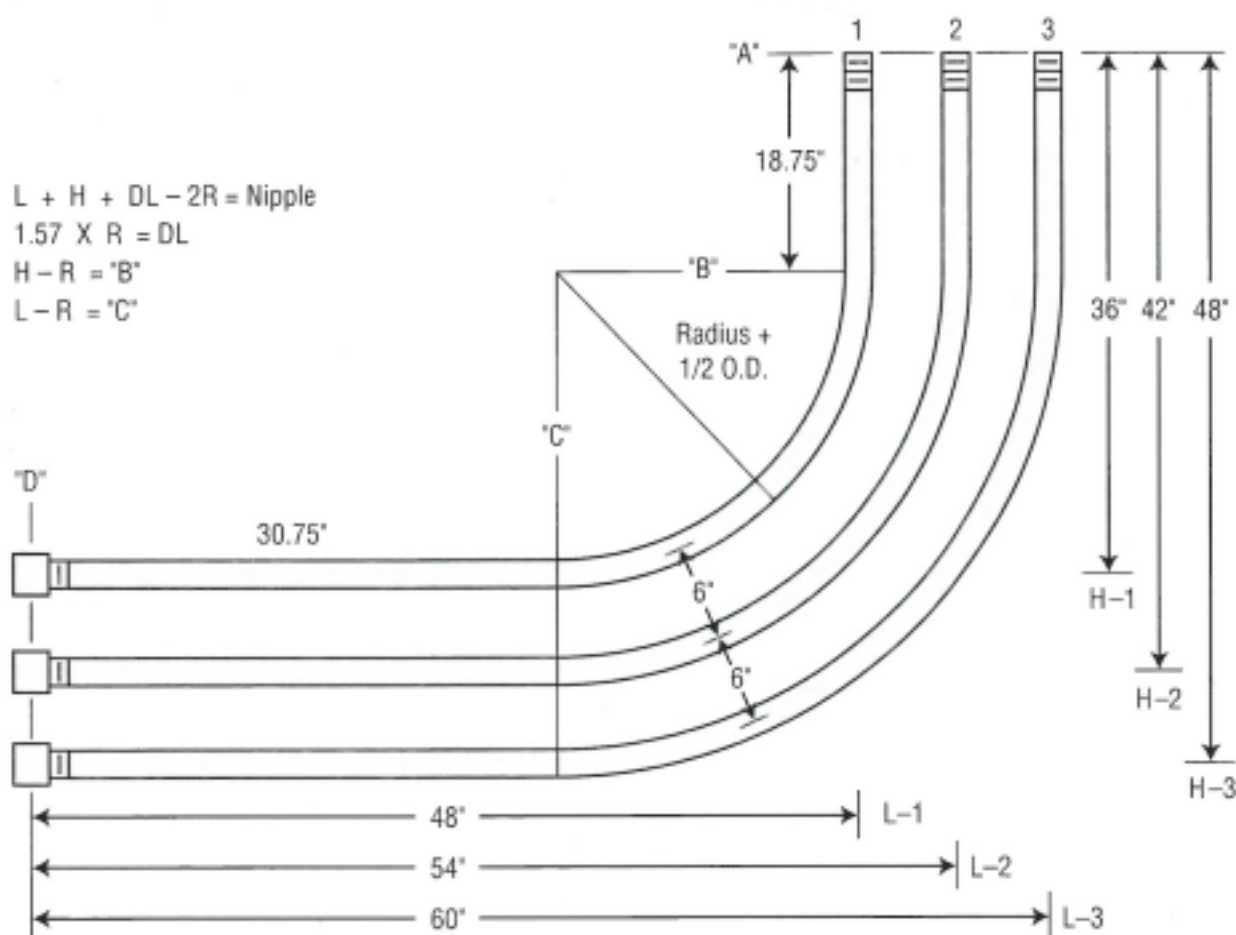
MULTI-SHOT: 90° CONDUIT BENDING

$$L + H + DL - 2R = \text{Nipple}$$

$$1.57 \times R = DL$$

$$H - R = "B"$$

$$L - R = "C"$$



| 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).

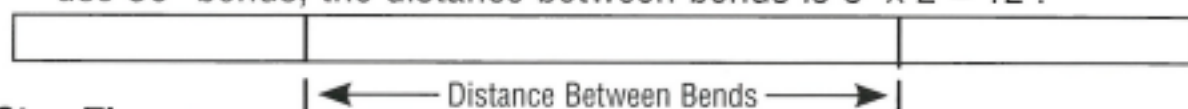


Step Two:

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

| Angle | Multiplier |
|--|------------|
| $10^{\circ} \times 10^{\circ}$ | = 6 |
| $22\frac{1}{2}^{\circ} \times 22\frac{1}{2}^{\circ}$ | = 2.6 |
| $30^{\circ} \times 30^{\circ}$ | = 2 |
| $45^{\circ} \times 45^{\circ}$ | = 1.4 |
| $60^{\circ} \times 60^{\circ}$ | = 1.2 |

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

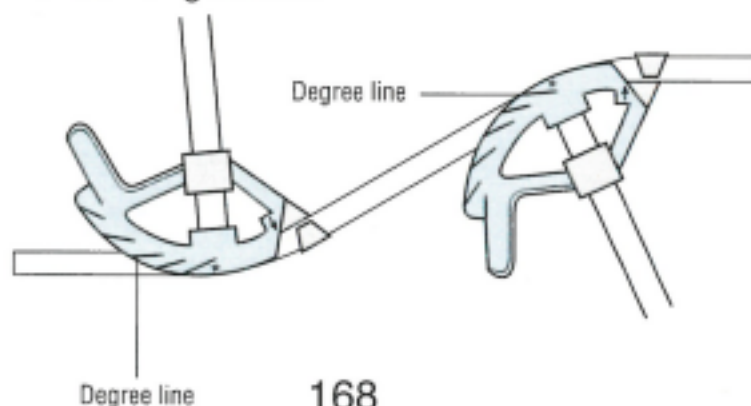


Step Three:

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.

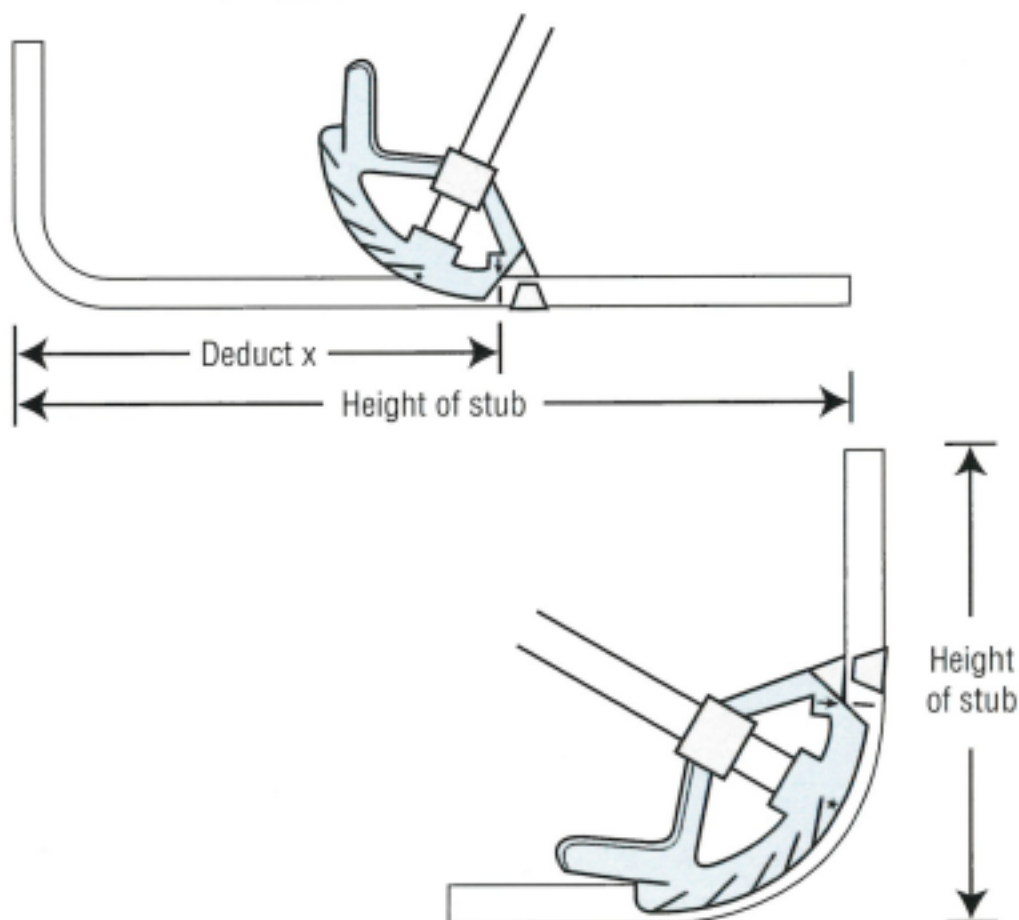
Step Two:

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

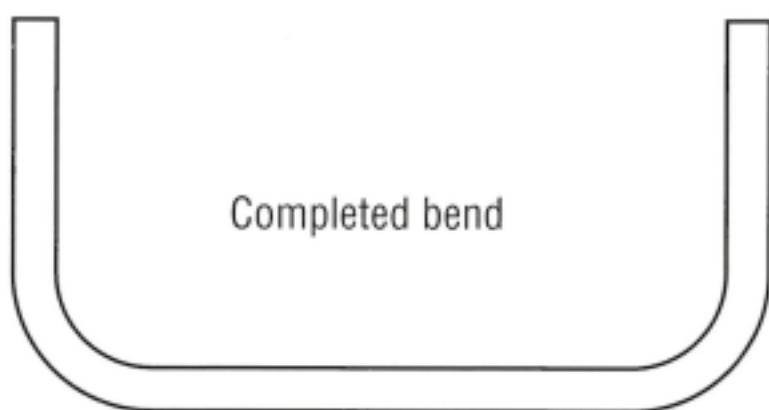
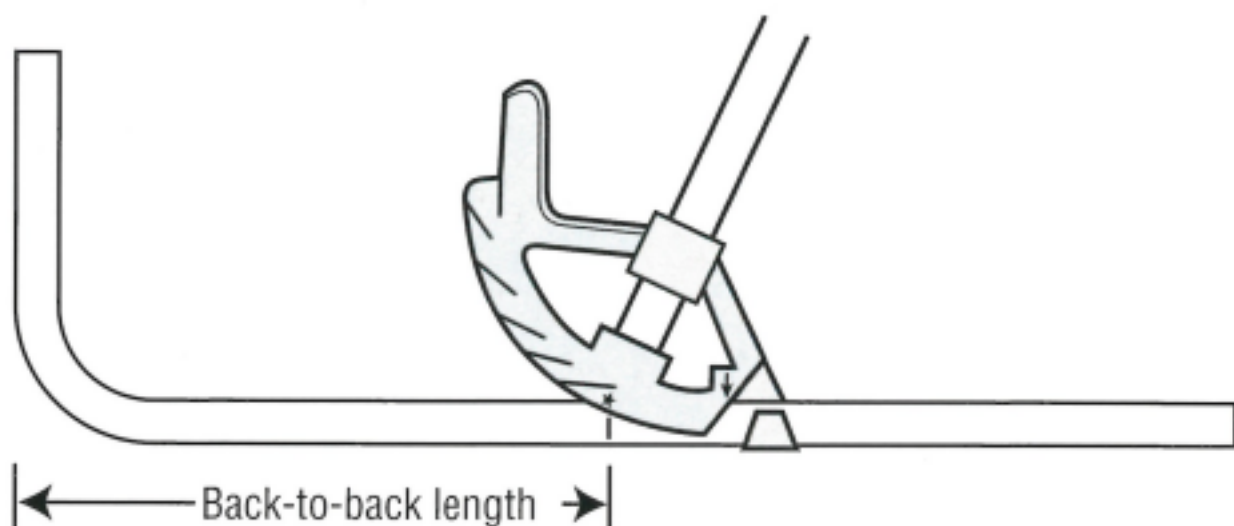
A back-to-back bend results in a “U” shape in a length of conduit. It’s used for a conduit that runs along the floor or ceiling and turns up or down a wall.

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°.





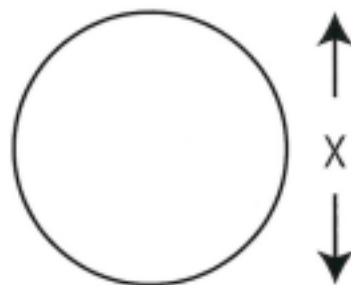
THREE-POINT SADDLE BENDS

EMT: Using Hand Bender

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

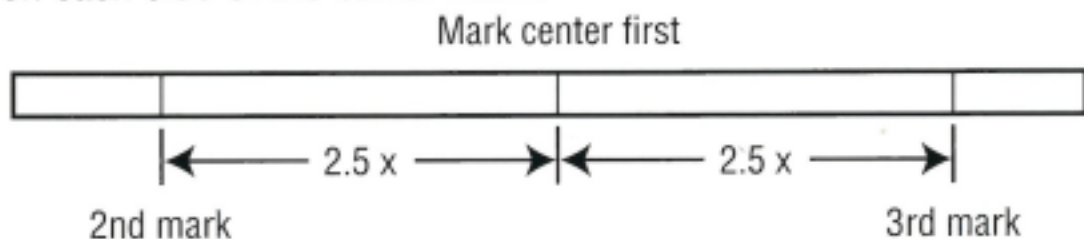
Step One:

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:

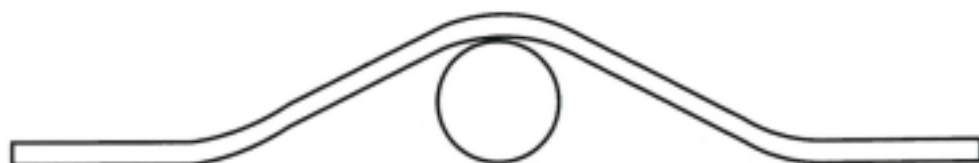
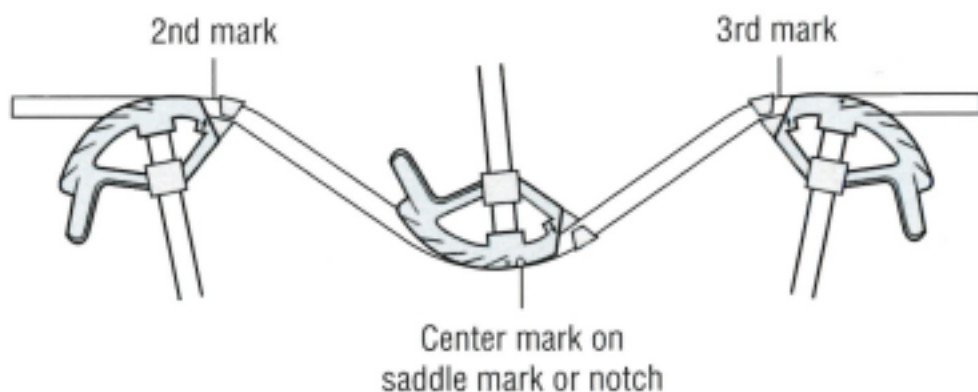
Place the center mark on the saddle mark or notch. Bend to 45° .

Step Four:

Bend the second mark to $22\frac{1}{2}^\circ$ angle at arrow.

Step Five:

Bend the third mark to $22\frac{1}{2}^\circ$ angle at arrow. Be aware of the orientation of the EMT on all bends. Check alignment.





PULLEY CALCULATIONS

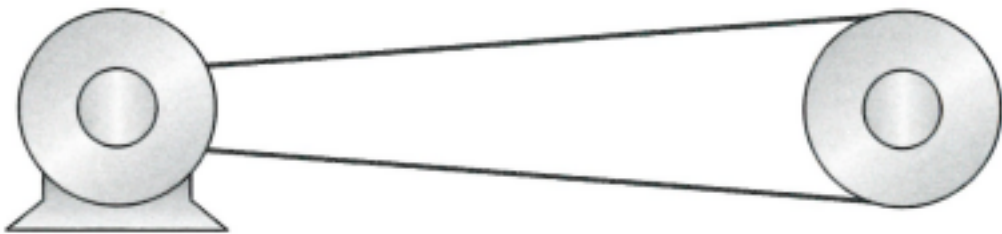
The most common configuration consists of a motor with a pulley attached to its shaft, connected by a belt to a second pulley. The motor pulley is referred to as the **Driving Pulley**. The second pulley is called the **Driven Pulley**. The speed at which the Driven Pulley turns is determined by the 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

d¹ = Diameter of Driven Pulley

S = Speed of Driving Pulley (revolutions per minute)

s¹ = Speed of Driven Pulley (revolutions per minute)



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

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

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

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

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

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

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

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



USEFUL KNOTS



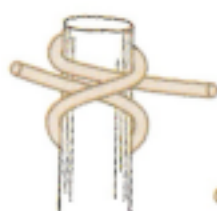
Bowline



Running bowline



Bowline on the bight



Clove hitch



Sheep shank



Rolling hitch



Single
blackwall hitch



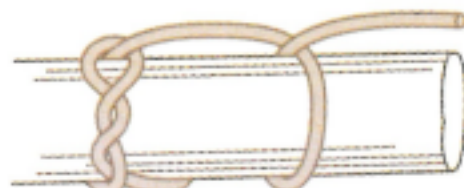
Catspaw



Double
blackwall hitch



Square knot



Timber hitch
with half hitch



Single
sheet bend



HAND SIGNALS



Stop



Stop
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/cm²).

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" 3.7 | Arc Flash Boundary 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.

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

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

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 | <p>Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm² (16.75 J/cm²)^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</p> <p>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)</p> |
| 2 | <p>Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² (33.5 J/cm²)^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</p> <p>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</p> |
| 3 | <p>Arc-Rated Clothing Selected So That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm² (104.7 J/cm²)^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</p> <p>Protective Equipment Hard hat Safety glasses or safety goggles (SR) Hearing protection (ear canal inserts)^c Leather footwear^e</p> |

(continued on next page)



ELECTRICAL SAFETY: PERSONAL PROTECTION EQUIPMENT GUIDE

| PPE Category | PPE |
|--------------|---|
| 4 | <p>Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm² (167.5 J/cm²)^a</p> <ul style="list-style-type: none"> 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 <p>Protective Equipment</p> <ul style="list-style-type: none"> 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.

^aArc rating is defined in Article 100 of NFPA 70E.

^bFace 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.

^cOther 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.

^dRubber 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.

^eFootwear 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.

^fThe 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.

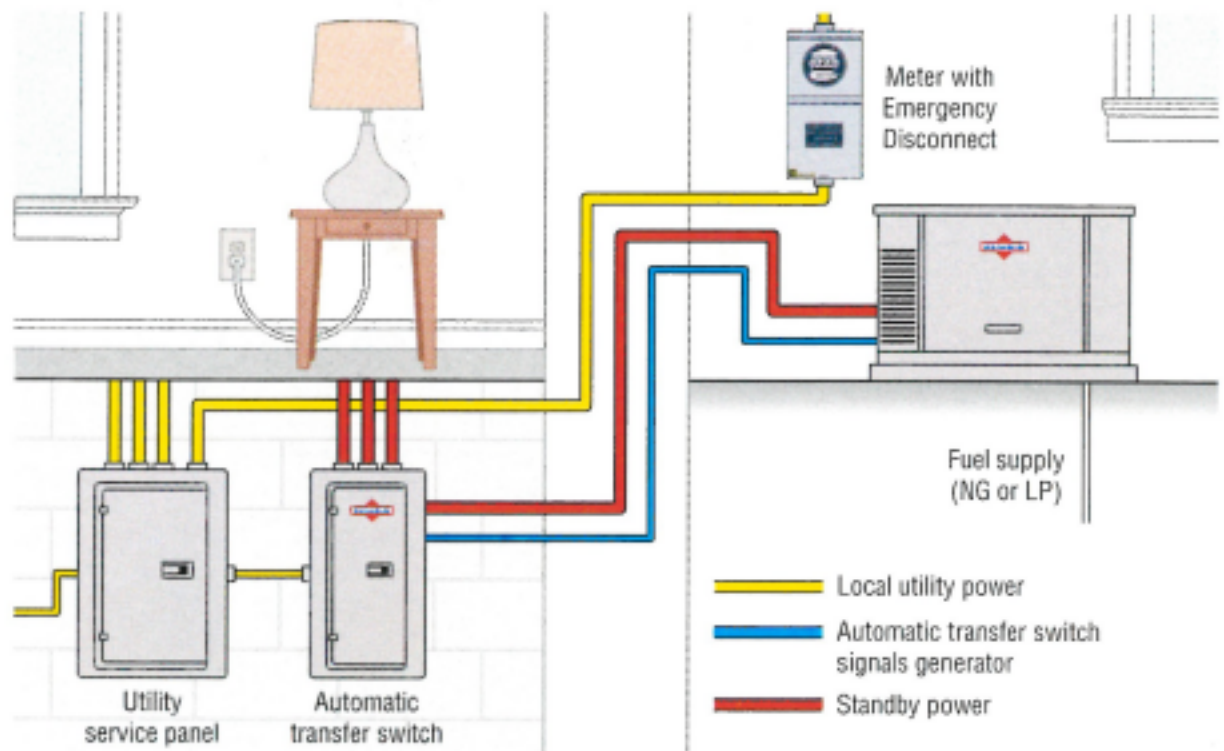
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ALTERNATIVE ENERGY

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

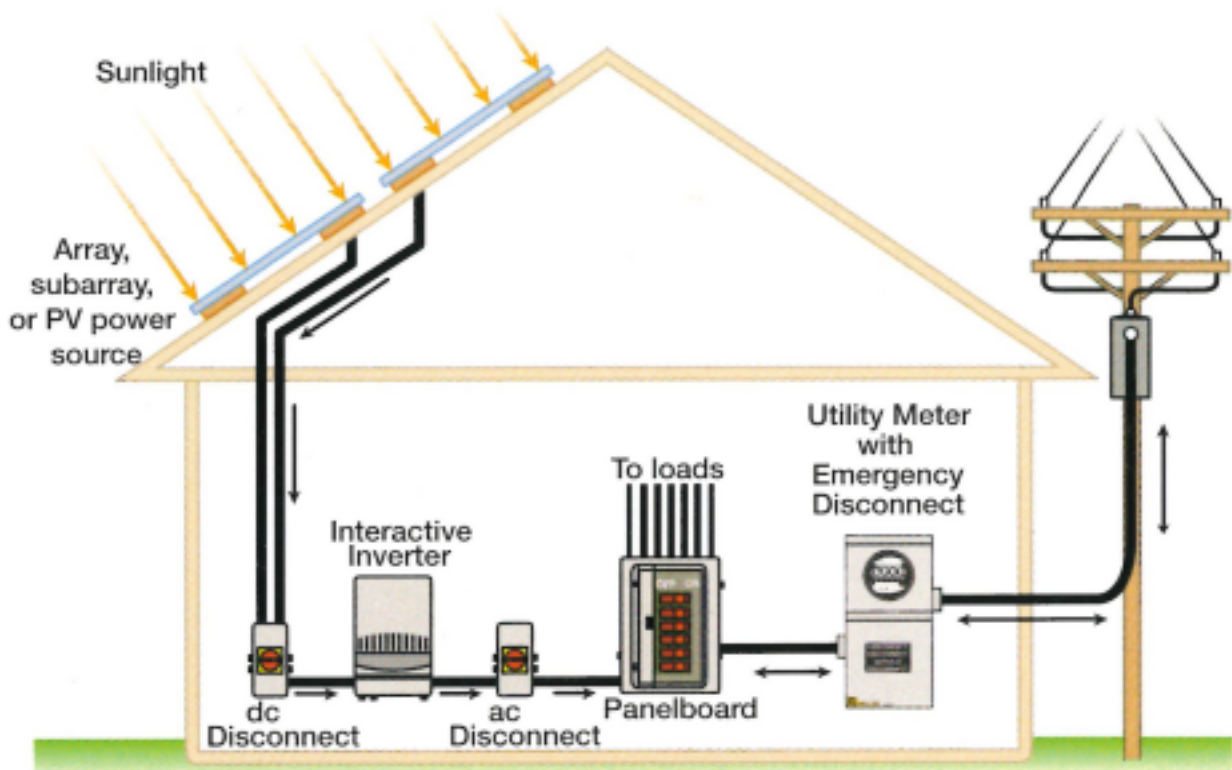


Engine-generation is the most common type of distributed generation system currently available and can be used almost anywhere. Engine-generators have the following:

- 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.

ALTERNATIVE ENERGY

Solar Photovoltaic Systems

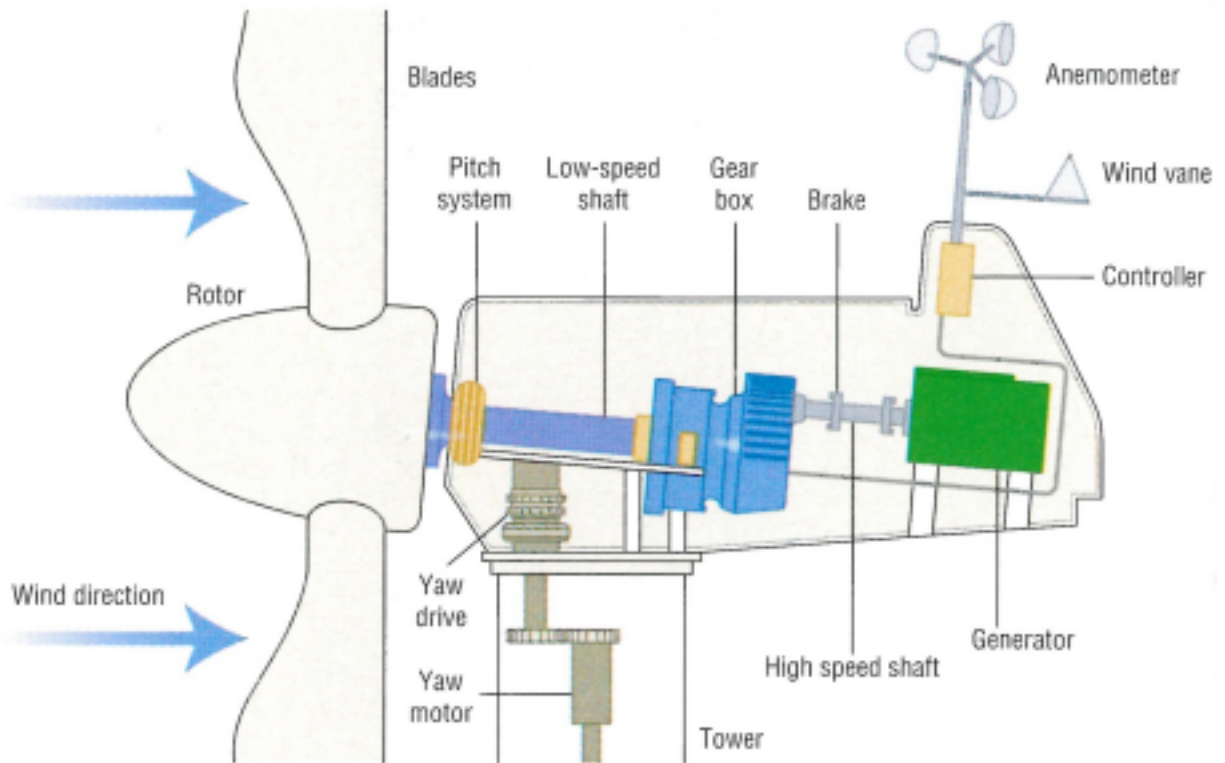


Solar photovoltaic power converts sunlight to dc electrical energy. Solar is limited because of its requirement of sunlight.

- 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.

ALTERNATIVE ENERGY

Wind Turbines

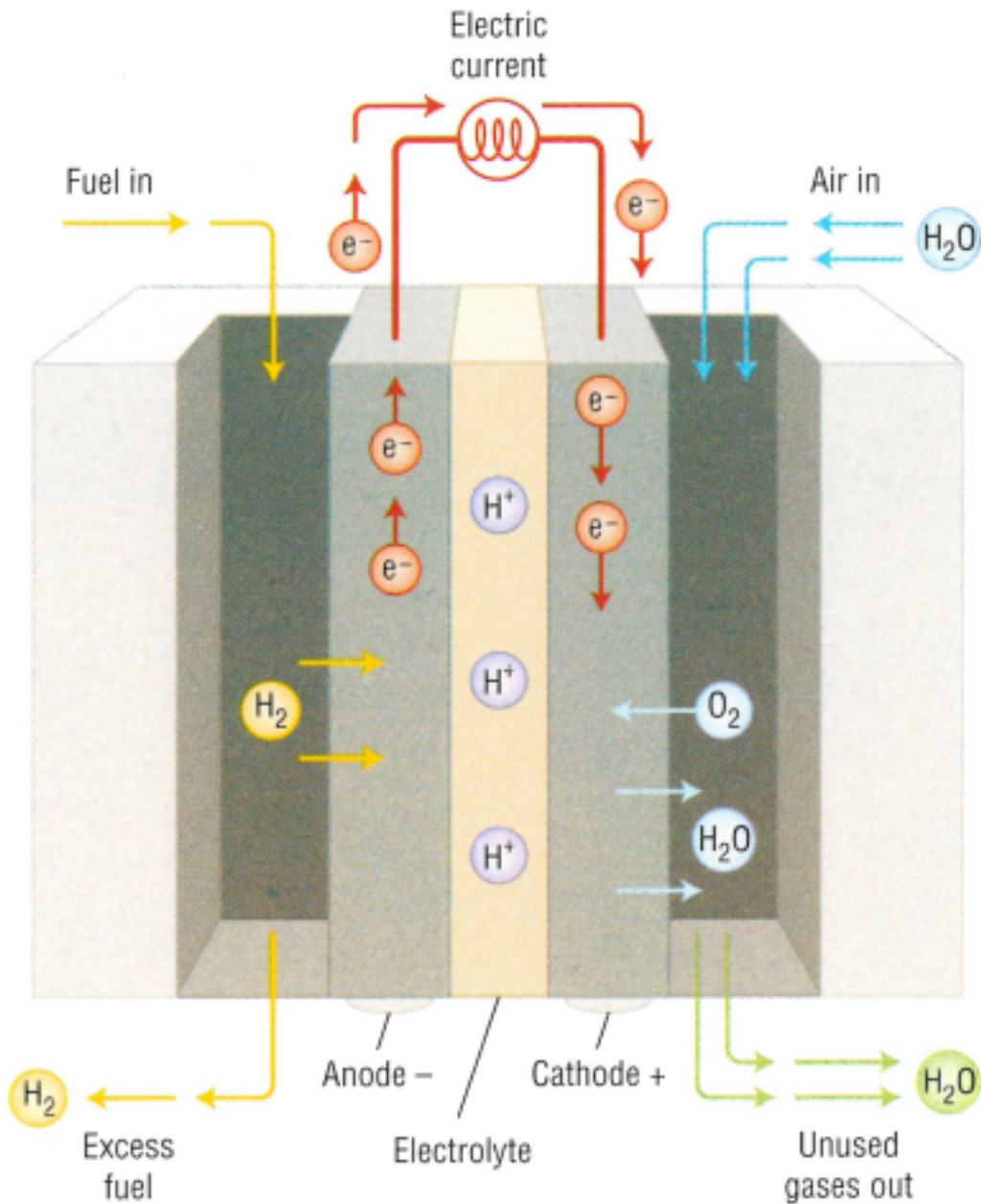


Wind power converts wind to either ac or dc electrical energy. Wind is limited because it needs to be in an area of steady reliable wind.

- 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.

ALTERNATIVE ENERGY

Fuel Cells



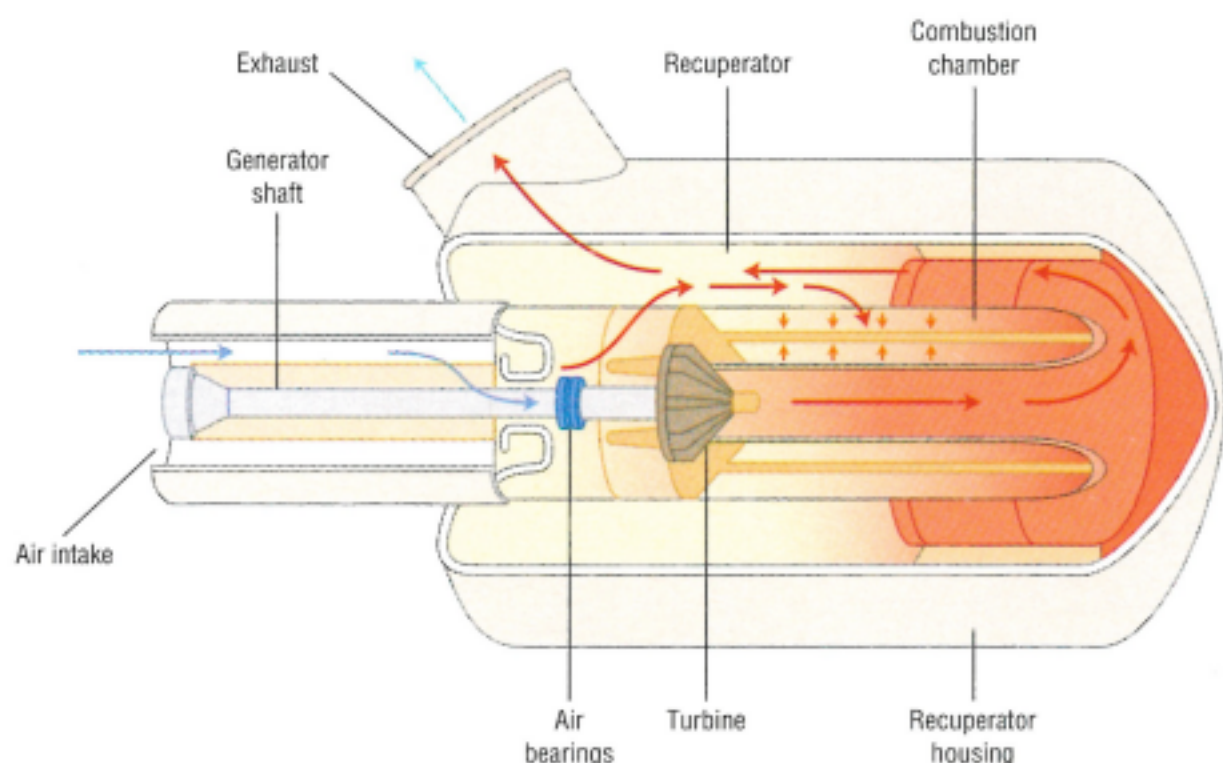
Fuel cells use an electrochemical reactor to generate dc electrical energy. Fuel cells are basically batteries that use hydrogen and oxygen as fuel instead of storing electrical energy.

- 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.

ALTERNATIVE ENERGY

- 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.

ALTERNATIVE ENERGY

- 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.

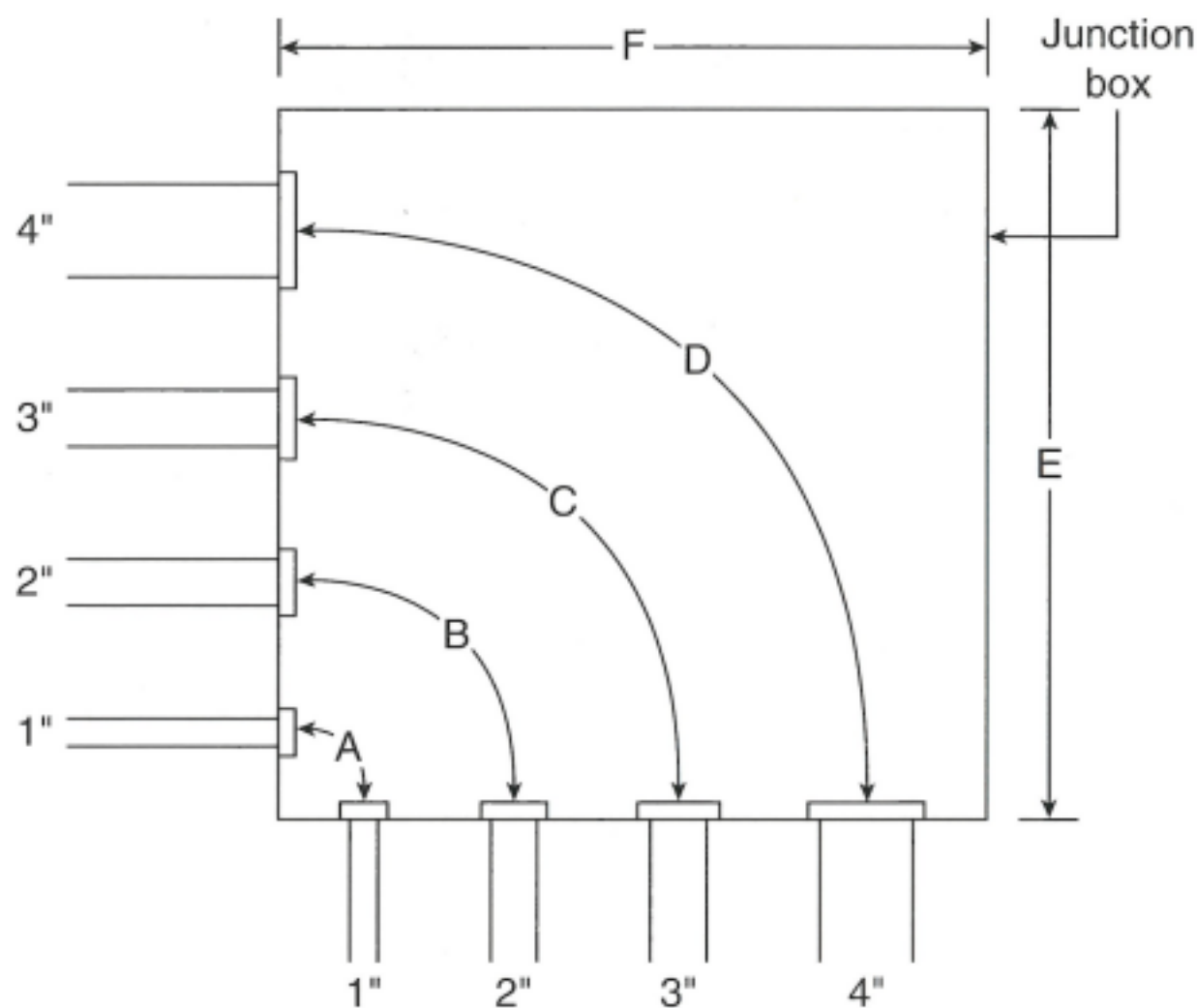
Interconnected Generation Systems

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.

$6 \times 4 + 3 + 2 + 1 = 30$ " minimum

F—In this case, same as E.



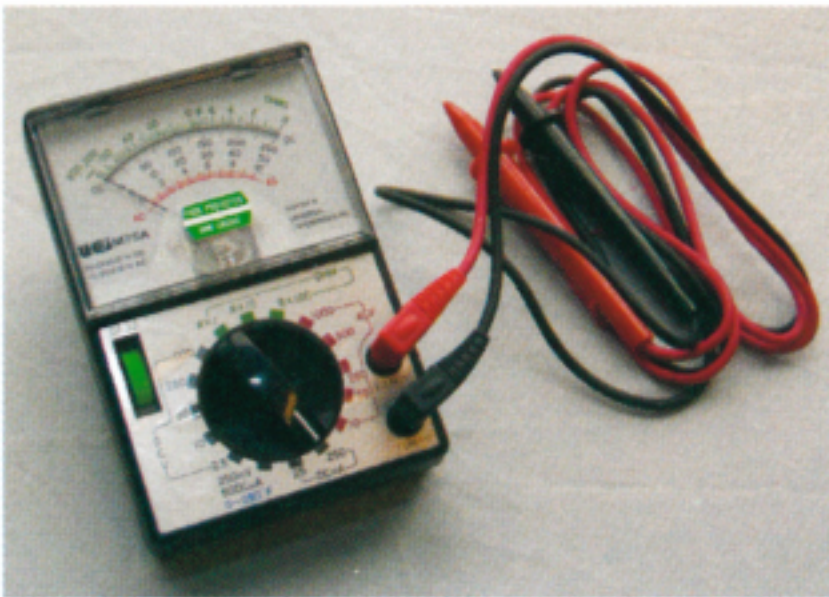
SELECTING AND USING TEST INSTRUMENTS

Single Instrument

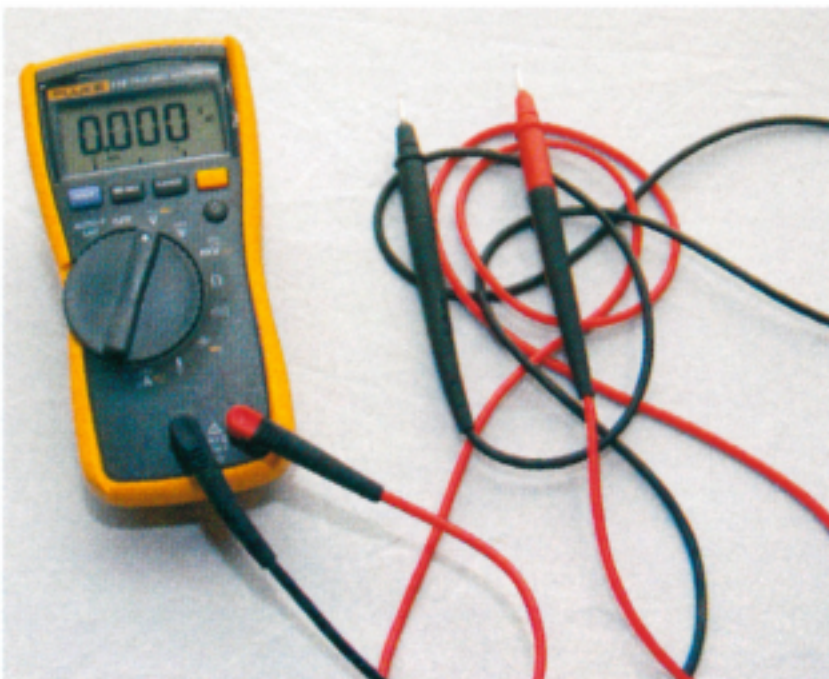
A multimeter combines the voltmeter, ohmmeter, and milliammeter into a single instrument. In the field, this one instrument can be used to measure (alternating current) ac and (direct current) dc voltages, ac and dc current flow, and electrical resistance.

Although analog multimeters have long been available, most multimeters used today are digital multimeters (DMMs).

Analog:



Digital:





SELECTING AND USING TEST INSTRUMENTS

Instrument Safety Categories

Overvoltage Categories for Test Instruments

| Overvoltage Category | In Brief | Examples |
|----------------------|--|--|
| CAT IV | Three-phase at utility connection, any outdoor conductors | <ul style="list-style-type: none">• Refers to the “origin of installation”: i.e., where low-voltage connection is made to utility power• Electricity meters, primary overcurrent protection equipment• Outside and service entrance, service drop from pole to building, run between meter and panel• Overhead line to detached building, underground line to well pump |
| CAT III | Three-phase distribution, including single-phase commercial lighting | <ul style="list-style-type: none">• Equipment in fixed installation, such as switchgear and polyphase motor• Bus and feeder in industrial plants• Feeders and short branch circuits, distribution panel devices• Lighting system in larger buildings• Appliance outlets with short connection to service entrance |



SELECTING AND USING TEST INSTRUMENTS

| Overvoltage Category | In Brief | Examples |
|----------------------|---|---|
| CAT II | Single-phase receptacle connected loads | <ul style="list-style-type: none">• Appliance, portable tool, and other household and similar loads• Outlet and long branch circuits• Outlets at more than 10 meters (30 ft) from CAT III source• Outlets at more than 20 meters (60 ft) from CAT IV source |
| CAT I | Electronic | <ul style="list-style-type: none">• Protected electronic equipment• Equipment connected to (Source) circuits in which measures are taken to limit transient overvoltages to an appropriately low level• Any high-voltage, low-energy source derived from a highwinding resistance transformer, such as the high-voltage section of a copier |



SELECTING AND USING TEST INSTRUMENTS

Selecting an Appropriate Multimeter

- Choose a meter that is properly rated for the circuit or component to be tested.
- Ensure that both the meter and the leads have the correct category rating for each task.
- Check that the ratings of the leads or accessories meet or exceed the rating of the multimeter.
- Ensure that the meter case is not wet, oily, or cracked; that the input jacks are not broken; and that there are no other obvious signs of damage.
- Check the test leads carefully. Ensure that the insulation is not cut, cracked, or melted and that the tips are not loose.

Testing a Multimeter

To measure continuity:

- Set the multimeter to the lowest setting for resistance.
- Touch the tips of the two probes together.
- The display should show 0 ohms (Ω). A DMM will typically display OL (overload or out of limits) when a circuit is open (lacks continuity).
- If OL is displayed during this test, either the meter is defective or the test leads are defective.

To check a meter's ability to measure resistance:

- Use a resistor with a known value.
- Set the multimeter to measure resistance.
- Place one probe at each end of the resistor.



SELECTING AND USING TEST INSTRUMENTS

- The value in the display should be very close to the known value of the resistor being used for the test.
- If the multimeter does not measure the resistance correctly, double-check it by repeating the test with a different resistor of a known value.

To check the dc voltage function:

- Use a new battery.
- Set the multimeter to measure dc voltage.
- Place the red probe on the positive terminal of the battery and the black probe on the negative terminal.
- The multimeter should display a reading of, or close to, the battery's labeled voltage.
- Reversing the leads on a digital meter will display a negative (–) reading.

To check the ac-voltage function:

- Use a 120 volts ac receptacle known to be energized.
- Plug in and turn on a lamp or another simple device to ensure that the receptacle is energized. Set the multimeter to measure ac voltage.
- Place the red probe into the energized side—the smaller slot of the receptacle—and the black probe into the other side (neutral).
- The multimeter should display a reading of, or close to, 120 volts ac.

If the multimeter fails any one of these tests, it is best to return it to the manufacturer for service. Technicians should never attempt to open and repair the meter's electronics or movement. If the multimeter will not perform any functions or provide a display when tested, the problem may be weak or dead batteries. DMMs have a battery indicator that will display when the battery is weak but still functional. Always replace



SELECTING AND USING TEST INSTRUMENTS

the battery as soon as the indication is displayed to ensure continued reliable operation.

If the batteries are not the problem, determine if there is an accessible fuse inside the battery compartment. If there is, check to see whether it is open; another meter may be needed to check the continuity of the fuse if its condition cannot be determined visually. Replace an open fuse with one of the proper current and voltage rating. Using the wrong fuse, especially one that has a higher current rating than it should, can result in the meter being damaged beyond repair.

Return a multimeter to the manufacturer for an annual calibration to ensure its accuracy.

Common Testing Errors

Try to avoid the following common errors when using a multimeter to measure voltage:

- Measuring voltage while the red test lead is in the wrong jack. The test-lead jack for the red lead is usually marked with the V symbol and is often marked with the Ω symbol. Applying voltage to the meter while the red lead is plugged into the wrong jack may damage the meter.
- Measuring ac voltage on a dc setting. The dial symbol usually associated with measuring ac voltage is a V with a wavy line above it, or an mV with the same wavy line above. The latter is for measuring in the millivolt range.
- Keeping the test probe in contact with an energized surface longer than necessary. The longer it is in contact, the more time there is for an accident to occur.
- Using the meter above its rated voltage. Technicians should have a general idea of the expected voltage or current to be measured and ensure that the meter is capable of safely making such readings.



SELECTING AND USING TEST INSTRUMENTS

Using a Multimeter to Measure Voltage

Take all available and necessary precautions to avoid contact with energized surfaces, and ensure that the probe of the test lead does not accidentally bridge two points with different electrical potentials. Use test leads with finger guards, and always keep fingers behind them.

- Select an appropriate multimeter for the job.
- Visually inspect it and the test leads for any signs of damage. Before using the multimeter on the job, always test it on a known voltage source to verify that it is functioning properly.
- Insert the black test lead into the common input jack (COM) and the red test lead into the input jack for ac volts (V or V Ω). Take care to insert the test leads into the correct jacks.
- Select ac as the type of voltage to be measured. If the meter has no auto-ranging feature, select the voltage range.
- Place the red probe onto the energized side of the circuit.
- Place the black probe onto the neutral side of the circuit or to ground.
- Read the voltage displayed on the meter while both probes make good electrical contact with their individual targets.

Using a Multimeter to Measure Resistance

- The ohmmeter function can be used to determine whether a circuit has continuity or to determine a specific resistance value.
- Select an appropriate multimeter for the job. Visually inspect it and the test leads for any signs of damage.
- Test the multimeter to verify that it is functioning properly and can measure continuity and resistance. A small resistor of a known value can be used to verify meter operation.



SELECTING AND USING TEST INSTRUMENTS

- Insert the black test lead into the common input jack (COM) and the red test lead into the input jack for $V\Omega$ or Ω . If the meter has no auto-ranging feature, select the voltage range, starting with the highest.
- Set the meter to measure resistance (Ω).
- Ensure the circuit is deenergized.
- Touch the test leads to the two points in the circuit across the resistance.
- Read and record the resistance value displayed on the meter.

Using a Multimeter to Measure Current

A technician will frequently use a meter to measure ac. In some cases, ac values that are in the milliamp, or even the microamp (μA), range may need to be measured.

Most multimeters can measure these small current values by placing the meter in series with the circuit and then energizing the circuit to read the current flow.

Multimeters typically have a maximum current limit of 10 A when using this method of measurement. Do not exceed the maximum current limit of the meter.

Remember that exceeding the current limit with the meter in series with the load can result in significant damage to the meter.

To measure current values that exceed the meter's limit, use either a clamp-on ammeter or a clamp-on ammeter accessory designed for the multimeter in use.

Selecting a Clamp-On Ammeter

Many clamp-on ammeters are designed to provide most or all the functions of a DMM, with the added convenience of a built-in ammeter that can measure a significant amount of current. Therefore, they may



SELECTING AND USING TEST INSTRUMENTS

be used to measure voltage, resistance, and current like any DMM. A major distinguishing feature of a clamp-on ammeter is that it has a current transformer built into the jaws that can be opened and closed around a conductor. Closing the jaws around a conductor enables the current flow to be measured without having to handle the conductor or disrupt the operation of the component or system being tested. Through induction, a small current is induced in the jaws by the current in the conductor.

Typical clamp-on ammeter features and functions include, but are not limited to, the following:

- A selector switch for selecting the desired test function (voltage, current, or resistance)
- An auto-ranging feature to automatically select the proper measurement range
- A HOLD function to freeze the reading shown on the display
- A minimum/maximum memory function to determine the highest and lowest reading over the course of a test. (The maximum function is valuable for measuring the inrush current when a motor starts.)
- A capacitor-testing feature that measures capacitance and checks for shorts and opens
- A continuity beeper that is activated when continuity through a circuit is detected. (The beeper is an advantage for troubleshooting, particularly in tight spaces, because attention can remain focused on the meter leads—listening for the beeper instead of diverting attention from the leads to check the readings.)
- Overload protection to prevent damage to the meter and to protect the user

Always read and follow the manufacturer's instructions for the meter to make the best use of its features.



SELECTING AND USING TEST INSTRUMENTS

Carefully review an ammeter's specifications, features, and functions. Be sure that it has overload protection to protect the meter and the user. Choose an ammeter that can provide the degree of accuracy required. Ensure the ammeter is properly rated for the expected current. Inductive loads, such as electric motors, experience a significant inrush of current when they start. This surge occurs when a motor is first energized and must be brought up to speed from a complete stop. Although the surge may last less than one second, the current can be many times higher than the current shown on the motor data plate, especially if the motor has mechanical or electrical defects. Remember to consider the possible inrush current when selecting an ammeter and the range. The range can be changed, if needed, to a more appropriate level while the ammeter is actively measuring current. Meters with an auto-ranging feature eliminate this concern. Ensure that the ammeter has the correct category rating for each task. Also, be sure that the ratings of the leads or other accessories meet or exceed the rating of the ammeter. When making a current measurement, ensure that the clamp is firmly and completely closed to get an accurate reading.





SELECTING AND USING TEST INSTRUMENTS

Testing a Clamp-On Ammeter

- Verify that the clamp-on ammeter is working properly before using it. The procedures for testing a clamp-on ammeter are the same as those used to test the functions of a multimeter.
- Always inspect a clamp-on ammeter before using it. Ensure that the case is not cracked or greasy and that there are no obvious signs of damage. Be sure that the jaw tips are not dirty and that they meet and interlock properly. Proper jaw alignment at the tips is essential for an accurate measurement. If the jaws are dirty or misaligned, the meter will not read correctly.
- Test a clamp-on ammeter to verify that it can measure continuity/resistance and voltage. Do not use the meter if it fails any one of the tests. If the ammeter is not performing any functions at all when it is tested, check for a blown fuse and/or replace the battery.

Using a Clamp-On Ammeter to Measure Current

Most digital clamp-on ammeters have an auto-ranging feature. If, however, the range needs to be set manually, always start at the highest range and adjust the range as needed to obtain an accurate reading. Place the jaws of the ammeter around only one conductor at a time. Placing the jaws around two conductors at the same time will produce an inaccurate reading.

- While the system is deenergized, select the location for the current measurement and separate the target conductor from others so that the jaws can safely and easily be snapped closed around the conductor when the power is on.
- Make any preparations for measurement that can be made while the power is off to significantly reduce exposure to serious injury.
- Note that wire insulation is not a factor; there is no need to place the jaws around bare conductors. In fact, doing so can be dangerous.



SELECTING AND USING TEST INSTRUMENTS

- If the current reading is expected to be at the low end of the lowest ammeter range, a more accurate reading can be obtained by wrapping the single conductor wire multiple times around one jaw of the ammeter.
- It is not often necessary for digital meters, but it is a significant help to read low current values on an analog model. Each time the wire passes through the jaws, the current it carries is sensed by the meter.
- If the same conductor passes through the jaws five times, the current measured will be five times the actual current flow. Be sure, however, to divide the reading by the number of times the wire passes through the jaws.
- While wrapping the conductor, do not allow the wraps to cross over each other. This can affect the accuracy.
- Note that this works equally well with a clamp-on ammeter accessory used with multimeters.

Non-Contact Voltage Tester





SELECTING AND USING TEST INSTRUMENTS

Although a non-contact voltage tester is not suitable for work that requires any level of accuracy, it is useful for quickly verifying that a circuit is energized or deenergized. It is important to note that it should not replace voltmeter testing to prove that a circuit is deenergized for safety reasons. Electrical safety demands that a more dependable test device be used. The test instrument must be able to test each phase conductor or circuit part both phase-to-phase and phase-to-ground.

Non-contact voltage testers are relatively small, compact, battery-powered instruments that fit in a shirt pocket. They typically have the following features:

- An On/Off power button
- A flashlight or indicator light that shows the tester is operational and the flashlight may help illuminate the workplace (in some models, the flashlight can be operated independently of the voltage tester)
- A high-intensity LED light and/or a warning tone to notify when voltage is detected
- An automatic shutoff to conserve power and extend battery life
- A low-battery indicator
- A built-in self-test feature

Non-contact voltage testers are available in several voltage ranges. A standard model may be sensitive only to voltages above a range of 90–100 volts ac.

Dual-voltage models can register and differentiate between standard voltages and lower voltages. This feature makes these models more suitable for testing low-voltage ac circuits for the presence of power.

Note that these tools are not designed to sense the presence of dc voltage, since they rely on the presence of a magnetic field generated by ac. They may occasionally respond to the presence of dc voltage, but not reliably.



SELECTING AND USING TEST INSTRUMENTS

Selecting a Non-Contact Voltage Tester

- When selecting a non-contact voltage tester, choose one with a range suitable for the expected voltage.
- Be sure the instrument is sensitive enough in terms of the minimum voltage that it can detect. Inspect the tester for any obvious signs of damage. Ensure the batteries for the tester are working.
- Many testers offer a battery test button to ensure the device is working properly.

Testing a Non-Contact Voltage Tester

Check the tester on a known, energized voltage source prior to using the instrument in the field. Use the built-in self-test feature, if the tester is so equipped. Otherwise, a simple way to test it is to place the tip of the tester near the line-voltage side (smaller slot) of an electrical outlet known to be energized. If the tester is working properly, the tester should give a clear audible and/or visual indication that voltage is present.

Using a Non-Contact Voltage Tester

Although non-contact voltage testers may detect voltages up to 1000 volts ac or more, working near voltages this high can be extremely hazardous. They are best used to detect voltages well below that value.

When safety is at stake and the intention is to make contact with conductors and/or electrical parts, use a multimeter to conduct the test to ensure that the circuit has been deenergized.

- Select an appropriate non-contact voltage tester for the job.
- Inspect it for any obvious damage.
- Ensure the batteries are working. If the instrument is equipped with a self-test feature, use it to ensure the instrument is functioning properly.



SELECTING AND USING TEST INSTRUMENTS

- Before using the voltage tester on the job, always test it to verify that it is functioning properly.
- Gradually move the tester as close as possible to the wire you wish to test.
- If voltage is present, the tester will react with both an audio and visual signal.
- If the circuit is off, there should be no voltage present and no response from the tester.
- If the circuit is live, the tester should provide a visual, and possibly an audible, indication that voltage is present.
- Move the tester from one power wire to the other to be sure.
- Cycle the power off and watch for the indication that voltage is no longer present.

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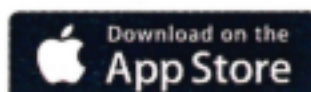
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