# Ferraz Shawmut Book of Electrical Information

# The Ferraz Shawmut Book of Electrical Information
# – A Technical Handbook –

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# ELECTRICAL DEFINITIONS

**1. Volt.*** The unit of electromotive force, electrical pressure, or difference of potential. Represented by E or V.

**2. Ampere.*** The unit of current flow. Represented by I.

**3. Ohm.*** The unit of electrical resistance. Represented by R.

**4. Energy.** The capacity for doing work.

**5. Power.** Rate of work, equals work divided by time.

**6. Watt.** The unit of electrical power. Represented by P or W.

**7. Joule.** The unit of work.

**8. Kilowatt.** One thousand watts. Expressed by kW.

**9. Current.** The motion of a charge in a conductor.

**10. Direct Current.** A unidirectional current. Abbreviated DC.

**11. Pulsating Current.** Direct current which changes regularly in magnitude.

**12. Continuous Current.** Steady-state current, AC or DC.

**13. Alternating Current.** A current which reverses regularly in direction. The term "alternating current," or AC, refers to a current with successive waves of the same shape, area and period.

**14. Cycle.** One complete wave of positive and negative values of an alternating current.

**15. Electrical Degree.** One 360th part of a cycle.

**16. Period.** The time required for the current to pass through one cycle.

**17. Frequency.** The number of cycles per second. One cycle per second equals one **Hertz (Hz).**

*One volt will cause on ampere of current to flow through a resistance of one ohm.

**18. Root-Mean Square or Effective Value.** The square root of the mean of the squares of the instantaneous values for one complete cycle. It is usually abbreviated r.m.s. Unless otherwise specified, the numerical value of an alternating current refers to its r.m.s. value. The r.m.s. value of a sinusoidal wave is equal to its maximum, or peak value, divided by $\sqrt{2}$.

**19. Wave-Form or Wave-Shape.** The shape of the curve obtained when the instantaneous values of an alternating current are plotted against time in rectangular coordinates. The distance along the time axis corresponding to one complete cycle of values is usually taken as $2\pi$ radians, or 360 electrical degrees.

**20. Simple Alternating or Sinusoidal Current.** Current whose waveshape is sinusoidal. Alternating current calculations are commonly based upon the assumption of sinusoidal currents and voltages.

**21. Phase.** The factional part of the period of a sinusoidal wave, usually expressed in electrical degrees and referenced to the origin.

**22. Crest Factor.** The ratio of the peak or maximum value of a wave, to the r.m.s. value. The crest factor of a sine wave is $\sqrt{2}$.

**23. Form Factor.** The ratio of the r.m.s. to the average value of a periodic wave.

***24. Phase Difference: Lead and Lag.** The difference in phase between two sinusoidal waves having the same period, usually expressed in electrical degrees. The voltage wave if generally taken as the reference, so in an inductive circuit the current lags the voltage, and in a capacitive circuit the current leads the voltage. Sometimes called the phase angle.

***25. Counter-Clockwise Convention.** It is a convention that in any vector diagram, the leading vector be drawn counter-clockwise with respect to the lagging vector, as in the accompanying diagram, where OI represent the vector of a current in a simple alternating current circuit, lagging behind the vector OE or impressed voltage.


* Refers only to cases where the current and voltage are both sinusoidal.

***26. The Active or In-Phase Component** of the current in a circuit is that component which is in phase with the voltage across the circuit.

***27. Reactive or Quadrature Component.** That component of the current which is quadrature, or 90 degrees out of phase, with the voltage across the circuit.

***28. Reactive Factor.** The ratio of the reactive volt-amperes to the apparent power.

***29. Reactive Volt Amperes.** The product of the voltage, current and the sine of the phase difference between them. Expressed in vars.

***30. Non-Inductive Load and Inductive Load.** A non-inductive load is a load in which the current is in phase with the voltage across the load. An inductive load is a load in which the current lags behind the voltage across the load.

**31. Power in an Alternating-Current Circuit.** The product of the voltage, current and the cosine of the phase difference between them. Expressed in watts.

**32. Volt Amperes or Apparent Power.** The product of the voltage across a circuit and the current in the circuit. Expressed in VA.

**33. Power Factor.** The ratio of the power as defined in (**31**) to the volt amperes (**32**). In the case of sinusoidal current and voltage, the power factor is equal to the cosine of their phase angle.

**34. Single-Phase.** A term characterizing a circuit energized by a single alternating voltage source.

**35. Three Phase.** A term characterizing a combination of three circuits energized by alternating voltage sources which differ in phase by one-third of a cycle, 120 degrees.

**36. Quarter-Phase or Two-Phase.** A term characterizing a combination of two circuits energized by alternating voltage sources which differ in phase by a quarter of a cycle, 90 degrees.

* Refers only to cases in where the current and voltage are both sinusoidal.

**37. Six-Phase.** A term characterizing the combination of six circuits energized by alternating e.m.f.'s which differ in phase by one-sixth of a cycle; i.e., 60 degrees.

**38. Polyphase.** A general term applied to any system of more than a single phase. This term is ordinarily applied to symmetrical systems.

**39. The Load Factor of a Machine, Plant or System.** The ratio of the average power to the peak power during a specified period of time. In each case, the interval of maximum load and the period over which the average is taken should be definitely specified. The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

**40. Plant Factor or Plant Capacity.** The ratio of the average load to the rated capacity of the power plant.

**41. Demand Factor.** The ratio of the maximum demand of any system to the total connected load of the system, or of the part of the system under consideration.

**42. Diversity Factor.** The ratio of the sum of the maximum power demands of the subdivisions, or parts of a system, to the maximum demand of the whole system or of part of the system under consideration.

**43. Connected Load.** The combined continuous rating of all the equipment connected to the system or part of the system under consideration.

**44. Efficiency.** The efficiency of an electrical machine or apparatus is the ratio of its useful power output to its total power input.

**45. Rating.** The rating of an electrical device includes (1) the normal r.m.s. current which it is designed to carry, (2) the normal r.m.s. voltage of the circuit in which it is intended to operate, (3) the normal frequency of the current and the interruption (or withstand) rating of the device (see **52**).

**46. Continuous Rating.** The maximum constant load that can be carried continuously without exceeding established temperature rise limitations under prescribed conditions.

**47. Short-Time Rating.** The maximum constant load that can be carried for a specified time without exceeding established temperature rise limitations under prescribed conditions.

**48. Ampacity.** The current a conductor can carry continuously without exceeding its temperature rating. Ampacity is a function of cable size, insulation type and the conditions of use.

**49. Overcurrent.** Any current in excess of conductor ampacity or in excess of equipment continuous current rating.

**50. Overload.** The operation of conductors or equipment a current that will cause damage if allowed to persist.

**51. Short Circuit.** Excessive current flow caused by insulation breakdown or wiring error.

**52. Interrupting Rating or Capacity.** Interrupting (breaking or rupturing) capacity is the highest r.m.s. current at normal voltage which a device can interrupt under prescribed conditions.

**53 Ambient Temperature.** The temperature surrounding an object under consideration.

## ROTATING MACHINES

**54. Generator.** A machine which converts mechanical power into electrical power.

**55. Motor.** A machine which converts electrical power into mechanical power.

**56. Booster.** A generator inserted in series in a circuit to add or subtract from the circuit voltage.

**57. Motor-Generator Set.** A conversion device consisting of one or more motors mechanically coupled to one or more generators.

**58. Dynamotor.** A converter with both motor and generator in one magnetic field, either with two armatures, or with one armature having two separate windings.

**59. Direct-Current Compensator or Balancer.** Comprises two or more similar direct-current machines (usually with shunt or compound excitation) directly coupled to each other and connected in series across the outer conductors a multiple-wire system of distribution, for the purpose of maintaining the potentials of the intermediate wires of the system, which are connected to the junction points between the machines.

**60. Double-Current Generator.** Supplies both direct and alternating currents from the same winding.

**61. Converter.** A device which changes electrical energy from one form to another. There are several types of converters:

**62. Direct-Current Converter.** A device which converts direct current to direct current, usually with a change of voltage.

**63. Synchronous Converter or Rotary Converter.** Converts an alternating current to a direct current.

**64. Frequency Converter.** Converts the power of an alternating current system form one frequency to one more other frequencies.

**65. Rotary Phase Converter.** Converts an alternating current system of one or more phases to alternating current system of a different number of phases, but of the same frequency.

**66. Phase Modifier or Phase Advancer.** A machine which supplies leading or lagging reactive volt amperes to the system to which it is connected. Phase modifiers may be either synchronous or asynchronous.

**67. Synchronous Phase Modifier or Synchronous Condenser.** A synchronous motor, running without mechanical load, the field excitation of which may be varied so as to modify the power factor of the system.

**68. Alternator.** An alternating current generator, either single phase or polyphase.

**69. Inductor Alternator.** An alternator in which both field and armature windings are stationary and in which the voltage is produced by varying the flux linking the armature winding.

**70. Synchronous Motor.** An alternating current motor which operates at the speed of rotation of the magnetic flux.

**71. Induction Motor.** An alternating current motor, either single phase or polyphase, comprising independent primary and secondary windings, in which the secondary receives power from the primary by electromagnetic induction.

**72. Induction Generator.** An induction machine, driven above synchronous speed, used to convert mechanical power to electrical power.

**73. Unipolar or Acyclic Machine.** A direct current machine in which the voltage generated in the active conductors maintains the same direction with respect to those conductors.

**74. Constant-Speed Motor.** A motor whose speed is either constant or varies little, such as synchronous motors, induction motors with low slip and ordinary direct-current shunt motors.

**75. Multispeed Motor.** A motor which can be operated at any of several distinct speeds, usually by changing the number of poles or number of windings.

**76. Adjustable-Speed Motor.** A motor whose speed may be varied gradually over a considerable range, but remains practically unaffected by the load.

**77. Varying-Speed Motor.** A motor whose speed varies with the load, ordinarily decreasing when the load increases.

**78. Base Speed of an Adjustable-Speed Motor.** That speed of a motor obtained with full field under full load with no resistor in the armature circuit.

**79. Variable Speed Motor.** A motor with a positively damped speed-torque characteristic which lends itself to controlled speed applications.

## TRANSFORMERS

**80. Transformer.** A device for transferring energy in an alternating current system from one circuit to another, consisting of two independent electric circuits linked by a common magnetic circuit.

**81. Potential Transformer.** A transformer designed for shunt or parallel connection in its primary circuit, with the ratio of transformation appearing as a ratio of potential differences.

**82. Current Transformer.** A transformer designed for series connection in its primary circuit with the ratio of transformation appearing as a ratio of currents.

**83. Instrument Transformer.** A transformer (current or potential) suitable for use with measuring instruments; i.e., one in which the conditions of the current, voltage and phase angle in the primary circuit are represented with acceptable accuracy in the secondary circuit.

**84. Auto-Transformer.** A transformer having some of its turns common to both primary and secondary circuits.

**85. Primary.** The windings of a transformer which receive energy from the supply circuit.

**86. Secondary.** The windings which receive the energy by induction from the primary.

**87. Voltage Ratio.** The voltage ratio of a transformer is the ratio of the r.m.s. primary terminal voltage to the r.m.s. secondary current, under specified conditions of load.

**88. Current Ratio.** The current ratio of a current transformer is th ratio of r.m.s. primary current to r.m.s. secondary current, under specified conditions of load.

**89. Marked Ratio.** The marked ratio of an instrument transformer is the ratio of the rated primary value to the rated secondary value as stated on the nameplate.

## FUSES

**90. Fuse.** An overcurrent protective device containing a calibrated current-carrying member which melts and opens under specified overcurrent conditions.

**91. General Purpose Fuse.** A fuse which meets industry standards for overload and short circuit protection as well as physical dimensions. This fuse type is tested and certified by nationally recognized testing laboratories and may be applied in accordance with the National Electrical Code and the Canadian Electrical Code to provide main, feeder and branch circuit protection.

**92. Enclosed Cartridge Fuse.** A fuse with a tubular body having a terminal on each end and a current-responsive element (link) inside.

**93. Non-Renewable Fuse.** An enclosed fuse with a link which cannot be replaced after operation. This fuse contains an arc quenching filler.

**94. Renewable Fuse.** An enclosed fuse, the body of which can be opened and the fusible link replaced for re-sue. This fuse usually does not a have a filler.

**95. Time Delay Fuse.** A fuse which will carry an overcurrent of a specified magnitude for a minimum specified time without opening, as defined in the tri-national Fuse Standard 248.

**96. Current-Limiting Fuse.** A fuse which will limit both the magnitude and duration of current flow under short circuit conditions.

**97. UL/CSA Class Fuses.** General purpose fuses meeting one of the industry standards called "classes." Fuse classifications H, J, K, L, R, CC, G and T. Qualifying fuses are typically tested and certified by UL or CSA to tri-national Fuse Standard 248.

**98. Rejection Fuse.** A current-limiting fuse with high interrupting rating and with unique dimensions or mounting provisions.

**99. Bolt-In Fuse.** A fuse which is intended to be bolted directly to bus bars, contact pads or fuse blocks.

**100. Semiconductor Fuse.** An extremely fast-acting fuse intended for the protection of power semiconductors. Sometimes referred to as a rectifier fuse.

**101. Midget Fuse.** A term describing a group of fuses used for supplementary circuit or component protection, all having dimensions of 1-1/2" long and 13/32" diameter.

**102. Glass Fuses.** A loose term describing a group of low voltage fuses, with glass or ceramic bodies, having dimensions smaller than midget fuses. Also called "miniature" fuses, they are typically 1/4" x 1-1/4," 1/4" x 1," or 5mm x 20mm. These fuses are used to protect electronic circuits or components.

**103. Micro Fuses.** Term describing the smallest sizes of fuses, usually mounted on, or used to protect, printed circuit boards or small electronic components.

**104. Special Purpose Fuses.** Fuses with special performance characteristics or ratings intended to protect equipment or components under specified conditions.

**105. Limiter**. A special purpose fuse which is intended to provide short circuit protection only.

**106. Welder Protector.** A fuse with special characteristics to meet heavy inrush current demands of an electric welder and protect the welder on short circuits.

**107. Cable Protector**. A fuse with characteristics designed to protect cables against fault damage. Cable protectors have unique mounting and crimping terminals.

**108. Low Voltage Fuses.** Fuses rated 600 volts and below.

**109. Medium voltage Fuses.** Fuses rated from 601 volts to 34,500 volts.

**110. High Voltage Fuses.** Fuses rated 34,500 volts and above.

**111. Plug Fuse.** A “household” type fuse with a threaded base such as an Edison-base or Type S tamperproof base. Rated 0-30 amperes, 125 volts.

**112. Class CC Fuse.** A small current-limiting rejection type fuse for control circuits. Rated 0-30 amperes, 600 volts and 200,000 amperes interrupting rating.

**113. Class G Fuse**. A small current-limiting fuse which comes in four sizes 0-15A, 20A, 25-30A and 35-60A which are non-interchangeable. Rated 480 volts with a 100,000 ampere interrupting rating.

**114. Class H Fuse.** Any 250 or 600 volt “standard” dimension fuse, either renewable or non-renewable which has a 10,000 ampere interrupting rating.

**115. Class J Fuse.** A 600 volt non-interchangeable current-limiting fuse of small, unique dimensions. Available in ratings 0-600 amperes with a 200,000 ampere interrupting rating.

**116. Class K Fuse.** A 250 or 600 volt standard dimension fuse (no rejection feature) with an interrupting rating of 50,000 or 100,000 amperes, meeting specific Ip and $1^2t$ limits. Available in ratings 0-600 amperes.

**117. Class L Fuse.** A 600 volt bolt-in, current-limiting fuse of unique dimensions. Class L fuses are rated 601-6000 amperes with a 200,000 ampere interrupting rating.

**118. Class R Fuse.** A 250 or 600 volt standard dimensions fuse with a 200,000 ampere interrupting rating and a rejection feature on one terminal. They are current-limiting fuses rated 0-600 amperes.

**119. Class T Fuse.** A small, unique dimension current limiting fuse, non-interchangeable with any other fuse. Available in 300 volt and 600 volt sizes, rated 0-1200 amperes, with a 200,000 ampere interrupting rating.

**120. Ampere Rating.** The continuous current carrying capability of a fuse under defined laboratory conditions. The ampere rating is marked on each fuse. Class L fuses and E-rated fuses may be loaded to 100% of their ampere rating. For all other fuses, continuous load current should not exceed 80% of fuse rating.

**121. Filler.** A non-conductive medium filling the inside of a fuse for quenching electric arcs and absorbing energy produced by element or link melting during interruption.

**122. Fuse Block or Fuse Holder.** A device, designed and intended to hold a fuse and provide the means to connect it to the electrical circuit. Fuse blocks consist of fuse clips, insulator and terminals.

**123. Rejection Fuse Block.** A fuse block designed to accept fuses of a specific class.

**124. Fuse Clip.** A conductive mechanical device for accepting and securing the conductive part of a fuse to an electrical terminal or connection point.

## SWITCHES, CIRCUIT BREAKERS AND AUXILIARY APPARATUS

**125. Circuit Breaker.** A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

**126. Air Switch.** A switch arranged to interrupt circuits in air.

**127. Air Circuit Breaker.** A circuit breaker arranged to interrupt one or more electric circuits in air.

**128. Molded-Case Circuit Breaker.** A circuit breaker which is assembled as an integral unit in a supporting and enclosing housing of molded insulating material.

**129. Thermal-Magnetic Circuit Breaker.** A circuit breaker which has the overcurrent and tripping means of the thermal type, the magnetic type or a combination of both.

**130. Fused Circuit Breaker.** An integrally fused circuit breaker which combines the design and operating features of a circuit breaker and current-limiting fuse in one package.

**131. Oil Switch.** A switch arranged to interrupt one or more electric circuits in oil.

**132. Oil Circuit Breaker.** A circuit breaker arranged to interrupt one or more electric circuits in oil.

**133. Conducting Parts.** Those parts designed to carry current or which are conductively connected therewith.

**134. Contact.** The surface common to two conducting parts, united by pressure, for the purpose of carrying current.

**135. Grounded Parts.** Parts that are intentionally connected to ground.

**136. Dust-Proof.** Apparatus is designated as dust-proof when so constructed or protected that the accumulation of dust with or without the device will not interfere with its successful operation.

**137. Dust-Tight.** Apparatus is designated as dust-tight when so constructed that the dust will not enter the enclosing case under specified test conditions.

**138. Gas-Proof.** Apparatus is designated as gas-proof when so constructed or protected that the specified gas will not interfere with successful operation.

**139. Gas-Tight.** Apparatus is designated as gas-tight when so constructed that the specified gas will into enter the enclosing case under specified test conditions.

**140. Totally Enclosed.** Apparatus with an integral enclosure so constructed that, while not airtight, the enclosed air has no deliberate connection with external air except for draining and breathing.

**141. Moisture-Resisting.** Apparatus is designated as moisture-resisting when so constructed or treated that it will not be readily injured by moisture.

**142. Drip-Proof.** Apparatus is designated as drip-proof when it is constructed so that successful operation is not interfered with when falling drops of liquid or solid particles strike or enter the enclosure at an angle of 0 to 15 degrees from vertical.

**143. Splash-Proof.** An open apparatus in which the ventilation openings are so constructed that drops of liquid or solid particles coming toward it at any angle up to 100° downward from vertical cannot enter directly or by running along a surface.

**144. Submersible.** Apparatus is designated as submersible when so constructed that it operates successfully in water under specified pressure and time conditions.

**145. Sleet-Proof.** Apparatus is designated as sleet-proof when so constructed or protected that the accumulation of sleet will not interfere with its successful operation.

**146. Contactor.** A device for repeatedly establishing or interrupting an electrical circuit under normal conditions. It is usually magnetically operated.

**147. Electric Controller.** A device, or group of devices, which serves to control, in some manner, the electric power delivered to the apparatus to which it is connected.

**148. Switch.** A device for making, breaking, or changing connections in an electric circuit, the operation of which is independent of the circuit to which it is connected.

**149. Master Switch.** A switch which serves to dominate the operation of contactors, relays and auxiliary devices of an electric controller.

**150. Control Switch.** A manually operated switch for controlling power operated switches and circuit breakers.

**151. Auxiliary Switch.** A switch actuated by the main device for signaling, interlocking, etc.

**152. Disconnecting Switch.** A switch which is intended to open a circuit only after the load has been removed by some other means.

**153. Load-Break Switch.** A switch which is designed for, and intended to open a circuit which may be under load.

**154. Relay.** A device which is operative by variation in the conditions of one electric circuit to effect the operation of other devices in the same or another electric circuit.

**155. Rheostat.** An adjustable resistor constructed so that its resistance may be changed without opening the circuit.

## SKIN EFFECT

Alternating current causes an unequal distribution of current in a wire. The current density decreases toward the center of the conductor so that for large wires the central portion is used as a conductor, thus increasing the resistance of the wire above that which it would for a continuous current.

This is known as "Skin Effect"

The skin effect increases with the frequency and also with the diameter of the wire, in such a way that for the same percentage of increase in the resistance due to skin effect, the product (diameter$^2$ x frequency) is constant.

Table A gives skin effect factors for different values of the product of frequency and cross-sectional area. Table B gives skin effect factors for different frequencies and sizes of wire.

### SKIN EFFECT AT 20°C. FOR STRAIGHT CYLINDRICAL CONDUCTORS

**A**

| Frequency x Area in C.M. | Skin Effect Factor: Copper u = 1. p = 1.72 | Skin Effect Factor: Aluminum u = 1. p = 2.77 |
|---|---|---|
| 10,000,000 | 1.00 | 1.00 |
| 20,000,000 | 1.008 | 1.00 |
| 30,000,000 | 1.025 | 1.006 |
| 40,000,000 | 1.045 | 1.015 |
| 50,000,000 | 1.070 | 1.026 |
| 60,000,000 | 1.096 | 1.04 |
| 70,000,000 | 1.126 | 1.053 |
| 80,000,000 | 1.158 | 1.069 |
| 90,000,000 | 1.195 | 1.085 |
| 100,000,000 | 1.23 | 1.104 |
| 125,000,000 | 1.332 | 1.151 |
| 150,000,000 | 1.433 | 1.206 |
| 175,000,000 | 1.53 | 1.266 |
| 200,000,000 | 1.622 | 1.33 |

**B**

| Copper Wire: Diameter and AWG | Skin Effect: 25 Cycle | Skin Effect: 60 Cycle |
|---|---|---|
| 2.00" | 1.222 | 1.75 |
| 1.75" | 1.145 | 1.56 |
| 1.50" | 1.085 | 1.38 |
| 1.25" | 1.042 | 1.201 |
| 1.125" | 1.028 | 1.143 |
| 1.000" | 1.018 | 1.095 |
| 0.75" | 1.006 | 1.031 |
| 0.50" | 1.001 | 1.007 |
| 0000 | 1.000 | 1.004 |
| 000 | | 1.003 |
| 00 | | 1.002 |
| 0 | | 1.001 |

# WIRE DATA AND APPLICATIONS

**Wire Gages**
The American Wire Gage (AWG) - once called Browne and Sharpe or B. and S., is used almost exclusively in the U.S. for copper wire. The Birmingham Wire Gage (B.W.G.) is used for steel wire. In England, copper wire sizes are often specified by the English (or Imperial) Standard Wire Gage (S.W.G.), sometimes called New British Standard or N.B.S.

**AWG**
The diameters according to the AWG are defined as follows: The diameter of size #0000 (often written 4/0) is chosen to be 0.4600 inch and that of size #36, 0.0050 inch. Intermediate sizes are found by geometric progression. That is, the ratio of one size to that of the next smaller size (larger gage number) is:

$$\sqrt[39]{\frac{0.4600}{0.0050}} = 1.122\,932$$

**Circular Mil**
Also called cmil, the circular mil is used to define cross-sectional area of wires, being a unit of area equal to the area of a circle 1 mil (0.001 in.) in diameter. Such a circle has an area of 0.7854 (or $\pi/4$) mil$^2$. Thus, a wire 10 mils in diameter has a cross-sectional area of 100 cmils or 78.54 mil$^2$. A kcmil is 1000 cmils (785.4 mil$^2$).

**Conductivity of Copper**
The conductivity of copper is usually expressed in percent of a standard conductivity based upon the International Annealed Copper Standard of resistance, which is defined as follows: The resistance of a wire one meter in length and weighting one gram at a temperature of 20° C is 0.15328 ohm. Expressed in various units, the International Annealed Copper Standard has the values:

0.15328 ohm (meter, gram) at 20° C
875.20 ohms (mile, pound) at 20° C
0.017241 ohm (meter, sq. mm) at 20° C
0.67879 microhm-inch at 20° C
10.371 ohms (mil, foot) at 20° C
1.7241 microhm-cm at 20° C

**Temperature Coefficient**
The D.C. resistance of copper wire increases with increasing temperature in accordance with the formula:

$$R_t = R_o\left[1 + \propto (t - t_o) + \frac{\propto^2}{2}(t - t_o)^2 + \ldots\right]$$

where $R_t$ = Resistance at temperature t
$R_o$ = Resistance at temperature to
$\propto$ = Temp. Coefficient of Resistance

At 20° C. (68° F.) the temperature coefficient of copper with 100% conductivity is 0.00393 per degree Centigrade or 0.00218 per degree Fahrenheit. The temperature coefficient at another temperature or for copper of any conductivity (e.g., hard drawn wire) may be calculated from the following formula, which depends upon the fact that the temperature coefficient is proportional to conductivity:

$$\propto = \frac{0.0407}{\text{ohms (mil, foot) at }_t\text{°C}} \text{ per degree C}$$

$$\propto = \frac{0.0226}{\text{ohms (mil, foot) at }_t\text{°C}} \text{ per degree C}$$

Common practice in the wire and cable industry is to refer all measurements of copper resistance to 25° C. (77° F.). At this temperature, the temperature coefficient is 0.00385 per degree C. or 0.00214 per degree F.

A value of copper resistance measured at any temperature in the range 0° - 50° C. (32° - 122° F.) may be corrected to the corresponding value at 25° C. (77°F.) by the multiplying factor taken from the following table:

## COPPER RESISTANCE - TEMPERATURE

**Resistance Correction Factor**

| COPPER TEMPERATURE, DEGREES | | MULTIPLYING FACTOR |
|---|---|---|
| **Centigrade** | **Fahrenheit** | |
| 0 | 32 | 1.107 |
| 5 | 41 | 1.084 |
| 10 | 50 | 1.061 |
| 15 | 59 | 1.040 |
| 20 | 68 | 1.020 |
| 25 | 77 | 1.000 |
| 30 | 86 | 0.981 |
| 35 | 95 | 0.963 |
| 40 | 104 | 0.945 |
| 45 | 113 | 0.929 |
| 50 | 122 | 0.912 |

# COMPARATIVE DATA OF STRANDED COPPER AND ALUMINUM CABLES

| SIZE AWG/ kcMil | AREA | | WEIGHTS | | | |
|---|---|---|---|---|---|---|
| | Circular Mils | Square Millimeters | POUNDS PER KFT | | POUNDS PER MILE | |
| | | | Copper | Aluminum | Copper | Aluminum |
| 30 | 100.5 | 0.051 | 0.3042 | 0.0924 | 1.606 | 0.488 |
| 28 | 159.8 | 0.081 | 0.4837 | 0.147 | 2.554 | 0.776 |
| 26 | 254.1 | 0.123 | 0.7692 | 0.234 | 4.061 | 1.236 |
| 24 | 404.0 | 0.205 | 1.223 | 0.371 | 6.458 | 1.959 |
| 22 | 642.4 | 0.326 | 1.945 | 0.591 | 10.27 | 3.120 |
| 20 | 1022 | 0.518 | 3.092 | 0.939 | 16.33 | 4.958 |
| 18 | 1620 | 0.823 | 4.917 | 1.49 | 25.96 | 7.87 |
| 16 | 2580 | 1.31 | 7.818 | 2.37 | 41.28 | 12.5 |
| 14 | 4110 | 2.08 | 12.43 | 3.78 | 65.64 | 20.0 |
| 12 | 6530 | 3.31 | 19.77 | 6.00 | 104.4 | 31.7 |
| 10 | 10380 | 5.26 | 31.43 | 9.55 | 165.9 | 50.4 |
| 8 | 16510 | 8.37 | 49.97 | 15.2 | 263.9 | 80.3 |
| 6 | 26240 | 13.3 | 79.46 | 24.1 | 419.6 | 127 |
| 4 | 41740 | 21.2 | 126.4 | 39.0 | 667.1 | 206 |
| 3 | 52620 | 26.7 | 159.3 | 49.0 | 841.3 | 260 |
| 2 | 66360 | 33.6 | 200.9 | 62.0 | 1061 | 327 |
| 1 | 83690 | 42.4 | 253.3 | 78.1 | 1338 | 412 |
| 1/0 | 105600 | 53.5 | 319.5 | 97 | 1687 | 513 |
| 2/0 | 133100 | 67.4 | 402.8 | 123 | 2127 | 647 |
| 3/0 | 167800 | 85.0 | 507.9 | 155 | 2682 | 816 |
| 4/0 | 211600 | 107 | 640.5 | 195 | 3382 | 1028 |
| 250 | --- | 127 | 762 | 230 | 4026 | 1215 |
| 300 | --- | 152 | 915 | 276 | 4831 | 1458 |
| 350 | --- | 177 | 1068 | 322 | 5636 | 1701 |
| 400 | --- | 203 | 1220 | 368 | 6442 | 1924 |
| 500 | --- | 253 | 1525 | 469 | 8052 | 2477 |
| 600 | --- | 304 | 1830 | 552 | 9662 | 2916 |
| 700 | --- | 355 | 2135 | 644 | 11273 | 3402 |
| 750 | --- | 380 | 2288 | 690 | 12078 | 3645 |
| 800 | --- | 405 | 2440 | 736 | 12883 | 3888 |
| 900 | --- | 456 | 2745 | 828 | 14494 | 4374 |
| 1000 | --- | 507 | 3050 | 920 | 16104 | 4860 |
| 1250 | --- | 634 | 3813 | 1150 | 20130 | 6075 |
| 1500 | --- | 760 | 4575 | 1380 | 24160 | 7290 |
| 1750 | --- | 887 | 5338 | 1610 | 28180 | 8505 |
| 2000 | --- | 1014 | 6100 | 1840 | 32210 | 9720 |

## COMPARATIVE DATA OF STRANDED COPPER AND ALUMINUM CABLES,cont.

| SIZE AWG/ kcMil | AREA Circular Mils | STRANDS | | Diameter Overall Inches | Area Square Inches | DC RESISTANCE | |
|---|---|---|---|---|---|---|---|
| | | Number | Diameter | | | Copper Ohms/kFt | Aluminum Ohms/kFt |
| 18 | 1620 | 1 | --- | 0.040 | 0.001 | 7.77 | 12.8 |
| 18 | 1620 | 7 | 0.015 | 0.046 | 0.002 | 7.95 | 13.1 |
| 16 | 2580 | 1 | --- | 0.051 | 0.002 | 4.89 | 8.05 |
| 16 | 2580 | 7 | 0.019 | 0.058 | 0.003 | 4.99 | 8.21 |
| 14 | 4110 | 1 | --- | 0.064 | 0.003 | 3.07 | 5.06 |
| 14 | 4110 | 7 | 0.024 | 0.073 | 0.004 | 3.14 | 5.17 |
| 12 | 6530 | 1 | --- | 0.081 | 0.005 | 1.93 | 3.18 |
| 12 | 6530 | 7 | 0.030 | 0.092 | 0.006 | 1.98 | 3.25 |
| 10 | 10380 | 1 | --- | 0.102 | 0.008 | 1.21 | 2.00 |
| 10 | 10380 | 7 | 0.038 | 0.116 | 0.011 | 1.24 | 2.04 |
| 8 | 16510 | 1 | --- | 0.128 | 0.013 | 0.764 | 1.26 |
| 8 | 16510 | 7 | 0.049 | 0.146 | 0.017 | 0.778 | 1.28 |
| 6 | 26240 | 7 | 0.061 | 0.184 | 0.027 | 0.491 | 0.808 |
| 4 | 41740 | 7 | 0.077 | 0.232 | 0.042 | 0.308 | 0.508 |
| 3 | 52620 | 7 | 0.087 | 0.260 | 0.053 | 0.245 | 0.403 |
| 2 | 66360 | 7 | 0.097 | 0.292 | 0.067 | 0.194 | 0.319 |
| 1 | 83690 | 19 | 0.066 | 0.332 | 0.087 | 0.154 | 0.253 |
| 1/0 | 105600 | 19 | 0.074 | 0.373 | 0.109 | 0.122 | 0.201 |
| 2/0 | 133100 | 19 | 0.084 | 0.419 | 0.138 | 0.0967 | 0.159 |
| 3/0 | 167800 | 19 | 0.094 | 0.470 | 0.173 | 0.0766 | 0.126 |
| 4/0 | 211600 | 19 | 0.106 | 0.528 | 0.219 | 0.0608 | 0.100 |
| 250 | --- | 37 | 0.082 | 0.575 | 0.260 | 0.0515 | 0.0847 |
| 300 | --- | 37 | 0.090 | 0.630 | 0.312 | 0.0429 | 0.0707 |
| 350 | --- | 37 | 0.097 | 0.681 | 0.364 | 0.0367 | 0.0605 |
| 400 | --- | 37 | 0.104 | 0.728 | 0.416 | 0.0321 | 0.0529 |
| 500 | --- | 37 | 0.116 | 0.813 | 0.519 | 0.0258 | 0.424 |
| 600 | --- | 61 | 0.099 | 0.893 | 0.626 | 0.0214 | 0.0353 |
| 700 | --- | 61 | 0.107 | 0.964 | 0.730 | 0.0184 | 0.0303 |
| 750 | --- | 61 | 0.111 | 0.998 | 0.782 | 0.0171 | 0.0282 |
| 800 | --- | 61 | 0.114 | 1.03 | 0.834 | 0.0161 | 0.0265 |
| 900 | --- | 61 | 0.122 | 1.09 | 0.940 | 0.0143 | 0.0235 |
| 1000 | --- | 61 | 0.128 | 1.15 | 1.04 | 0.0129 | 0.0212 |
| 1250 | --- | 91 | 0.117 | 1.29 | 1.30 | 0.0103 | 0.0169 |
| 1500 | --- | 91 | 0.128 | 1.41 | 1.57 | 0.00858 | 0.0141 |
| 1750 | --- | 127 | 0.117 | 1.52 | 1.83 | 0.00735 | 0.0121 |
| 2000 | --- | 127 | 0.126 | 1.63 | 2.09 | 0.00643 | 0.0106 |

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Table 310-16. Allowable Ampacities of Single Insulated Conductors
Rated 0-2000 Volts, 60° to 90°C (140° to 194°F)
Not more than three conductors in Raceway or Cable or Earth
(Directly Buried), Based on Ambient Temperature of 30°C (86°F)

| Size | Temperature Rating of Conductor, See Table 310-13 | | | | | | Size |
|---|---|---|---|---|---|---|---|
| | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | 60°C (140°C) | 75°C (167°C) | 90°C (194°F) | |
| AWG/ kcmil | TYPES TW† UF† | TYPES RHW†, THHW†, THW†, THWN†, XHHW†, USE†,ZW† | TYPES TBS,SA SIS,FEP†, FEPB†,MI RHH†,RHW-2 THHN†,THHW†, THW-2,THWN-2, USE-2,XHH, XHHW† XHHW-2,ZW-2 | TYPES TW† UF† | TYPES RH†,RHW†, THHW†, THW†, THWN†, XHHW†, USE† | TYPES TBS SA,SIS, THHN†, THHW†, THW-2,THWN-2, RHH†,RHW-2 USE-2 XHH,XHHW XHHW-2,ZW-2 | AWG/ kcmil |
| | COPPER | | | ALUMINUM OR COPPER CLAD ALUMINUM | | | |
| 18 | --- | --- | 14 | --- | --- | --- | --- |
| 16 | --- | --- | 18 | --- | --- | --- | --- |
| 14 | 20† | 20† | 25† | --- | --- | --- | --- |
| 12 | 25† | 25† | 30† | 20† | 20† | 25† | 12 |
| 10 | 30 | 35† | 40† | 25 | 30† | 35† | 10 |
| 8 | 40 | 50 | 55 | 30 | 40 | 45 | 8 |
| 6 | 55 | 65 | 75 | 40 | 50 | 60 | 6 |
| 4 | 70 | 85 | 95 | 55 | 65 | 75 | 4 |
| 3 | 85 | 100 | 110 | 65 | 75 | 85 | 3 |
| 2 | 95 | 115 | 130 | 75 | 90 | 100 | 2 |
| 1 | 110 | 130 | 150 | 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 | 190 | 230 | 255 | 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 | 355 | 420 | 475 | 285 | 340 | 385 | 600 |
| 700 | 385 | 460 | 520 | 310 | 375 | 420 | 700 |
| 750 | 400 | 475 | 535 | 320 | 385 | 435 | 750 |
| 800 | 410 | 490 | 555 | 330 | 395 | 450 | 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 | 520 | 625 | 705 | 435 | 520 | 585 | 1500 |
| 1750 | 545 | 650 | 735 | 455 | 545 | 615 | 1750 |
| 2000 | 560 | 665 | 750 | 470 | 560 | 630 | 2000 |
| CORRECTION FACTORS | | | | | | | |
| Ambient Temp °C | For ambient temperatures other than 30° C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below. | | | | | | Ambient Temp °C |
| 21-25 | 1.08 | 1.05 | 1.04 | 1.08 | 1.05 | 1.04 | 70-77 |
| 26-30 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 78-86 |
| 31-35 | .91 | .94 | .96 | .91 | .94 | .96 | 87-95 |
| 36-40 | .82 | .88 | .91 | .82 | .88 | .91 | 96-104 |
| 41-45 | .71 | .82 | .87 | .71 | .82 | .87 | 105-113 |
| 46-50 | .58 | .75 | .82 | .58 | .75 | .82 | 114-122 |
| 51-55 | .41 | .67 | .76 | .41 | .67 | .76 | 123-131 |
| 56-60 | --- | .58 | .71 | --- | .58 | .71 | 132-140 |
| 61-70 | --- | .33 | .58 | --- | .33 | .58 | 142-158 |
| 71-80 | --- | --- | .41 | --- | --- | .41 | 159-176 |

†Unless otherwise specifically permitted elsewhere in this Code, the overcurrent protection for conductor types marked with an obelisk (†) shall not exceed 15 amperes for No.14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for No. 10 aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

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Table 310-17. Allowable Ampacities of Single Insulated Conductors
Rated 0-2000 Volts, In Free Air
Based on Ambient Temperature of 30°C (86°F)

| Size | Temperature Rating of Conductor, See Table 310-13 | | | | | | Size |
|---|---|---|---|---|---|---|---|
| AWG/ kcmil | 60°C (140°F) | 75°C (167°F) | 90°C (194°F) | 60°C (140°C) | 75°C (167°C) | 90°C (194°F) | AWG/ kcmil |
| | TYPES TW† UF† | TYPES RHW†, THHW†, THW†, THWN† XHHW†, ZW† | TYPES TBS,SA SIS,FEP† FEPB†,MI RHH†,RHW-2 THHN†,THHW†, THW-2,THWN-2, USE-2,XHH, XHHW† XHHW-2,ZW-2 | TYPES TW† UF† | TYPES RH†,RHW†, THHW† THW†, THWN† XHHW†, | TYPES TBS SA,SIS, THHN†, THHW† THW-2,THWN-2, RHH†,RHW-2 USE-2 XHH,XHHW XHHW-2,ZW-2 | |
| | 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† | 40† | 10 |
| 8 | 60 | 70 | 80 | 45 | 55 | 60 | 8 |
| 6 | 80 | 95 | 105 | 60 | 75 | 80 | 6 |
| 4 | 105 | 125 | 140 | 80 | 100 | 110 | 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 | 275 | 3/0 |
| 4/0 | 300 | 360 | 405 | 235 | 280 | 315 | 4/0 |
| 250 | 340 | 405 | 455 | 265 | 315 | 355 | 250 |
| 300 | 375 | 445 | 505 | 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 | 855 | 500 | 595 | 675 | 700 |
| 750 | 655 | 785 | 885 | 515 | 620 | 700 | 750 |
| 800 | 680 | 815 | 920 | 535 | 645 | 725 | 800 |
| 900 | 730 | 870 | 985 | 580 | 700 | 785 | 900 |
| 1000 | 780 | 935 | 1055 | 625 | 750 | 845 | 1000 |
| 1250 | 890 | 1065 | 1200 | 710 | 855 | 960 | 1250 |
| 1500 | 980 | 1175 | 1325 | 795 | 950 | 1075 | 1500 |
| 1750 | 1070 | 1280 | 1445 | 875 | 1050 | 1185 | 1750 |
| 2000 | 1155 | 1385 | 1560 | 960 | 1150 | 1335 | 2000 |

| CORRECTION FACTORS | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ambient Temp °C | For ambient temperatures other than 30° C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below. | | | | | | Ambient Temp °F |
| 21-25 | 1.08 | 1.05 | 1.04 | 1.08 | 1.05 | 1.04 | 70-77 |
| 26-30 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 78-86 |
| 31-35 | .91 | .94 | .96 | .91 | .94 | .96 | 87-95 |
| 36-40 | .82 | .88 | .91 | .82 | .88 | .91 | 96-104 |
| 41-45 | .71 | .82 | .87 | .71 | .82 | .87 | 105-113 |
| 46-50 | .58 | .75 | .82 | .58 | .75 | .82 | 114-122 |
| 51-55 | .41 | .67 | .76 | .41 | .67 | .76 | 123-131 |
| 56-60 | --- | .58 | .71 | --- | .58 | .71 | 132-140 |
| 61-70 | --- | .33 | .58 | --- | .33 | .58 | 141-158 |
| 71-80 | --- | --- | .41 | --- | --- | .41 | 159-176 |

†Unless otherwise specifically permitted elsewhere in this Code, the overcurrent protection for conductor types marked with an obelisk (†) shall not exceed 15 amperes for No.14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for No. 10 aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

# CANADIAN ELECTRICAL CODE - 2002
# TABLE 1

(See Rules 4-004, 8-104, 12-2212, 26-000, 26-742, 42-008 and 42-016 and Tables 5A, 5B, 19 and D3)

## Allowable Ampacities for Single Copper Conductors in Free Air

Based on Ambient Temperature of 30°C*

| Size AWG kcmil | Allowable Ampacity† | | | | | |
|---|---|---|---|---|---|---|
| | 60°C‡ | 75°C‡ | 85 - 90°C‡ | 110°C‡ | 125°C‡ | 200°C‡ |
| | Type TW | Types RW75 TW75 | Types R90, RW90 T90 NYLON / Single-Conductor Mineral-Insulated Cables§ | See Note (3) | See Note (3) | Bare Wire |
| 14 | 20 | 20 | 20 | 40 | 40 | 45 |
| 12 | 25 | 25 | 25 | 50 | 50 | 55 |
| 10 | 40 | 40 | 40 | 65 | 70 | 75 |
| 8 | 55 | 65 | 70 | 85 | 90 | 100 |
| 6 | 80 | 95 | 100 | 120 | 125 | 135 |
| 4 | 105 | 125 | 135 | 160 | 170 | 180 |
| 3 | 120 | 145 | 155 | 180 | 195 | 210 |
| 2 | 140 | 170 | 180 | 210 | 225 | 240 |
| 1 | 165 | 195 | 210 | 245 | 265 | 280 |
| 0 | 195 | 230 | 245 | 285 | 305 | 325 |
| 00 | 225 | 265 | 285 | 330 | 355 | 370 |
| 000 | 260 | 310 | 330 | 385 | 410 | 430 |
| 0000 | 300 | 360 | 385 | 445 | 475 | 510 |
| 250 | 340 | 405 | 425 | 495 | 530 | --- |
| 300 | 375 | 445 | 480 | 555 | 590 | --- |
| 350 | 420 | 505 | 530 | 610 | 655 | --- |
| 400 | 455 | 545 | 575 | 665 | 710 | --- |
| 500 | 515 | 620 | 660 | 765 | 815 | --- |
| 600 | 575 | 690 | 740 | 855 | 910 | --- |
| 700 | 630 | 755 | 815 | 940 | 1005 | --- |
| 750 | 655 | 785 | 845 | 980 | 1045 | --- |
| 800 | 680 | 815 | 880 | 1020 | 1085 | --- |
| 900 | 730 | 870 | 940 | --- | --- | --- |
| 1000 | 780 | 935 | 1000 | 1165 | 1240 | --- |
| 1250 | 890 | 1065 | 1130 | --- | --- | --- |
| 1500 | 980 | 1175 | 1260 | 1450 | --- | --- |
| 1750 | 1070 | 1280 | 1370 | --- | --- | --- |
| 2000 | 1155 | 1385 | 1470 | 1715 | --- | --- |
| **Col. 1** | **Col. 2** | **Col. 3** | **Col. 4** | **Col. 5** | **Col. 6** | **Col. 7** |

Notes: See next page.

## TABLE 1 NOTES

* See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.

† The ampacity of single-conductor aluminum-sheathed cable is based on the type of insulation used on the copper conductor.

‡ These are maximum allowable conductor temperatures for single conductors run in free air and may be used in determining the ampacity of other conductor types in Table 19, which are so run as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type; then from Table 1 determine the ampacity under the column of corresponding temperature rating.

§ These ratings are based on the use of 90°C insulation on the emerging conductors and for sealing. Where a deviation has been allowed in accordance with Rule 2-030, mineral-insulated cable may be used at higher temperatures without decrease in allowable ampacity, provided that insulation and sealing material approved for such higher temperature is used.

NOTES: (1) The ratings of Table 1 may be applied to a conductor mounted on a plane surface of masonry, plaster, wood, or any material having a conductivity not less than 0.4W/(m°C).

(2) For correction factors where from 2 to 4 conductors are present and in contact see Table 5B.

(3) These ampacities are only applicable under special circumstances where the use of insulated conductors having this temperature rating are acceptable.

(4) Type R90 silicone wiring may be used in ambient temperatures up to 65°C without applying the correction factors for ambient temperatures above 30°C provided the temperature of the conductor at the termination does not exceed 90°C.

# CANADIAN ELECTRICAL CODE - 2002
# TABLE 2

(See Rules 4-004, 8-104, 12-2212, 26-000,
26-742, 42-008 and 42-016 and Tables 5A, 5C, 19 and D3)

## Allowable Ampacities for Not More Than 3 Copper Conductors in Raceway or Cable

Based on Ambient Temperature of 30°C*

| Size AWG kcmil | Allowable Ampacity † ‡ ‡ | | | | | |
|---|---|---|---|---|---|---|
| | 60°C‡ | 75°C‡ | 85 - 90°C‡ | 110°C‡ | 125°C‡ | 200°C‡ |
| | Type TW | Types RW75 TW75 | Types R90, RW90 T90 NYLON / Paper / Mineral-Insulated Cable** | See Note (1) | See Note (1) | See Note (1) |
| 14 | 15 | 15 | 15 | 30 | 30 | 30 |
| 12 | 20 | 20 | 20 | 35 | 40 | 40 |
| 10 | 30 | 30 | 30 | 45 | 50 | 55 |
| 8 | 40 | 45 | 45 | 60 | 65 | 70 |
| 6 | 55†† | 65 | 65 | 80 | 85 | 95 |
| 4 | 70 | 85 | 85 | 105 | 115 | 120 |
| 3 | 80 | 100 | 105 | 120 | 130 | 145 |
| 2 | 100 | 115 | 120 | 135 | 145 | 165 |
| 1 | 110 | 130 | 140 | 160 | 170 | 190 |
| 0 | 125 | 150 | 155 | 190 | 200 | 225 |
| 00 | 145 | 175 | 185†† | 215 | 230 | 250 |
| 000 | 165 | 200 | 210 | 245 | 265 | 285 |
| 0000 | 195 | 230 | 235 | 275 | 310 | 340 |
| 250 | 215 | 255 | 265 | 315 | 335 | --- |
| 300 | 240 | 285 | 295 | 345 | 380 | --- |
| 350 | 260 | 310 | 325 | 390 | 420 | --- |
| 400 | 280 | 335 | 345 | 420 | 450 | --- |
| 500 | 320 | 380 | 395 | 470 | 500 | --- |
| 600 | 355 | 420 | 455 | 525 | 545 | --- |
| 700 | 385 | 460 | 490 | 560 | 600 | --- |
| 750 | 400 | 475 | 500 | 580 | 620 | --- |
| 800 | 410 | 490 | 515 | 600 | 640 | --- |
| 900 | 435 | 520 | 555 | --- | --- | --- |
| 1000 | 455 | 545 | 585 | 680 | 730 | --- |
| 1250 | 495 | 590 | 645 | --- | --- | --- |
| 1500 | 520 | 625 | 700 | 785 | --- | --- |
| 1750 | 545 | 650 | 735 | --- | --- | --- |
| 2000 | 560 | 665 | 775 | 840 | --- | --- |
| Col. 1 | Col. 2 | Col. 3 | Col. 4 | Col. 5 | Col. 6 | Col. 7 |

Notes: See next page.

## TABLE 2 NOTES

* See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.

† The ampacity of aluminum-sheathed cable is based on the type of insulation used on the copper conductor.

‡ These are maximum allowable conductor temperatures for 1, 2 or 3 conductors run in a raceway, or 2 or 3 conductors run in a cable and may be used in determining the ampacity of other conductor types in Table 19, which are so run as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type; then from Table 2 determine the ampacity under the column of corresponding temperature rating.

** These ratings are based on the use 90°C insulation on the emerging conductors and for sealing. Where a deviation has been allowed in accordance with Rule 2-030, mineral-insulated cable may be used at higher temperatures without decrease in allowable ampacity, provided that insulation and sealing material approved for such higher temperature is used.

†† For 3-wire 120/240 and 120/208 V residential services or sub-services, the allowable ampacity for sizes No. 6 and No. 2/0 AWG shall be 60 A and 200 A respectively. In this case, the 5% adjustment of Rule 8-106(1) cannot be applied.

‡‡See Table 5C for the correction factors to be applied to the values in Columns 2 to 7 where there are more than 3 conductors in a run of raceway or cable.

NOTES: (1) These ampacities are only applicable under special circumstances where the use of insulated conductors having this temperature rating are acceptable.

(2) Type R90 silicone wiring may be used in ambient temperatures up to 65°C without applying the correction factors for ambient temperatures above 30°C provided the temperature of the conductor at the termination does not exceed 90°C.

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## TABLE 3

(See Rules 4-004, 8-104, 12-2212, 26-000,
26-742, 42-008 and 42-016 and Tables 5A, 5B, and D3)

## Allowable Ampacities for Single Aluminum Conductors in Free Air

Based on Ambient Temperature of 30°C*

| | Allowable Ampacity† | | | | | |
|---|---|---|---|---|---|---|
| | 60°C‡ | 75°C‡ | 85 - 90°C‡ | 110°C‡ | 125°C‡ | 200°C‡ |
| Size AWG kcmil | Type TW | Types RW75 TW75 | Types R90, RW90 T90 NYLON | See Note (3) | See Note (3) | Bare Wire |
| 12 | 20 | 20 | 20 | 40 | 40 | 45 |
| 10 | 30 | 30 | 30 | 50 | 55 | 60 |
| 8 | 45 | 45 | 45 | 65 | 70 | 80 |
| 6 | 60 | 75 | 80 | 95 | 100 | 105 |
| 4 | 80 | 100 | 105 | 125 | 135 | 140 |
| 3 | 95 | 115 | 120 | 140 | 150 | 165 |
| 2 | 110 | 135 | 140 | 165 | 175 | 185 |
| 1 | 130 | 155 | 165 | 190 | 205 | 220 |
| 0 | 150 | 180 | 190 | 220 | 240 | 255 |
| 00 | 175 | 210 | 220 | 225 | 275 | 290 |
| 000 | 200 | 240 | 255 | 300 | 320 | 335 |
| 0000 | 230 | 280 | 300 | 345 | 370 | 400 |
| 250 | 265 | 315 | 330 | 385 | 415 | --- |
| 300 | 290 | 350 | 375 | 435 | 460 | --- |
| 350 | 330 | 395 | 415 | 475 | 510 | --- |
| 400 | 355 | 425 | 450 | 520 | 555 | --- |
| 500 | 405 | 485 | 515 | 595 | 635 | --- |
| 600 | 455 | 545 | 585 | 675 | 720 | --- |
| 700 | 500 | 595 | 645 | 745 | 795 | --- |
| 750 | 515 | 620 | 670 | 775 | 825 | --- |
| 800 | 535 | 645 | 695 | 805 | 855 | --- |
| 900 | 580 | 700 | 750 | --- | --- | --- |
| 1000 | 625 | 750 | 800 | 930 | 990 | --- |
| 1250 | 710 | 855 | 905 | --- | --- | --- |
| 1500 | 795 | 950 | 1020 | 1175 | --- | -- |
| 1750 | 875 | 1050 | 1125 | --- | --- | --- |
| 2000 | 960 | 1150 | 1220 | 1425 | --- | --- |
| **Col. 1** | **Col. 2** | **Col. 3** | **Col. 4** | **Col. 5** | **Col. 6** | **Col. 7** |

Notes: See next page.

## TABLE 3 NOTES

* See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.

† The ampacity of single-conductor aluminum-sheathed cable is based on the type of insulation used on the copper conductor.

‡ These are maximum allowable conductor temperatures for single conductors run in free air and may be used in determining the ampacity of other conductor types in Table 19, which are so run as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type; then from Table 3 determine the ampacity under the column of corresponding temperature rating.

NOTES: (1) The ratings of Table 3 may be applied to a conductor mounted on a plane surface of masonry, plaster, wood, or any material having a conductivity not less than 0.4 W/(m°C).

(2) For correction factors where from 2 to 4 conductors are present and in contact see Table 5B.

(3) These ampacities are only applicable under special circumstances where the use of insulated conductors having this temperature rating are acceptable.

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## TABLE 4

(See Rules 4-004, 8-104, 12-2212, 26-000,
26-742, 42-008 and 42-016 and Tables 5A, 5C, and D3)

### Allowable Ampacities for Not More than 3 Aluminum Conductors in Raceway or Cable

Based on Ambient temperature of 30°C*

| Size AWG kcmil | Allowable Ampacity† § | | | | | |
|---|---|---|---|---|---|---|
| | 60°C‡ | 75°C‡ | 85 - 90°C‡ | 110°C‡ | 125°C‡ | 200°C‡ |
| | Type TW | Types RW75 TW75 | Types R90, RW90 T90 NYLON / Paper | See Note | See Note | See Note |
| 12 | 15 | 15 | 15 | 25 | 30 | 30 |
| 10 | 25 | 25 | 25 | 35 | 40 | 45 |
| 8 | 30 | 30 | 30 | 45 | 50 | 55 |
| 6 | 40 | 50 | 55** | 60 | 65 | 75 |
| 4 | 55 | 65 | 65 | 80 | 90 | 95 |
| 3 | 65 | 75 | 75 | 95 | 100 | 115 |
| 2 | 75 | 90 | 95** | 105 | 115 | 130 |
| 1 | 85 | 100 | 105 | 125 | 135 | 150 |
| 0 | 100 | 120 | 120 | 150 | 160 | 180 |
| 00 | 115 | 135 | 145 | 170 | 180 | 200 |
| 000 | 130 | 155 | 165 | 195 | 210 | 225 |
| 0000 | 155 | 180 | 185** | 215 | 245 | 270 |
| 250 | 170 | 205 | 215 | 250 | 270 | --- |
| 300 | 190 | 230 | 240 | 275 | 305 | --- |
| 350 | 210 | 250 | 260 | 310 | 335 | --- |
| 400 | 225 | 270 | 290 | 335 | 360 | --- |
| 500 | 260 | 310 | 330 | 380 | 405 | --- |
| 600 | 285 | 340 | 370 | 425 | 440 | --- |
| 700 | 310 | 375 | 395 | 455 | 485 | --- |
| 750 | 320 | 385 | 405 | 470 | 500 | --- |
| 800 | 330 | 395 | 415 | 485 | 520 | --- |
| 900 | 355 | 425 | 455 | --- | --- | --- |
| 1000 | 375 | 445 | 480 | 560 | 600 | --- |
| 1250 | 405 | 485 | 530 | --- | --- | --- |
| 1500 | 435 | 520 | 580 | 650 | --- | --- |
| 1750 | 455 | 545 | 615 | --- | --- | --- |
| 2000 | 470 | 560 | 650 | 705 | --- | --- |
| **Col. 1** | **Col. 2** | **Col. 3** | **Col. 4** | **Col. 5** | **Col. 6** | **Col. 7** |

Notes: See next page.

## TABLE 4 NOTES

* See Table 5A for the correction factors to be applied to the values in Columns 2 to 7 for ambient temperatures over 30°C.

† The ampacity of aluminum-sheathed cable is based on the type of insulation used on the copper conductor.

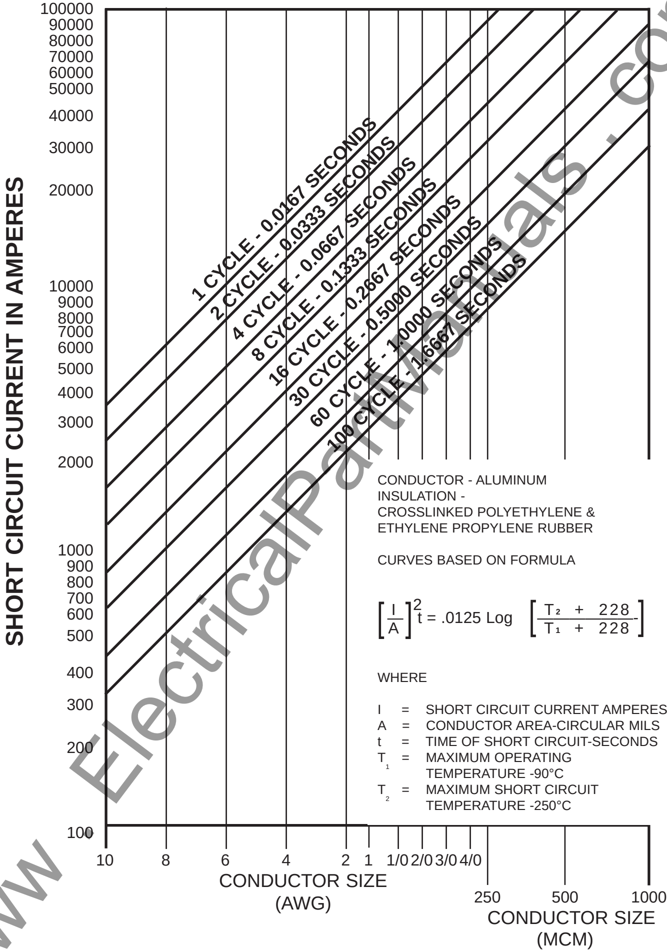
‡ These are maximum allowable conductor temperatures for 1, 2 or 3 conductors run in a raceway, or 2 or 3 conductors run in a cable and may be used in determining the ampacity of other conductor types in Table 19, which are so run as follows: From Table 19 determine the maximum allowable conductor temperature for that particular type; then from Table 4 determine the ampacity under the column of corresponding temperature rating.

§ See Table 5C for the correction factors to be applied to the values in Columns 2 to 7 where there are more than 3 conductors in a run of raceway or cable.

** For 3-wire 120/240 and 120/208 V residential services or subservices, the allowable ampacity for sizes No. 6 and No 2 and No. 4/0 AWG shall be 60 A, 100 A and 200 A respectively. In this case, the 5% adjustment of Rule 8-106(1) cannot be applied.

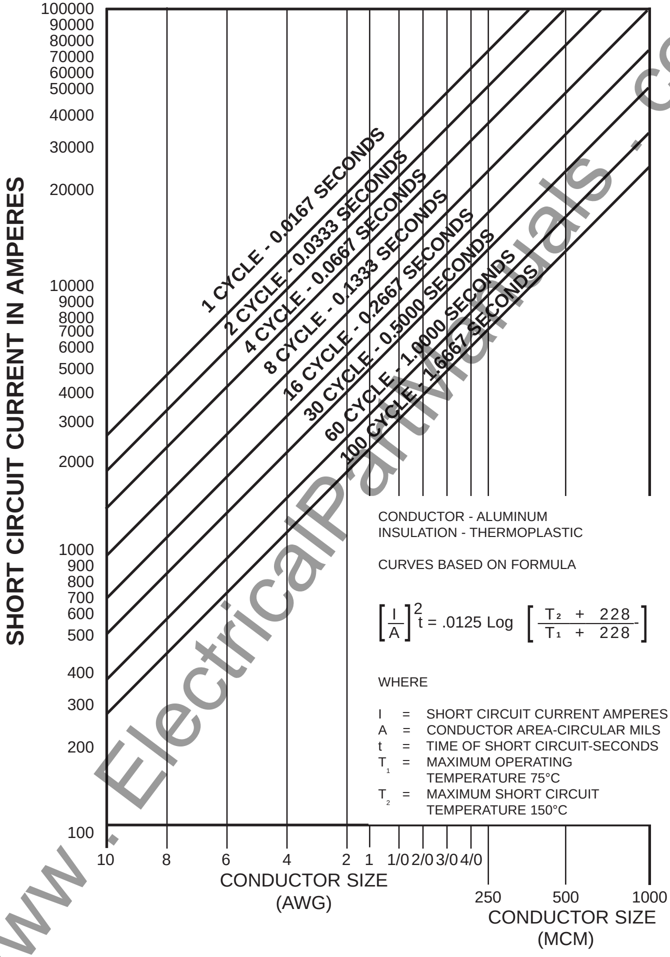
NOTES: (1) These ampacities are only applicable under special circumstances where the use of insulated conductors having this temperature rating are acceptable.

## Allowable Short Circuit Currents for Insulated Aluminum Conductors (90°C-RHH, RHW-2, XHH, XHHW, Etc.)



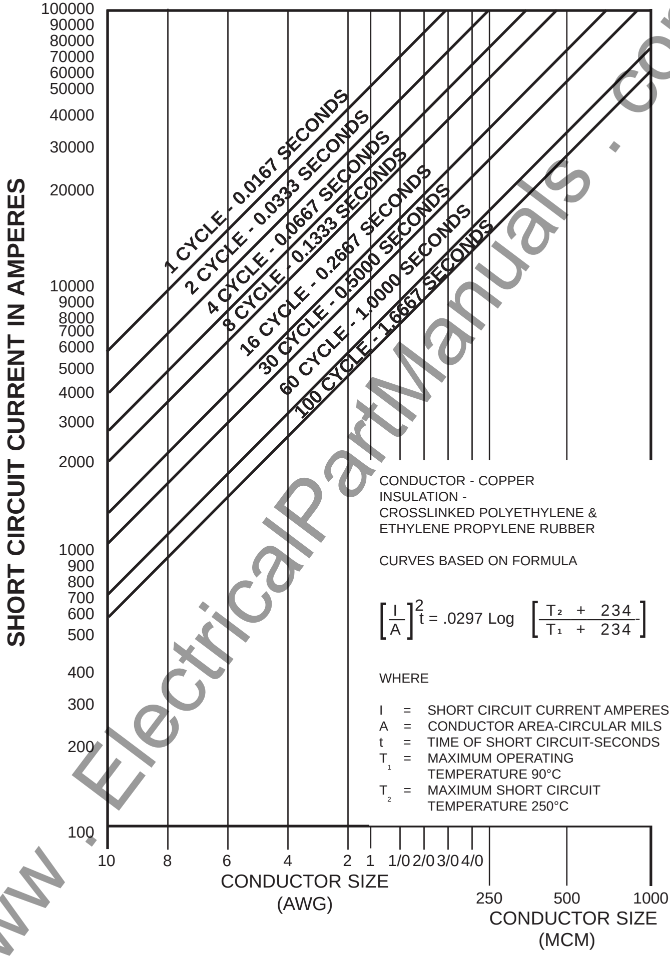

Source: Insulated Cable Engineers Association

## Allowable Short Circuit Currents for Insulated Aluminum Conductors (75°C-RH, RHW, THW, THHW, THWN, Etc.)




Source: Insulated Cable Engineers Association

## Allowable Short Circuit Currents for Insulated Copper Conductors (90°C-FEP, RHH, XHH, XHHW, Etc.)




CONDUCTOR - COPPER
INSULATION -
CROSSLINKED POLYETHYLENE &
ETHYLENE PROPYLENE RUBBER

CURVES BASED ON FORMULA

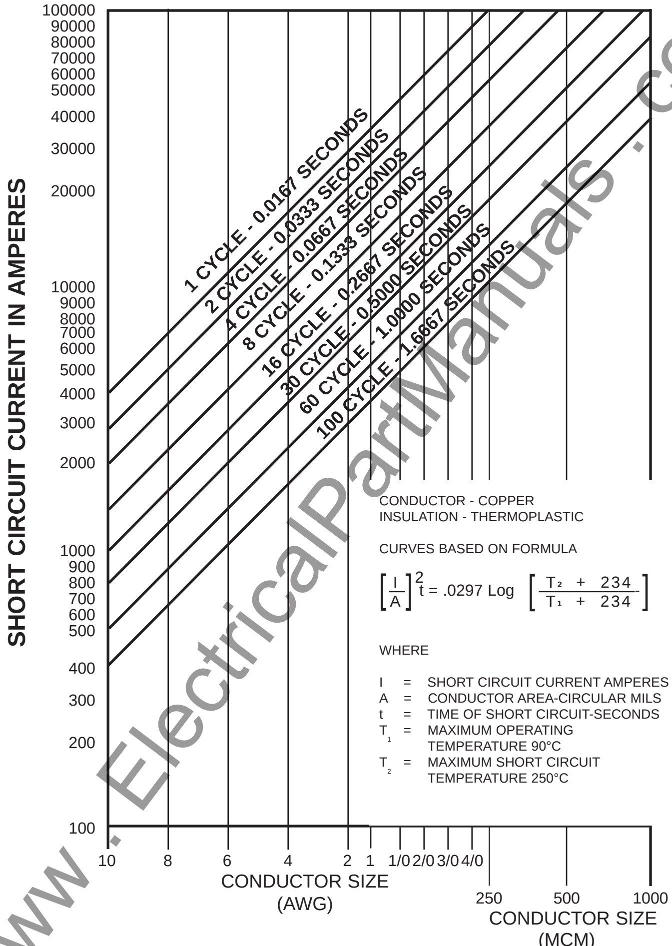
$$\left[\frac{I}{A}\right]^2 t = .0297 \text{ Log } \left[\frac{T_2 + 234}{T_1 + 234}\right]$$

WHERE

I = SHORT CIRCUIT CURRENT AMPERES
A = CONDUCTOR AREA-CIRCULAR MILS
t = TIME OF SHORT CIRCUIT-SECONDS
$T_1$ = MAXIMUM OPERATING TEMPERATURE 90°C
$T_2$ = MAXIMUM SHORT CIRCUIT TEMPERATURE 250°C

Source: Insulated Cable Engineers Association

## Allowable Short Circuit Currents for Insulated Copper Conductors (75°C-RH, RHW, THW, THHW, THWN, Etc.)




Source: Insulated Cable Engineers Association

# WIRE CALCULATIONS

## Ohm's Law

**Ohm's Law: $I = \frac{E}{R}$, where I is current;**

**E is voltage; and R is resistance.**

Example: With a voltage of 112 and a resistance of 8 ohms what current would flow?

$$I = \frac{112}{8} \text{ or 14 amperes}$$

Example: What resistance is necessary to obtain a current of 14 amperes at 112 volts?

$$R = \frac{E}{I} \text{ or } R = \frac{112}{14} \text{ or 8 ohms.}$$

Example: What voltage would be required to produce a flow of 14 amperes through a resistance of 8 ohms?

$$E = IR \text{ or } E = 14 \times 8 \text{ or 112 volts}$$

## Voltage Drop

The resistance of a copper wire one foot long and one circular mil in cross section is approximately 10.8 ohms. (Aluminum = 17.0 ohms).

In Ohm's law $I = \frac{E}{R}$, R is equal to: Length conductor in feet × 10.8 divided by the circular mills of the conductor or,

$$R = \frac{2 \times \text{feet (length of circuit)} \times 10.8}{CM}$$

Using Ohm's law, E = IR

$$E = \frac{\text{Amps} \times 2 \times \text{feet} \times 10.8}{CM}$$

where the term "feet" indicates the length of the circuit, the number of feet of wire in the circuit being double the length of the circuit.

Example: What would be the volts drop in a circuit of No. 12 wire carrying 20 amperes a distance of 50 feet? (Find CM on page 21).

$$E = \frac{20 \times 2 \times 50 \times 10.8}{6530} \text{ or 3.3 volts drop, or 3\% on a 110-volt circuit}$$

Example: What size of conductor would be necessary to give a 3% drop on a 110 volt circuit carrying 20 amperes a distance of 50 feet?

$$C = \frac{Amps \times 2 \times feet \times 10.8}{CM} \text{ or}$$

$$CM = \frac{20 \times 2 \times 50 \times 10.8}{3.3} \text{ or 6545 CM or a No. 12 wire.}$$

Example: What current can a No. 12 wire carry on a 50 foot circuit with a voltage drop of 3.3 volts.

$$Amp. = \frac{CM \times E}{2 \times feet \times 10.8} \text{ or}$$

$$I = \frac{6545 \times 3.3}{50 \times 2 \times 10.8} \text{ or 20 amperes.}$$

**Current Calculations**

The formula W = EI, where W = watts; E = voltage; I = current, can be used to determine the watts, W = EI; the voltage $E = \frac{W}{I}$; or the current, $I = \frac{W}{E}$. This formula is applicable where the power-factor is unity. To determine the current.

**2-Wire, Direct Current:** $I = \frac{W}{E}$.

**3-Wire, Direct Current:** $I = \frac{W}{2E}$ where E is the voltage between the outside wire and the neutral.

**2-Wire, Single-Phase:** $I = \frac{W}{E \times PF}$, where PF represents the power factor of the circuit.

**3-Wire, Single-Phase:** $I = \frac{W}{2E \times PF}$, where E is voltage between the outside wire and the neutral.

**3-Wire and 4-Wire, Three-Phase:** $I = \frac{W}{1.73\,E \times PF}$, where E is the voltage between outside wires.

# VOLTAGE DROP

## Direct Current or 100% Power Factor Alternating Current Circuits From the Handbook of Interior Wiring Design

This table can be used only for d-c or 100% power factor a-c loads such as single phase 2 or 3 wire, 3 phase 3 or 4 wire incandescent lamp circuits; resistance type heating units ; or unity power factor motors. All calculations are based on a copper temperature of 49°C.

| Wire Size | KILO-AMPERE FEET | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Volts Drop | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 14 | .177 | .354 | .531 | .705 | .866 | 1.06 | 1.06 | 1.24 | 1.77 |
| 12 | .282 | .563 | .845 | 1.13 | 1.41 | 1.69 | 1.97 | 2.25 | 2.82 |
| 10 | .448 | .895 | 1.34 | 1.79 | 2.24 | 2.69 | 3.13 | 3.58 | 4.48 |
| 8 | .712 | 1.42 | 2.14 | 2.85 | 3.56 | 4.27 | 4.98 | 5.69 | 7.12 |
| 6 | 1.11 | 2.22 | 3.33 | 4.44 | 5.55 | 6.66 | 7.77 | 8.88 | 11.1 |
| 4 | 1.76 | 3.53 | 5.29 | 7.06 | 8.82 | 10.6 | 12.3 | 14.1 | 17.6 |
| 2 | 2.88 | 5.75 | 8.63 | 11.5 | 14.4 | 17.3 | 20.1 | 23.0 | 28.8 |
| 1 | 3.54 | 7.07 | 10.6 | 14.1 | 17.7 | 21.2 | 24.8 | 28.3 | 35.4 |
| 1/0 | 4.46 | 8.91 | 13.4 | 17.8 | 22.3 | 26.7 | 31.2 | 35.6 | 44.6 |
| 2/0 | 5.62 | 11.2 | 16.9 | 22.5 | 28.1 | 33.7 | 39.3 | 44.9 | 56.2 |
| 3/0 | 7.08 | 14.2 | 21.2 | 28.3 | 35.4 | 42.5 | 49.6 | 56.6 | 70.8 |
| 4/0 | 8.92 | 17.8 | 26.7 | 35.7 | 44.6 | 53.5 | 62.4 | 71.3 | 89.2 |
| 250,000 cm | 10.5 | 21.0 | 31.6 | 42.1 | 52.6 | 63.1 | 73.7 | 84.2 | 105. |
| 300,000 cm | 12.6 | 25.2 | 37.8 | 50.4 | 63.0 | 75.6 | 88.2 | 101. | 126. |
| 350,000 cm | 14.7 | 29.3 | 44.0 | 58.7 | 73.3 | 88.0 | 103. | 117. | 147. |
| 400,000 cm | 16.7 | 33.4 | 50.2 | 66.9 | 83.6 | 100. | 117. | 134. | 167. |
| 500,000 cm | 20.8 | 41.5 | 62.3 | 83.1 | 104. | 125. | 145. | 166. | 208. |
| 750,000 cm | 30.5 | 60.9 | 91.4 | 122. | 152. | 183. | 213. | 244. | 305. |
| 1,000,000 cm | 39.5 | 79.0 | 118. | 158. | 198. | 237. | 277. | 316. | 395. |

Note: See next page for examples.

# USE OF VOLTAGE DROP TABLE

**1. To Find The Size of Wire Required for a Given Line Drop in Volts:**

a. Find the "kilo-ampere feet"by multiplying the current in amperes by the length of of one wire in feet (not the total length of wire in the circuit) and dividing by 1,000.

b. Starting with the given voltage drop, follow the column down to the number of kilo-ampere feet nearest to the actual number calculated. Follow the horizontal line and find the correct size of wire at the extreme left column.

c. With very short runs, the table may indicate that a size of wire smaller than permitted by Code regulations will hold the voltage drop within the limits desired. In such cases, the wire size must be increased to meet the Code requirements.

**2. To Find the Drop in Volts, Which Will be Produced by a Given Size of Wire:**

a. Find the kilo-ampere feet as above.

b. Starting with the given size of wire, follow the horizontal line to the right to the number of kilo-ampere feet nearest the actual number calculated. Follow this column up and find the drop in volts.

**3. Example**

A 23-KW balanced lighting load is to be supplied from 3-wire, 120-240 volt mains. The length of the run between service switch and distribution panel is 250 feet. The voltage drop is not to exceed 2 per cent. What size of conductor should be used? Solution:

On a balanced 3-wire system, the current in each of the outside wires would be calculated as follows:

$$\frac{\text{23 K.W} \times \text{1,000 (conversion to watts)}}{\text{240 V.}} = \text{95.8 amperes}$$

The kilo-ampere feet would equal:

$$\frac{\text{95.8 amperes} \times \text{250 ft.}}{\text{1,000}} = \text{22.0 kilo-ampere feet}$$

Since the permitted percentage voltage drop is 2, the actual drop permitted is:

$$.02 \times 240 = 4.8 \text{ volts}$$

To determine the wire size required, start at the top of column marked 5 volts (which is nearest to 4.8). Follow down until the figure 22.3 is reached (which is nearest 22.0) This would indicate the use of 1/0 conductors. The actual drop would then be:

$$\frac{22.0}{22.3} \times 5 \text{ volts} = 4.93 \text{ volts}$$

This degree of error (2.05 per cent instead of 2 per cent) is entirely permissible for feeder design.

## Three-Phase Line-to-Line Voltage Drop for 600 V Single-Conductor Cable per 10,000 A-ft.
## 60°C Conductor Temperature, 60 Hz
## (IEEE)

| To convert voltage drop to | Multiply by |
|---|---|
| Single phase, three wire, line to line | 1.18 |
| Single phase, three wire, line to neutral | 0.577 |
| Three phase, line to neutral | 0.577 |

| Load Power Factor Lagging | 1000 | 900 | 800 | 750 | 700 | 600 | 500 | 400 | 350 | 300 | 250 | 4/0 | 3/0 | 2/0 | 1/0 | 1 | 2 | 4 | 6 | 8* | 10 | 12* | 14* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Wire Size (AWG or kcmil) | | | | | | | | | | | | | | | | | | | | | | |
| Section 1: Copper Conductors in Magnetic Conduit | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | 0.28 | 0.31 | 0.34 | 0.35 | 0.37 | 0.42 | 0.50 | 0.60 | 0.68 | 0.78 | 0.92 | 1.1 | 1.4 | 1.7 | 2.1 | 2.6 | 3.4 | 5.3 | 8.4 | 13 | 21 | 33 | 53 |
| 0.95 | 0.50 | 0.52 | 0.55 | 0.57 | 0.59 | 0.64 | 0.71 | 0.81 | 0.88 | 1.0 | 1.1 | 1.3 | 1.5 | 1.9 | 2.3 | 2.8 | 3.5 | 5.3 | 8.2 | 13 | 20 | 32 | 50 |
| 0.90 | 0.57 | 0.59 | 0.62 | 0.64 | 0.66 | 0.71 | 0.78 | 0.88 | 0.95 | 1.1 | 1.2 | 1.3 | 1.6 | 1.9 | 2.3 | 2.8 | 3.4 | 5.2 | 8.0 | 12 | 19 | 30 | 48 |
| 0.80 | 0.66 | 0.68 | 0.71 | 0.73 | 0.74 | 0.80 | 0.85 | 0.95 | 1.0 | 1.1 | 1.2 | 1.4 | 1.6 | 1.9 | 2.3 | 2.6 | 3.2 | 4.8 | 7.3 | 11 | 17 | 27 | 43 |
| 0.70 | 0.71 | 0.73 | 0.76 | 0.78 | 0.80 | 0.83 | 0.88 | 0.97 | 1.0 | 1.1 | 1.2 | 1.3 | 1.5 | 1.8 | 2.1 | 2.5 | 3.0 | 4.4 | 6.6 | 9.9 | 15 | 24 | 38 |
| Section 2: Copper Conductors in Nonmagnetic Conduit | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | 0.23 | 0.26 | 0.28 | 0.29 | 0.33 | 0.38 | 0.45 | 0.55 | 0.62 | 0.73 | 0.88 | 1.0 | 1.3 | 1.6 | 2.1 | 2.6 | 3.3 | 5.3 | 8.4 | 13 | 21 | 33 | 53 |
| 0.95 | 0.40 | 0.43 | 0.45 | 0.47 | 0.50 | 0.54 | 0.62 | 0.71 | 0.80 | 0.92 | 1.0 | 1.1 | 1.5 | 1.8 | 2.2 | 2.7 | 3.4 | 5.3 | 8.2 | 13 | 20 | 32 | 50 |
| 0.90 | 0.47 | 0.48 | 0.52 | 0.54 | 0.55 | 0.59 | 0.68 | 0.76 | 0.85 | 0.95 | 1.1 | 1.1 | 1.5 | 1.8 | 2.2 | 2.7 | 3.3 | 5.1 | 7.9 | 12 | 19 | 30 | 48 |
| 0.80 | 0.54 | 0.55 | 0.57 | 0.59 | 0.62 | 0.66 | 0.73 | 0.81 | 0.88 | 0.97 | 1.1 | 1.1 | 1.4 | 1.7 | 2.1 | 2.5 | 3.1 | 4.7 | 7.2 | 11 | 17 | 27 | 43 |
| 0.70 | 0.57 | 0.59 | 0.62 | 0.64 | 0.66 | 0.69 | 0.74 | 0.83 | 0.88 | 0.97 | 1.1 | 1.1 | 1.4 | 1.6 | 2.0 | 2.4 | 2.8 | 4.3 | 6.4 | 9.7 | 15 | 24 | 38 |
| Section 3: Aluminum Conductors in Magnetic Conduit | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | 0.42 | 0.45 | 0.49 | 0.52 | 0.55 | 0.63 | 0.74 | 0.91 | 1.0 | 1.2 | 1.4 | 1.7 | 2.1 | 2.6 | 3.3 | 4.2 | 5.2 | 8.4 | 13 | 21 | 33 | 52 | - |
| 0.95 | 0.62 | 0.69 | 0.70 | 0.73 | 0.76 | 0.83 | 0.94 | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 2.3 | 2.7 | 3.4 | 4.2 | 5.3 | 8.2 | 13 | 20 | 32 | 50 | - |
| 0.90 | 0.69 | 0.72 | 0.76 | 0.79 | 0.82 | 0.88 | 0.99 | 1.2 | 1.3 | 1.4 | 1.6 | 1.9 | 2.3 | 2.7 | 3.4 | 4.1 | 5.1 | 7.9 | 12 | 19 | 30 | 48 | - |
| 0.80 | 0.76 | 0.80 | 0.83 | 0.85 | 0.88 | 0.95 | 1.0 | 1.2 | 1.3 | 1.4 | 1.6 | 1.8 | 2.2 | 2.6 | 3.2 | 3.9 | 4.7 | 7.3 | 11 | 17 | 27 | 43 | - |
| 0.70 | 0.80 | 0.83 | 0.87 | 0.89 | 0.92 | 0.98 | 1.1 | 1.2 | 1.3 | 1.4 | 1.6 | 1.7 | 2.1 | 2.4 | 2.9 | 3.6 | 4.3 | 6.5 | 10 | 15 | 24 | 37 | - |
| Section 4: Aluminum Conductors in Nonmagnetic Conduit | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00 | 0.36 | 0.39 | 0.44 | 0.47 | 0.51 | 0.59 | 0.70 | 0.88 | 1.0 | 1.2 | 1.4 | 1.7 | 2.1 | 2.6 | 3.3 | 4.2 | 5.2 | 8.4 | 13 | 21 | 33 | 52 | - |
| 0.95 | 0.52 | 0.56 | 0.60 | 0.63 | 0.67 | 0.74 | 0.85 | 1.0 | 1.1 | 1.3 | 1.5 | 1.8 | 2.2 | 2.7 | 3.4 | 4.2 | 5.2 | 8.2 | 13 | 20 | 32 | 50 | - |
| 0.90 | 0.57 | 0.61 | 0.65 | 0.68 | 0.71 | 0.79 | 0.89 | 1.1 | 1.2 | 1.3 | 1.5 | 1.8 | 2.2 | 2.6 | 3.3 | 4.1 | 5.0 | 7.9 | 12 | 19 | 30 | 48 | - |
| 0.80 | 0.63 | 0.66 | 0.71 | 0.73 | 0.76 | 0.83 | 0.92 | 1.1 | 1.2 | 1.3 | 1.5 | 1.7 | 2.1 | 2.5 | 3.1 | 3.8 | 4.6 | 7.2 | 11 | 17 | 27 | 42 | - |
| 0.70 | 0.66 | 0.69 | 0.73 | 0.75 | 0.78 | 0.83 | 0.92 | 1.1 | 1.1 | 1.3 | 1.4 | 1.6 | 1.7 | 2.3 | 2.8 | 3.4 | 4.2 | 6.4 | 9.9 | 15 | 24 | 37 | - |

*Solid Conductor. Other conductors are stranded.

## VOLTAGE DROP TABLE I.A.E.I. Circuit Footage for 3 Per Cent Drop
## COPPER CABLE

| Size AWG/MCM | 3 Amps | 6 Amps | 15 Amps | 20 Amps | 25 Amps | 35 Amps |
|---|---|---|---|---|---|---|
| 18 | 83 | -- | -- | -- | -- | -- |
| 16 | 131 | 66 | -- | -- | -- | -- |
| 14 | 209 | 104 | 42 | -- | -- | -- |
| 12 | 330 | 166 | 66 | 50 | -- | -- |
| 10 | 528 | 264 | 105 | 79 | 63 | -- |
| 8 | 840 | 420 | 168 | 126 | 100 | 72 |
| 6 | 1336 | 668 | 267 | 200 | 160 | 114 |
| 4 | 2125 | 1062 | 424 | 318 | 255 | 182 |
| 3 | 2680 | 1340 | 536 | 402 | 321 | 229 |
| 2 | 3379 | 1689 | 679 | 507 | 405 | 289 |
| 1 | 4262 | 2131 | 852 | 639 | 511 | 365 |
| 1/0 | 5372 | 2686 | 1074 | 806 | 644 | 460 |
| 2/0 | 6778 | 3389 | 1355 | 1016 | 813 | 581 |
| 3/0 | 8543 | 4272 | 1709 | 1281 | 1025 | 732 |
| 4/0 | -- | 5387 | 2155 | 1616 | 1293 | 923 |
| 250 | -- | -- | 2546 | 1911 | 1527 | 1091 |
| 300 | -- | -- | 3055 | 2291 | 1833 | 1309 |
| 350 | -- | -- | -- | 2673 | 2138 | 1526 |
| 400 | -- | -- | -- | 3055 | 2444 | 1746 |
| 500 | -- | -- | -- | -- | 3055 | 2182 |
| 600 | -- | -- | -- | -- | -- | 2619 |
| 700 | -- | -- | -- | -- | -- | 3055 |

## VOLTAGE DROP TABLE I.A.E.I. Circuit Footage for 3 Per Cent Drop

| Size AWG/MCM | 50 Amps | 70 Amps | 80 Amps | 90 Amps | 100 Amps | 125 Amps |
|---|---|---|---|---|---|---|
| 6 | 100 | -- | -- | -- | -- | -- |
| 4 | 127 | 91 | -- | -- | -- | -- |
| 3 | 160 | 114 | 100 | -- | -- | -- |
| 2 | 202 | 144 | 126 | 112 | -- | -- |
| 1 | 255 | 182 | 159 | 142 | 127 | -- |
| 1/0 | 322 | 230 | 201 | 179 | 161 | 128 |
| 2/0 | 405 | 290 | 254 | 225 | 203 | 162 |
| 3/0 | 512 | 366 | 320 | 284 | 256 | 205 |
| 4/0 | 646 | 461 | 404 | 359 | 323 | 258 |
| 250 | 763 | 545 | 477 | 424 | 381 | 305 |
| 300 | 916 | 654 | 572 | 509 | 458 | 366 |
| 350 | 1069 | 763 | 667 | 594 | 534 | 427 |
| 400 | 1222 | 873 | 763 | 679 | 611 | 488 |
| 500 | 1527 | 1091 | 934 | 848 | 763 | 611 |
| 600 | 1833 | 1309 | 1145 | 1018 | 916 | 733 |
| 700 | 2138 | 1527 | 1336 | 1188 | 1069 | 855 |

## VOLTAGE DROP TABLE I.A.E.I., cont. Circuit Footage for 3 Per Cent Drop

| Size AWG/MCM | 150 Amps | 175 Amps | 225 Amps | 250 Amps | 275 Amps | 300 Amps |
|---|---|---|---|---|---|---|
| 2/0 | 135 | -- | -- | -- | -- | -- |
| 3/0 | 170 | 143 | -- | -- | -- | -- |
| 4/0 | 215 | 184 | 143 | -- | -- | -- |
| 250 | 254 | 218 | 169 | 152 | -- | -- |
| 300 | 305 | 261 | 203 | 183 | 166 | -- |
| 350 | 356 | 305 | 237 | 213 | 194 | 178 |
| 400 | 407 | 349 | 271 | 244 | 220 | 203 |
| 500 | 509 | 436 | 339 | 305 | 277 | 254 |
| 600 | 611 | 523 | 407 | 366 | 333 | 305 |
| 700 | 712 | 611 | 475 | 427 | 389 | 356 |
| 750 | 763 | 654 | 509 | 458 | 416 | 381 |
| 800 | 814 | 698 | 543 | 488 | 444 | 407 |
| 900 | 916 | 785 | 611 | 550 | 500 | 458 |
| 1000 | 1018 | 873 | 679 | 611 | 555 | 509 |
| 1100 | 1120 | 960 | 746 | 672 | 611 | 560 |
| 1200 | 1222 | 1047 | 814 | 733 | 666 | 611 |
| 1300 | 1324 | 1134 | 882 | 794 | 722 | 662 |
| 1400 | 1425 | 1222 | 950 | 855 | 777 | 712 |
| 1500 | 1527 | 1309 | 1018 | 916 | 832 | 763 |
| 1600 | 1628 | 1396 | 1064 | 976 | 888 | 814 |
| 1700 | 1728 | 1484 | 1154 | 1038 | 944 | 864 |
| 1800 | 1832 | 1571 | 1222 | 1110 | 1000 | 916 |
| 1900 | 1932 | 1664 | 1290 | 1160 | 1054 | 966 |
| 2000 | 2036 | 1746 | 1358 | 1222 | 1110 | 1018 |

## VOLTAGE DROP TABLE I.A.E.I. Circuit Footage for 3 Per Cent Drop

| Size AWG/MCM | 325 Amps | 400 Amps | 450 Amps | 500 Amps | 525 Amps | 550 Amps |
|---|---|---|---|---|---|---|
| 400 | 188 | -- | -- | -- | -- | -- |
| 500 | 235 | 190 | -- | -- | -- | -- |
| 600 | 282 | 229 | 203 | -- | -- | -- |
| 700 | 329 | 267 | 237 | 213 | -- | -- |
| 750 | 352 | 286 | 254 | 229 | 218 | -- |
| 800 | 376 | 305 | 271 | 244 | 232 | 222 |
| 900 | 423 | 343 | 305 | 275 | 261 | 250 |
| 1000 | 470 | 381 | 339 | 305 | 291 | 277 |
| 1100 | 517 | 420 | 373 | 336 | 320 | 305 |
| 1200 | 564 | 458 | 407 | 366 | 349 | 333 |
| 1300 | 611 | 496 | 441 | 397 | 378 | 361 |
| 1400 | 657 | 534 | 475 | 427 | 407 | 388 |
| 1500 | 705 | 572 | 509 | 458 | 436 | 416 |
| 1600 | 752 | 611 | 532 | 488 | 465 | 444 |
| 1700 | 799 | 649 | 577 | 519 | 495 | 472 |
| 1800 | 846 | 687 | 611 | 555 | 523 | 500 |
| 1900 | 892 | 725 | 645 | 580 | 555 | 527 |
| 2000 | 940 | 763 | 679 | 611 | 582 | 555 |

## VOLTAGE DROP TABLE I.A.E.I., cont. Circuit Footage for 3 Per Cent Drop

| Size AWG/MCM | 600 Amps | 650 Amps | 690 Amps | 730 Amps | 770 Amps | 810 Amps |
|---|---|---|---|---|---|---|
| 900 | 229 | -- | -- | -- | -- | -- |
| 1000 | 254 | 235 | -- | -- | -- | -- |
| 1100 | 280 | 258 | 243 | -- | -- | -- |
| 1200 | 305 | 282 | 265 | 251 | -- | -- |
| 1300 | 331 | 305 | 287 | 272 | 258 | -- |
| 1400 | 356 | 328 | 309 | 292 | 277 | 264 |
| 1500 | 381 | 352 | 332 | 313 | 297 | 282 |
| 1600 | 407 | 376 | 354 | 334 | 339 | 301 |
| 1700 | 432 | 399 | 376 | 355 | 361 | 320 |
| 1800 | 458 | 423 | 398 | 376 | 382 | 339 |
| 1900 | 483 | 446 | 420 | 397 | 403 | 358 |
| 2000 | 509 | 470 | 442 | 418 | 424 | 377 |

## VOLTAGE DROP TABLE I.A.E.I. Circuit Footage for 3 Per Cent Drop

| Size AWG/MCM | 850 Amps | 890 Amps | 930 Amps | 970 Amps | 1010 Amps | 1050 Amps |
|---|---|---|---|---|---|---|
| 1500 | 269 | -- | -- | -- | -- | -- |
| 1600 | 287 | 274 | -- | -- | -- | -- |
| 1700 | 305 | 291 | 279 | -- | -- | -- |
| 1800 | 323 | 308 | 295 | 283 | -- | -- |
| 1900 | 341 | 325 | 312 | 299 | 287 | -- |
| 2000 | 359 | 343 | 328 | 315 | 302 | 291 |

Notes: Tables calculated for 110 volts dc. The footages shown are approximate for single-phase and two-phase at unity power factor. For 3-phase, the above footage may be increased by approximately 12 percent. The following factors may be used for other voltages:

220 volts -- multiply by 2
440 volts -- multiply by 4
550 volts -- multiply by 5
2200 volts -- multiply by 20

For 1 percent drop, allow one third the footage shown. For 2 percent drop, allow two-thirds the footage shown.

These tables compiled by G.M. Miller, Richmond, Virginia.

# LINE CURRENT AND VOLTAGE DROP

## (Simplex Wire & Cable Co.)

In the following formulas for line current and voltage drop, the meaning of most of the symbols will be found on the circuit diagrams. For completeness, they are also defined here. It should be emphasized that the letter E with subscripts is always used to designate circuit voltage. The primed values describe sending end conditions; and unprimed values, receiving end conditions. The letter V with subscripts always signifies a voltage drop.

Let $I$ = line current, amps

$E'_o$, $E_o$ = sending and receiving end voltages to neutral, volts

$E'_l$, $E_l$ = sending and receiving end voltages between lines, volts

$E'_p$, $E_p$ = sending and receiving end voltages per phase, volts

$Vo$ = $E'_o - E_o$ = voltage drop to neutral, volts

$V_l$ = $E'_l - E_l$ = voltage drop between lines, volts

$V_p$ = $E'_p - E_p$ = voltage drop per phase, volts

$R$ = D.C. or A.C. resistance of line, ohms per1000 ft. per conductor

$X$ = 60 cycle Reactance of line, ohms per 1000 ft. per conductor

$Z$ = 60 cycle Impedance of line, ohms per 1000 ft. per conductor

$I$ = length of line, feet

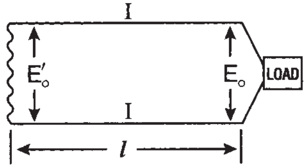
$W$ = watts delivered

$p.f.$ = $\cos \theta$ = power factor of load

$\theta$ = power factor angle of load

There is a SHAWMUT fuse for every purpose. Where you can use a fuse, use a SHAWMUT fuse; for a SHAWMUT fuse is the fuse to use. SHAWMUT engineering has seen to that, from the fullest experience in both shop and field, over a period of many years. Specify SHAWMUT fuses by name when you order fuses; it is the way to be sure that you will get the exact performance and protection you require.

**D.C - 2 WIRE**




$$I = \frac{W}{E} \text{ amps.}$$

$$V = E'_o - E_o = \frac{I \times R \times 2l}{1000} \text{ volts drop}$$

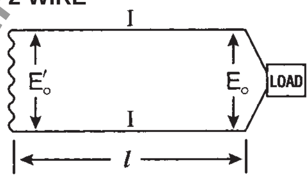
**D.C - 3 WIRE - BALANCED LOAD**


$$I = \frac{W}{2E_o} = \frac{W}{E_l} \text{ amps.}$$

$$V_o = E'_o - E_o = \frac{I \times R \times l}{1000} \text{ volts drop to neutral}$$

or $$V_l = E'_l - E_l = \frac{I \times R \times 2l}{1000} \text{ volts drop between lines}$$

**A.C - SINGLE PHASE - 2 WIRE**



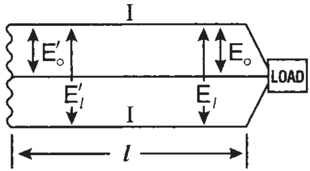

$$I = \frac{W}{E_o \times p.f.} \text{ amps.}$$

$$V_o = E'_o - E_o = \left[\sqrt{(E_o \cos\theta + IR)^2 + (E_o \sin\theta + IX)^2} - E_o\right]$$

$$\times \frac{2l}{1000} \text{ volts drop}$$

$$= \frac{I \times Z \times 2l}{1000} \text{ volts drop (approx.)}$$

## A.C - SINGLE PHASE - 3 WIRE - BALANCED LOAD



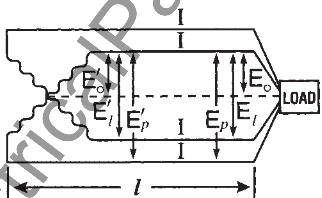

$$I = \frac{W}{2E_o \times p.f.} = \frac{W}{E_l \times p.f.} \text{ amps.}$$

$$V_o = E'_o - E_o = \left[\sqrt{(E_o \cos\theta + IR)^2 + (E_o \sin\theta + IX)^2} - E_o\right] \times \frac{l}{1000} \text{ volts drop to neutral}$$

$$= \frac{I \times Z \times 2l}{1000} \text{ volts drop (approx.)}$$

$$V_l = E'_l - E_l = \frac{I \times Z \times 2l}{1000} \text{ volts drop between lines (approx.)}$$

## A.C - TWO PHASE - 4 OR 5 WIRE - BALANCED LOAD




$$E_o = \frac{1}{\sqrt{2}} E = \frac{1}{2} E_p$$

$$I = \frac{W}{4E_o \times p.f.} = \frac{W}{2\sqrt{2}E_l \times p.f.} = \frac{W}{2E_p \times p.f.} \text{ amps.}$$

$$V_o = E'_o - E_o = \left[\sqrt{(E_o \cos\theta + IR)^2 + (E_o \sin\theta + IX)^2} - E_o\right] \times \frac{l}{1000} \text{ volts drop to neutral}$$

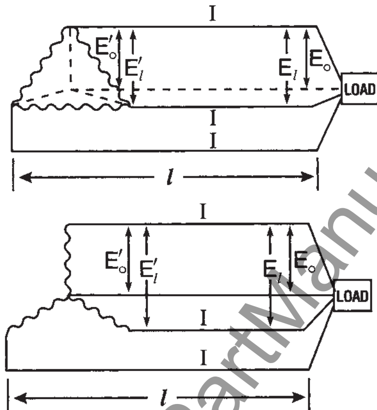
$$= \frac{I \times Z \times l}{1000} \text{ volts drop to neutral (approx.)}$$

$$V_l = E'_l - E_l = \frac{I \times Z \times \sqrt{2}\, l}{1000} \text{ volts drop between lines (approx.)}$$

$$V_p = E'_p - E_p = \frac{I \times Z \times 2l}{1000} \text{ volts drop per phase (approx.)}$$

When the line supplies a balanced load, the neutral wire carries no current Therefore, the formulas are the same whether there is a neutral wire or not (4 or 5-wire circuit).

## A.C - THREE PHASE -3 OR 4 WIRE - BALANCED LOAD




$$E_o = \frac{1}{\sqrt{3}} E$$

$$I = \frac{W}{3 E_o \times p.f.} = \frac{W}{\sqrt{3}\ E_l \times p.f.} = \text{amps.}$$

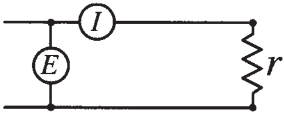
$$V_o = E'_o - E_o = \left[\sqrt{(E_o \cos\theta + IR)^2 + (E_o \sin\theta + IX)^2} - E_o\right] \times \frac{l}{1000} \text{ volts drop to neutral}$$

$$= \frac{I \times Z \times l}{1000} \text{ volts drop to neutral (approx.)}$$

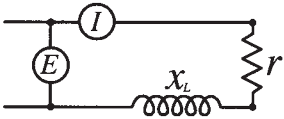
$$V_l = E'_l - E_l = \frac{I \times Z \times \sqrt{3}\, l}{1000} \text{ volts drop between lines (approx.)}$$

When the line supplies a balanced load, the neutral wire carries no current. Therefore, the formulas are the same whether there is a neutral wire or not (3 or 4 wire circuit).

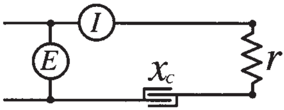
# FORMULAE FOR DETERMINING CURRENT IN ALTERNATING CURRENT CIRCUITS



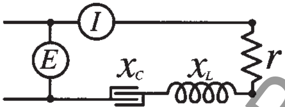

$$I = \frac{E}{r}$$



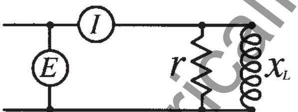

$$I = \frac{E}{\sqrt{r^2 + X_L^2}} = \frac{E}{Z}$$




$$I = \frac{E}{\sqrt{r^2 + X_C^2}} = \frac{E}{Z}$$

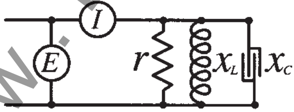



$$I = \frac{E}{\sqrt{r^2 + (X_L - X_C)^2}} = \frac{E}{Z}$$




$$I = \frac{E}{\dfrac{r X_L}{\sqrt{r^2 + X_L^2}}} = \frac{E}{Z}$$


$$I = \frac{E}{\dfrac{r X_C}{\sqrt{r^2 + X_C^2}}} = \frac{E}{Z}$$

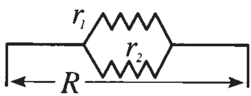



$$I = \frac{E}{\dfrac{r X_L X_C}{\sqrt{X_L^2 X_C^2 + r^2 (X_L - X_C)^2}}} = \frac{E}{Z}$$

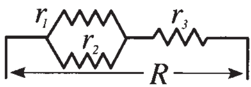
r = Resistance in ohms
$X_L$ = Inductive reactance in ohms
$X_C$ = Capacitive reactance in ohms
Z = Impedance in ohms
I = Current in amperes
E = Voltage in volts

## FORMULAE FOR COMBINING RESISTANCE AND REACTANCE

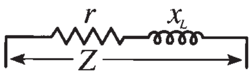

$$R = r$$



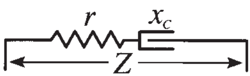

$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{r_1 r_2}{r_1 + r_2}$$



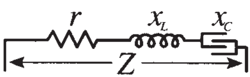

$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}} + r_3 = \frac{r_1 r_2}{r_1 + r_2} + r_3$$




$$Z = \sqrt{r^2 + X_L^2}$$



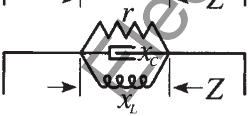

$$Z = \sqrt{r^2 + X_C^2}$$




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


$$Z = \frac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_L}\right)^2}} = \frac{r X_L}{\sqrt{r^2 + X_L^2}}$$


$$Z = \frac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_C}\right)^2}} = \frac{r X_C}{\sqrt{r^2 + X_C^2}}$$




$X_L$

$$Z = \frac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}} = \frac{r X_L X_C}{\sqrt{X_L^2 X_C^2 + r^2 (X_L - X_C)^2}}$$

R = Resistance in ohms

$X_L$ = Inductive reactance in ohms $\omega L = 2\pi fL$

$X_C$ = Capacitive reactance in ohms $\frac{1}{\omega C} = \frac{1}{2\pi f C}$

Z = Impedance in ohms

f = Frequency in cycles per second

L = Inductance in henrys

C = Capacitance in farads

$2\pi$ = 2 x 3.1416 = 6.2832

# USEFUL ELECTRICAL FORMULA FOR DETERMINING AMPERES, HORSEPOWER, KILOWATTS, AND K.V.A.

| To Find | Direct Current | ALTERNATING CURRENT | | |
|---|---|---|---|---|
| | | Single-Phase | Two-Phase* Four-Wire | Three-Phase |
| Amperes when Horsepower is known | $\frac{H.P. \times 746}{E \times E_{FF.}}$ | $\frac{H.P. \times 746}{E \times E_{FF.} \times P.F.}$ | $\frac{H.P. \times 746}{2 \times E \times E_{FF.} \times P.F.}$ | $\frac{H.P. \times 746}{1.73 \times E \times E_{FF.} \times P.F.}$ |
| Amperes when Kilowatts are Known | $\frac{K.W. \times 1000}{E}$ | $\frac{K.W.\ 1000}{E \times P.F.}$ | $\frac{K.W. \times 1000}{2 \times E \times P.F.}$ | $\frac{K.W. \times 1000}{1.73 \times E \times P.F.}$ |
| Amperes when K.V. A. is known | | $\frac{K.V.A. \times 1000}{E}$ | $\frac{K.V.A. \times 1000}{2 \times E}$ | $\frac{K.V.A. \times 1000}{1.73 \times E}$ |
| Kilowatts | $\frac{I \times E}{1000}$ | $\frac{I \times E \times P.F.}{1000}$ | $\frac{I \times E \times 2 \times P.F.}{1000}$ | $\frac{I \times E \times 1.73 \times P.F.}{1000}$ |
| K.V.A. | | $\frac{I \times E}{1000}$ | $\frac{I \times E \times 2}{1000}$ | $\frac{I \times E \times 1.73}{1000}$ |
| Horsepower (Output) | $\frac{I \times E \times E_{FF.}}{746}$ | $\frac{I \times E \times E_{FF.} \times P.F.}{746}$ | $\frac{I \times E \times 2 \times E_{FF.} \times P.F.}{746}$ | $\frac{I \times E \times 1.73 \times E_{FF.} \times P.F.}{746}$ |

I = Amperes; E = Volts; $E_{FF.}$ = Efficiency; P.F. = Power Factor
K.W. = Kilowatts; K.V.A. = Kilo-Volt-Amperes; H.P. = Horsepower
*For three wire, two phase circuits the current in the common conductor is 1.41 times that in either of the other two conductors.
For average values of efficiency and power factor see page 54.

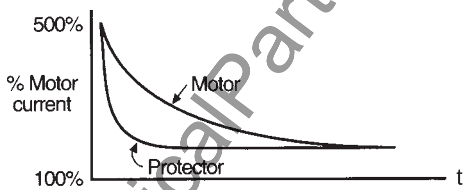
# MOTOR OVERCURRENT PROTECTION

Overcurrent protection of motors is a threefold problem involving normal starting currents, stalled rotors, and running overloads.

Many motors draw starting currents several times their full-load ratings, and because of the transient nature of these currents no harm is done to the motors nor any part of the electrical system.

In most applications motors are selected which have a horsepower rating equal to the power required by the application under normal conditions; and since motors are capable of carrying overloads for short periods without excessive heating, a properly designed and selected overcurrent protective device makes this temporary overload capacity available.

## TRIPPING CHARACTERISTICS OF A CURRENT SENSITIVE DEVICE COMPARED WITH MOTOR CURRENT-TIME CURVE




Motor-time to reach dangerous temperature
Protector-time to trip.

The above chart shows the inverse-time characteristics of motors and protective devices. When these curves coincide the entire motor capacity becomes available. Whenever the protector curve moves to the right of the motor curve the motor is inadequately protected. A protector curve to the left gives a margin of safety.

Non time delay fuses have time-current curves which cross the motor curve, but time-delay fuses (such as Ferraz Amp-Trap 2000 fuses or TRI-ONIC fuses) have characteristic curves which more nearly approximate the motor curve and when properly selected both protect the motor at all loads and make available most of the motor capacity.

# IDENTIFICATION OF MOTORS

The National Electrical Code rules and the standards of the National Electrical Manufacturers Association require that all alternating current motors rated at 1/2 horse power or larger, except polyphase wound-rotor motors, shall have the name-plate marked with a code letter to show its input in kilovolt-amperes with locked rotor, selected from the following table:

| 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 | | |

Knowing the horsepower and voltage rating of any particular motor, its locked rotor current may be determined from the "Locked KVA per Horsepower" by a simple formula which is:

**For Single-phase Motors**

$$\text{Locked rotor current} = \frac{\text{(Locked KVA per h.p.) (rated h.p.) 1000}}{\text{(rated voltage)}}$$

**For Three-phase Motors**

$$\text{Locked rotor current} = \frac{\text{(Locked KVA per h.p.) (rated h.p.) 1000}}{\text{(rated voltage)}\ \sqrt{3}}$$

**For Two-phase Motors**

$$\text{Locked rotor current} = \frac{\text{(Locked KVA per h.p.) (rated h.p.) 1000}}{\text{(rated voltage) 2}}$$

**Example**

Taking a 1/2 h.p., 220 volt, 3-phase motor with an "L" code letter

$$\text{Locked rotor current} = \frac{9.0 \times 1/2 \times 1000}{220\sqrt{3}} = 11.8 \text{ amperes (Minimum)}$$

$$\frac{9.99 \times 1/2 \times 1000}{220\sqrt{3}} = 13.1 \text{ amperes (Maximum)}$$

Therefore, the locked rotor current will be not less than 11.8 nor more than 13.1 amperes.

# AVERAGE EFFICIENCY AND POWER FACTOR VALUES OF MOTORS

## APPROXIMATE LOCKED ROTOR CURRENTS OF 3-PHASE SQUIRREL CAGE INDUCTION MOTORS

| HP | LOCKED ROTOR CURRENT IN AMPERES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DESIGN B, C AND D MOTORS* | | | | | HIGH EFFICIENCY MOTOR** | | | | |
| | 115V | 208V | 230V | 460V | 575V | 115V | 208V | 230V | 460V | 575V |
| 1/2 | 24.0 | 13.2 | 12.0 | 6.00 | 0.48 | 32.0 | 17.6 | 16.0 | 8.00 | 0.64 |
| 3/4 | 33.6 | 18.6 | 16.8 | 8.40 | 6.60 | 44.8 | 24.8 | 22.4 | 11.2 | 8.80 |
| 1 | 43.2 | 24.0 | 21.6 | 10.8 | 8.40 | 57.6 | 32.0 | 28.8 | 14.4 | 11.2 |
| 1-1/2 | 62.4 | 34.2 | 31.2 | 15.6 | 12.6 | 83.2 | 45.6 | 41.6 | 20.8 | 16.8 |
| 2 | 81.6 | 45.0 | 40.8 | 20.4 | 16.2 | 109 | 60.0 | 54.4 | 27.2 | 21.6 |
| 3 | -- | 63.6 | 57.6 | 28.8 | 23.4 | -- | 84.8 | 76.8 | 38.4 | 31.2 |
| 5 | -- | 100 | 91.2 | 45.6 | 36.6 | -- | 134 | 122 | 60.8 | 48.8 |
| 7-1/2 | -- | 145 | 132 | 66.0 | 54.0 | -- | 194 | 176 | 88.0 | 72.0 |
| 10 | -- | 185 | 168 | 84.0 | 66.0 | -- | 246 | 224 | 112 | 88.0 |
| 15 | -- | 277 | 252 | 126 | 102 | -- | 370 | 336 | 168 | 136 |
| 20 | -- | 356 | 324 | 162 | 132 | -- | 475 | 432 | 216 | 176 |
| 25 | -- | 449 | 408 | 204 | 162 | -- | 598 | 644 | 272 | 216 |
| 30 | -- | 528 | 480 | 240 | 192 | -- | 704 | 640 | 320 | 256 |
| 40 | -- | 686 | 624 | 312 | 246 | -- | 915 | 832 | 416 | 328 |
| 50 | -- | 858 | 780 | 390 | 312 | -- | 1140 | 1040 | 520 | 416 |
| 60 | -- | 1020 | 924 | 462 | 372 | -- | 1360 | 1230 | 616 | 496 |
| 75 | -- | 1270 | 1150 | 576 | 462 | -- | 1690 | 1540 | 768 | 616 |
| 100 | -- | 1640 | 1490 | 744 | 594 | -- | 2180 | 1980 | 992 | 792 |
| 125 | -- | 2060 | 1870 | 936 | 750 | -- | 2750 | 2500 | 1250 | 1000 |
| 150 | -- | 2380 | 2160 | 1080 | 864 | -- | 3170 | 2880 | 1440 | 1150 |
| 200 | -- | 3170 | 2880 | 1440 | 1150 | -- | 4220 | 3840 | 1920 | 1540 |

* Approx. 6 times the full-load currents shown on previous pages.
** Approx. 8 times the full-load currents shown on previous pages.

When the actual efficiencies and power factors of the motors to be controlled are not known, the following approximations may be used:

Efficiencies:

| | |
|---|---|
| D.C. motors, 35 horsepower and less | 80% to 85% |
| D.C. motors, above 35 horsepower | 85% to 90% |
| Synchronous motors (at 100% power factor) | 92% to 95% |

(“Apparent” efficiencies = Efficiency X power factor):

| | |
|---|---|
| Three phase induction motors, 25 horsepower and less | 70% |
| Three phase induction motors above 25 horsepower | 80% |

“High Efficiency” Three-Phase Motors:

| | |
|---|---|
| Induction motors, 20 horsepower and less | 88% to 92% |
| Induction motors, over 20 horsepower | 93% to 95% |

These figures may be decreased slightly for single-phase and two-phase induction motors.

# FULL LOAD CURRENT IN AMPERES
# FOR DC AND SINGLE PHASE AC MOTORS

| | DC MOTORS | | | SINGLE PHASE AC MOTORS | | |
|---|---|---|---|---|---|---|
| **HP** | **120V** | **240V** | **550V** | **115V** | **208V** | **230V** |
| 1/6 | -- | -- | -- | 4.4 | 2.4 | 2.2 |
| 1/4 | 3.1 | 1.6 | -- | 5.8 | 3.2 | 2.9 |
| 1/3 | 4.1 | 2.0 | -- | 7.2 | 4.0 | 3.6 |
| 1/2 | 5.4 | 2.7 | -- | 9.8 | 5.4 | 4.9 |
| 3/4 | 7.6 | 3.8 | -- | 13.8 | 7.6 | 6.9 |
| 1 | 9.5 | 4.7 | -- | 16 | 8.8 | 8.0 |
| 1-1/2 | 13.2 | 6.6 | -- | 20 | 11 | 10 |
| 2 | 17 | 8.5 | -- | 24 | 13.2 | 12 |
| 3 | 25 | 12.2 | -- | 34 | 18.7 | 17 |
| 5 | 40 | 20 | -- | 56 | 30.8 | 28 |
| 7-1/2 | 58 | 29 | 12.2 | 80 | 44 | 40 |
| 10 | 76 | 38 | 16 | 100 | 55 | 50 |
| 15 | -- | 55 | 24 | -- | -- | -- |
| 20 | -- | 72 | 31 | -- | -- | -- |
| 25 | -- | 89 | 38 | -- | -- | -- |
| 30 | -- | 106 | 46 | -- | -- | -- |
| 40 | -- | 140 | 61 | -- | -- | -- |
| 50 | -- | 173 | 75 | -- | -- | -- |
| 60 | -- | 206 | 90 | -- | -- | -- |
| 75 | -- | 255 | 111 | -- | -- | -- |
| 100 | -- | 341 | 148 | -- | -- | -- |
| 125 | -- | 425 | 185 | -- | -- | -- |
| 150 | -- | 506 | 222 | -- | -- | -- |
| 200 | -- | 675 | 294 | -- | -- | -- |

# FULL LOAD CURRENT IN AMPERES
# SQUIRREL CAGE MOTORS

| HP | TWO PHASE 115V | TWO PHASE 230V | TWO PHASE 460V | TWO PHASE 575V | THREE PHASE 115V | THREE PHASE 230V | THREE PHASE 460V | THREE PHASE 575V |
|---|---|---|---|---|---|---|---|---|
| 1/2 | 4 | 2.0 | 1.0 | 0.8 | 4.4 | 2.2 | 1.1 | 0.9 |
| 3/4 | 4.8 | 2.4 | 1.2 | 1.0 | 6.4 | 3.2 | 1.6 | 1.3 |
| 1 | 6.4 | 3.2 | 1.6 | 1.3 | 8.4 | 4.2 | 2.1 | 1.7 |
| 1-1/2 | 9.0 | 4.5 | 2.3 | 1.8 | 12 | 6.0 | 3.0 | 2.4 |
| 2 | 11.8 | 5.9 | 3.0 | 2.4 | 13.6 | 6.8 | 3.4 | 2.7 |
| 3 | -- | 8.3 | 4.2 | 3.3 | -- | 9.6 | 4.8 | 3.9 |
| 5 | -- | 13.2 | 6.6 | 5.3 | -- | 15.2 | 7.6 | 6.1 |
| 7-1/2 | -- | 19 | 9.0 | 8.0 | -- | 22 | 11 | 9.0 |
| 10 | -- | 24 | 12 | 10 | -- | 28 | 14 | 11 |
| 15 | -- | 36 | 18 | 14 | -- | 42 | 21 | 17 |
| 20 | -- | 47 | 23 | 19 | -- | 54 | 27 | 22 |
| 25 | -- | 59 | 29 | 24 | -- | 68 | 34 | 27 |
| 30 | -- | 69 | 35 | 28 | -- | 80 | 40 | 32 |
| 40 | -- | 90 | 45 | 36 | -- | 104 | 52 | 41 |
| 50 | -- | 113 | 56 | 45 | -- | 130 | 65 | 52 |
| 60 | -- | 133 | 67 | 53 | -- | 154 | 77 | 62 |
| 75 | -- | 166 | 83 | 66 | -- | 192 | 96 | 77 |
| 100 | -- | 218 | 109 | 87 | -- | 248 | 124 | 99 |
| 125 | -- | 270 | 135 | 108 | -- | 312 | 156 | 125 |
| 150 | -- | 312 | 156 | 125 | -- | 360 | 180 | 144 |
| 200 | -- | 416 | 208 | 167 | -- | 480 | 240 | 192 |

## CURRENT CORRECTION FACTORS
FOR LOW SPEED SQUIRREL CAGE MOTORS

| Synchronous Speed rpm | Multiplying Factor |
|---|---|
| 1800 | 1.00 |
| 1200 | 1.00 |
| 900 | 1.02 |
| 720 | 1.05 |
| 600 | 1.09 |
| 450 | 1.13 |
| 400 | 1.16 |
| 360 | 1.19 |
| 327 | 1.21 |
| 277 | 1.25 |
| 257 | 1.27 |

**AMPERE RATINGS OF SYNCHRONOUS MOTORS AT FULL LOAD**
**(Electric Machinery Mfg. Co.)**

Amperes given below are based on average efficiency for given H.P. at all speeds. For instance, 25 H.P. amperes are based on 87% Eff. for all speeds and 1000 H.P. on 95% Eff. for all speeds. For 80% P.F. amperes, multiply 100% P.F. values by 1.29.

| H.P. | Assumed Efficiency | 3-Ph. Amperes at 100% P.F. | | | | | 2-Ph. Amperes at 100% P.F. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 220 V. | 440 V. | 550 V. | 2200 V. | 4000 V. | 220 V. | 440 V. | 550 V. | 2200 V. | 4000 V. |
| 20 | 86.0 | 45.5 | 23 | 18.5 | -- | -- | 39.4 | 19.9 | 16 | -- | -- |
| 25 | 87.0 | 56 | 28 | 22.5 | -- | -- | 48.5 | 24.2 | 19.5 | -- | -- |
| 30 | 88.0 | 67 | 33.5 | 27 | -- | -- | 58 | 29 | 23.4 | -- | -- |
| 40 | 89.0 | 88 | 44 | 35 | 9 | -- | 76.2 | 38.1 | 30.6 | 7.8 | -- |
| 50 | 89.5 | 110 | 55 | 44 | 11 | -- | 95.3 | 47.6 | 38.1 | 9.5 | -- |
| 60 | 90.0 | 131 | 66 | 53 | 13.1 | -- | 113.5 | 57.2 | 45.9 | 11.4 | -- |
| 75 | 91.0 | 162 | 81 | 65 | 16.2 | -- | 140 | 70 | 56.3 | 14 | -- |
| 100 | 91.5 | 214 | 107 | 86 | 21.4 | 12 | 185 | 93 | 74 | 18.5 | 10.4 |
| 125 | 91.5 | 268 | 134 | 107 | 27 | 15 | 232 | 116 | 93 | 23.4 | 13 |
| 150 | 92.0 | 320 | 160 | 128 | 32 | 17.5 | 277 | 139 | 111 | 27.8 | 15.2 |
| 200 | 92.0 | 426 | 213 | 171 | 43 | 24 | 369 | 185 | 148 | 37.3 | 20.8 |
| 250 | 92.5 | 526 | 263 | 212 | 53 | 29 | 455 | 227 | 184 | 46 | 25.2 |
| 300 | 92.5 | 636 | 318 | 255 | 64 | 35 | 550 | 275 | 221 | 55 | 30.3 |
| 350 | 93.5 | 734 | 372 | 298 | 74 | 41 | 635 | 322 | 258 | 64 | 35.5 |
| 400 | 93.5 | 840 | 420 | 336 | 84 | 46 | 727 | 364 | 291 | 73 | 39.8 |
| 450 | 93.5 | 942 | 471 | 378 | 94 | 52 | 815 | 408 | 327 | 81 | 45 |
| 500 | 94.0 | 1045 | 523 | 418 | 105 | 58 | 903 | 456 | 362 | 90 | 50.2 |
| 550 | 94.0 | 1148 | 574 | 460 | 115 | 63 | 992 | 497 | 398 | 100 | 54.6 |
| 600 | 94.0 | 1250 | 625 | 500 | 125 | 69 | 1082 | 541 | 433 | 110 | 59.8 |
| 650 | 94.5 | 1350 | 675 | 540 | 135 | 75 | 1170 | 585 | 468 | 117 | 65 |
| 700 | 94.5 | 1450 | 725 | 580 | 145 | 80 | 1250 | 628 | 502 | 125 | 69 |
| 750 | 94.5 | 1560 | 780 | 625 | 156 | 86 | 1350 | 676 | 541 | 135 | 75 |
| 800 | 95.0 | 1660 | 830 | 665 | 166 | 91 | 1440 | 719 | 576 | 144 | 79 |
| 900 | 95.0 | 1860 | 930 | 745 | 186 | 102 | 1610 | 805 | 645 | 161 | 89 |
| 1000 | 95.0 | 2060 | 1030 | 825 | 206 | 113 | 1780 | 896 | 715 | 178 | 98 |

## SYNCHRONOUS SPEEDS - ALTERNATING CURRENT GENERATORS AND MOTORS

$$\text{Frequency} = \frac{\text{Poles x R.P.M.}}{120}$$

| Number of Poles Generator or Motor | Revolutions per Minute When Frequency is | | | | |
|---|---|---|---|---|---|
| | 25 Cycles | 30 Cycles | 40 Cycles | 50 Cycles | 60 Cycles |
| 2 | 1,500 | 1,800 | 2,400 | 3,000 | 3,600 |
| 4 | 750 | 900 | 1,200 | 1,500 | 1,800 |
| 6 | 500 | 600 | 800 | 1,000 | 1,200 |
| 8 | 375 | 450 | 600 | 750 | 900 |
| 10 | 300 | 360 | 480 | 600 | 720 |
| 12 | 250 | 300 | 400 | 500 | 600 |
| 14 | 214 | 257 | 343 | 428 | 514 |
| 16 | 188 | 225 | 300 | 375 | 450 |
| 18 | 167 | 200 | 267 | 333 | 400 |
| 20 | 150 | 180 | 240 | 300 | 360 |
| 22 | 136 | 164 | 217 | 273 | 327 |
| 24 | 125 | 150 | 200 | 250 | 300 |
| 26 | 115 | 138 | 185 | 231 | 280 |
| 28 | 107 | 128 | 171 | 214 | 257 |
| 30 | 100 | 120 | 160 | 200 | 240 |
| 32 | 94 | 113 | 150 | 188 | 225 |
| 36 | 83 | 100 | 133 | 166 | 200 |
| 44 | 79 | 82 | 109 | 136 | 164 |
| 48 | 63 | 75 | 100 | 125 | 150 |
| 54 | 56 | 66 | 90 | 111 | 133 |
| 60 | 50 | 60 | 80 | 100 | 120 |
| 68 | 44 | 53 | 71 | 88 | 106 |
| 72 | 42 | 50 | 67 | 83 | 100 |
| 96 | 31 | 38 | 50 | 64 | 75 |
| 100 | 30 | 36 | 48 | 60 | 72 |

## LOW VOLTAGE FUSES FOR MOTOR PROTECTION

**Overload Protection - Article 430 Part C CEC 28-2000**
The NEC and CEC allow fuses to be used as the sole means of overload protection for motor branch circuits(often practical with small single-phase motors). If used, the fuse ampere rating must not exceed the value shown in this table

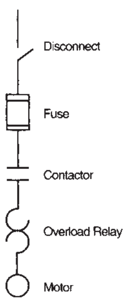


TABLE 1: Fuse Rating for Overload Protection

| Motor Service Factor or Marked Temperature Rise | Fuse Rating as a % of Motor Full Load |
|---|---|
| Service Factor of 1.15 or greater | 125 |
| Marked Temp. Rise not exceeding 40°C | 125 |
| All others | 115 |

*These percentages are not to be exceeded.

## Code Requirements

The NEC and CEC require that motor branch circuits be protected against overloads and short circuits. Overload protection may be provided by fuses, overload relays or motor thermal protectors. Short circuit protection may be provided by fuses or circuit breakers.

TABLE 2: Maximum Fuse Rating for Short Circuit Protection

| Type of Motor | Fuse Rating as a % Motor Full Load* Fuse Type | |
|---|---|---|
| | NON-TIME DELAY | TIME DELAY |
| All Single-phase AC motors | 300 | 175 |
| AC polyphase motors other thand wound-rotor: | | |
| Squirrel Cage | | |
| Other than Design E | 300 | 175 |
| Design E | 300 | 175 |
| Synchronous | 300 | 175 |
| Wound-rotor | 150 | 150 |
| Direct-current (constant voltage) | 150 | 150 |

*The non-time delay ratings apply to all class CC fuses.

## Overload Protection

The NEC or CEC allows fuses to be used as the sole means of overload protection for motor branch circuits. This approach is often practical with small single phase motors. If the fuse is the sole means of protection, the fuse ampere rating must not exceed the values shown in Table 1.

## Short Circuit Protection

The motor branch circuit fuses may be sized as large as shown in Table 2 when an overload relay or motor thermal protector is included in the branch circuit. Time delay fuse ratings may be increased to 225% and non-time delay fuse ratings to 400% (300% if over 600 amperes) if the ratings shown in Table 2 will not carry motor starting current. Some manufacturers' motor starters may not be adequately protected by the maximum fuse sizing shown in Table 2. If this is the case, the starter manufacturer is required by UL 508 to label the starter with a maximum permissible fuse size. If so labeled, this maximum value is not to be exceeded. Where the percentages shown in Table 2 do not correspond to standard fuse ratings the next larger fuse rating may be used.

| Motor HP | Full Load Current | Recommended Fuse Ampere Rating – Motor Acceleration Times | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum | Typical | Heavy | Minimum | Typical | Heavy | Minimum | Typical | Heavy |
| 115V | | RK5 - TR Tri-onic/RK1-A2D | | | J-AJT | | | U/L Class CC ATDR | | |
| 1/6 | 4.4 | 5-6/10 | 6-1/4 | 8 | 5-6/10 | 6-1/4 | 8 | 8 | 8 | 17-1/2 |
| 1/4 | 5.8 | 8 | 9 | 12 | 8 | 9 | 12 | 12 | 20 | 20 |
| 1/3 | 7.2 | 9 | 12 | 15 | 9 | 112 | 15 | 15 | 25 | 25 |
| 1/2 | 9,8 | 12 | 15 | 17-1/2 | 12 | 15 | 17-1/2 | 20 | 30 | - |
| 3/4 | 13.8 | 17-1/2 | 20 | 25 | 17-1/2 | 20 | 25 | 30 | - | - |
| 1 | 16 | 20 | 25 | 30 | 20 | 25 | 30 | - | - | - |
| 1-1/2 | 20 | 25 | 30 | 35 | 25 | 30 | 35 | - | - | - |
| 2 | 24 | 30 | 35 | 40 | 30 | 35 | 40 | - | - | - |
| 3 | 34 | 45 | 50 | 60 | 45 | 50 | 60 | - | - | - |
| 5 | 56 | 70 | 80 | 100 | 70 | 80 | 100 | - | - | - |
| 7-1/2 | 80 | 100 | 125 | 150 | 100 | 125 | 150 | - | - | - |
| 10 | 100 | 125 | 150 | 175 | 125 | 150 | 175 | - | - | - |
| 230V | | RK5 - TR Tri-onic/RK1-A2D | | | J-AJT | | | U/L Class CC ATDR | | |
| 1/6 | 2.2 | 2-8/10 | 3-1/2 | 4 | 2-8/10 | 3-1/2 | 4 | 4 | 7 | 8 |
| 1/4 | 2.9 | 3-1/2 | 4-1/2 | 5-6/10 | 3-1/2 | 4-1/2 | 5-6/10 | 6 | 9 | 10 |
| 1/3 | 3.6 | 4-1/2 | 5-6/10 | 7 | 4-1/2 | 5-6/10 | 7 | 7 | 12 | 15 |
| 1/2 | 4.9 | 6-1/4 | 7 | 9 | 6-1/4 | 7 | 9 | 10 | 15 | 17-1/2 |
| 3/4 | 6.9 | 9 | 10 | 15 | 9 | 10 | 15 | 15 | 20 | 25 |
| 1 | 8 | 10 | 12 | 15 | 10 | 12 | 15 | 20 | 25 | 30 |
| 1-1/2 | 10 | 12 | 15 | 17-1/2 | 12 | 15 | 17-1/2 | 20 | 30 | - |
| 2 | 12 | 15 | 17-1/2 | 25 | 15 | 17-1/2 | 25 | 25 | - | - |
| 3 | 17 | 20 | 25 | 30 | 20 | 25 | 30 | - | - | - |
| 5 | 28 | 35 | 40 | 50 | 35 | 40 | 50 | - | - | - |
| 7-1/2 | 40 | 50 | 60 | 70 | 50 | 60 | 70 | - | - | - |
| 10 | 50 | 60 | 80 | 90 | 60 | 80 | 90 | - | - | - |

**Minimum** This sizing is recommended if motor acceleration times do not exceed 2 seconds. Minimum sizing with RK1, RK5, and Class J fuses will provide overload protection.Minimum sizing is generally not heavy enough for motors with code letter G or higher.

**Typical** Suggested for most applications. Use with overload relays. Suitable for motor acceleration times up to 5 seconds.

**Heavy Load** Maximum fuse size in accordance with Table 2. If this fuse size is not sufficient to start the load, RK1, RK5, and J time delay fuse size may be increased to a maximum of 225% of full load amperes. Class CC fuses may be increased to 400% of full load amperes. The Heavy Load column should be used for Design E and high efficiency Design B motor fuse sizing.

**FUSE SELECTION TABLES FOR PROTECTION OF 230 VOLT THREE PHASE MOTORS**

| Motor HP | Full Load Amperes At 230V | Recommended Fuse Ampere Rating: RK5-TR(Tri-onic®)/RK1-A2D Min. 2 Secs | RK5-TR(Tri-onic®)/RK1-A2D Typical 5 secs | RK5-TR(Tri-onic®)/RK1-A2D Heavy > 5 Secs | J-AJT Min. 2 Secs | J-AJT Typical 5 Secs | J-AJT Heavy > 5 Secs | UL CLASS CC ATDR Min. 2 Secs | UL CLASS CC ATDR Typical 5 Secs | UL CLASS CC ATDR Heavy > 5 Secs |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/2 | 2.2 | 2-8/10 | 3-1/2 | 4 | 3 | 3-1/2 | 4 | 5 | 7 | 9 |
| 3/4 | 3.2 | 4 | 5 | 6 | 4 | 5 | 6 | 8 | 10 | 12 |
| 1 | 4.2 | 5 | 6-1/4 | 8 | 5 | 6-1/4 | 8 | 10 | 12 | 15 |
| 1-1/2 | 6.0 | 8 | 9 | 12 | 8 | 9 | 12 | 15 | 17 1/2 | 25 |
| 2 | 6.8 | 8 | 10 | 12 | 8 | 10 | 12 | 17 1/2 | 20 | 25 |
| 3 | 9.6 | 12 | 15 | 17-1/2 | 12 | 15 | 17 1/2 | 20 | 30 | - |
| 5 | 15.2 | 20 | 25 | 30 | 20 | 25 | 30 | - | - | - |
| 7-1/2 | 22 | 30 | 35 | 40 | 30 | 35 | 40 | - | - | - |
| 10 | 28 | 35 | 40 | 50 | 35 | 40 | 50 | - | - | - |
| 15 | 42 | 50 | 60 | 80 | 50 | 60 | 80 | - | - | - |
| 20 | 54 | 70 | 80 | 100 | 70 | 80 | 100 | - | - | - |
| 25 | 68 | 80 | 100 | 125 | 80 | 100 | 125 | - | - | - |
| 30 | 80 | 100 | 125 | 150 | 100 | 125 | 150 | - | - | - |
| 40 | 104 | 125 | 150 | 200 | 125 | 150 | 200 | - | - | - |
| 50 | 130 | 175 | 200 | 250 | 175 | 200 | 250 | - | - | - |
| 60 | 154 | 200 | 225 | 300 | 200 | 225 | 300 | - | - | - |
| 75 | 192 | 250 | 300 | 350 | 250 | 300 | 350 | - | - | - |
| 100 | 248 | 300 | 350 | 450 | 300 | 350 | 450 | - | - | - |
| 125 | 312 | 400 | 450 | 600 | 400 | 450 | 600 | - | - | - |
| 150 | 360 | 450 | 500 | 600 | 450 | 500 | 600 | - | - | - |
| 200 | 480 | 600 | -- | -- | 600 | -- | -- | - | - | - |

**Minimum** Fuses are sized near 125% of motor full load current and may not coordinate with some NEMA 20 overload relays.
**Typical** Suggested for most applications. Will coordinate with NEMA Class 20 overload relays.
**Heavy Load** Not applicable for motors marked with code letter A. Applies to high efficiency motors.

## FUSE SELECTION TABLES FOR PROTECTION OF 460 VOLT THREE PHASE MOTORS

| Motor HP | Full Load Amperes At 380V | Recommended Fuse Ampere Rating: RK5-TR(Tri-onic®)/RK1-A2D Min. 2 Secs | Typical 5 secs | Heavy > 5 Secs | J-AJT Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs | UL CLASS CC ATDR Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/2 | 1.3 | 1-6/10 | 2 | 2-8/10 | 1-6/10 | 2 | 2-8/10 | 3 | 4 | 5-6/10 |
| 3/4 | 1.7 | 2-1/2 | 2-8/10 | 3-1/2 | 2-1/2 | 2-8/10 | 3-1/2 | 4 | 6 | 8 |
| 1 | 2.7 | 3-2/10 | 4 | 4-1/2 | 3-2/10 | 4 | 4-1/2 | 5 | 8 | 10 |
| 1-1/2 | 3.6 | 4-1/2 | 5-6/10 | 7 | 4-1/2 | 5-6/10 | 7 | 8 | 12 | 15 |
| 2 | 4.1 | 5 | 6 | 8 | 5 | 6 | 8 | 9 | 15 | 15 |
| 3 | 5.8 | 7 | 8 | 12 | 8 | 8 | 12 | 12 | 17-1/2 | 20 |
| 5 | 9.2 | 12 | 15 | 17-1/2 | 12 | 15 | 17-1/2 | 20 | 30 | - |
| 7-1/2 | 13.3 | 15 | 20 | 25 | 17-1/2 | 20 | 25 | 30 | - | - |
| 10 | 17 | 20 | 25 | 30 | 20 | 25 | 30 | - | - | - |
| 15 | 25 | 30 | 35 | 45 | 30 | 35 | 45 | - | - | - |
| 20 | 33 | 40 | 45 | 60 | 40 | 50 | 60 | - | - | - |
| 25 | 41 | 50 | 60 | 75 | 50 | 60 | 80 | - | - | - |
| 30 | 48 | 60 | 70 | 90 | 60 | 80 | 90 | - | - | - |
| 40 | 68 | 75 | 90 | 125 | 80 | 100 | 125 | - | - | - |
| 50 | 79 | 90 | 110 | 150 | 90 | 125 | 150 | - | - | - |
| 60 | 93 | 110 | 125 | 175 | 110 | 150 | 175 | - | - | - |
| 75 | 116 | 10 | 175 | 225 | 150 | 175 | 225 | - | - | - |
| 100 | 150 | 175 | 225 | 300 | 175 | 225 | 300 | - | - | - |
| 125 | 189 | 250 | 300 | 350 | 250 | 300 | 350 | - | - | - |
| 150 | 218 | 300 | 350 | 400 | 300 | 350 | 400 | - | - | - |
| 200 | 291 | 350 | 450 | 600 | 350 | 450 | 600 | - | - | - |

**Minimum** Fuses are sized near 125% of motor full load current and may not coordinate with some NEMA 20 overload relays.
**Typical** Suggested for most applications. Will coordinate with NEMA Class 20 overload relays.
**Heavy Load** Not applicable for motors marked with code letter A. Applies to high efficiency motors.

**FUSE SELECTION TABLES FOR PROTECTION**
**OF 460 VOLT THREE PHASE MOTORS**

| Motor HP | Full Load Amperes At 460V | Recommended Fuse Ampere Rating | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | RK5 - TRS (Tri-onic®)/RK1-A6D | | | J-AJT | | | UL Class CC ATDR | | |
| | | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs |
| 1/2 | 1.1 | 1-4/10 | 1-6/10 | 2 | 1-1/2 | 1-6/10 | 2 | 3 | 3-1/2 | 4-1/2 |
| 3/4 | 1.6 | 2 | 2-1/4 | 2-8/10 | 2 | 2-1/4 | 2-8/10 | 3-1/2 | 5 | 6-1/4 |
| 1 | 2.1 | 2-1/2 | 3-2/10 | 4 | 2-1/2 | 3-2/10 | 4 | 5 | 6-1/4 | 9 |
| 1-1/2 | 3 | 3-1/2 | 4-1/2 | 5-6/10 | 3-1/2 | 4-1/2 | 5-6/10 | 6 | 9 | 12 |
| 2 | 3.4 | 4 | 5 | 6 | 4 | 5 | 5 | 8 | 10 | 12 |
| 3 | 4.8 | 5-6/10 | 7 | 9 | 6 | 8 | 9 | 15 | 15 | 17-1/2 |
| 5 | 7.6 | 10 | 12 | 15 | 10 | 12 | 15 | 25 | 25 | 30 |
| 7-1/2 | 11 | 15 | 17-1/2 | 20 | 15 | 17-1/2 | 20 | 30 | 30 | - |
| 10 | 14 | 17-1/2 | 20 | 25 | 17-1/2 | 20 | 25 | - | - | - |
| 15 | 21 | 25 | 30 | 40 | 25 | 30 | 40 | - | - | - |
| 20 | 27 | 35 | 40 | 50 | 35 | 40 | 50 | - | - | - |
| 25 | 34 | 40 | 50 | 60 | 40 | 50 | 60 | - | - | - |
| 30 | 40 | 50 | 60 | 70 | 50 | 60 | 70 | - | - | - |
| 40 | 52 | 70 | 80 | 100 | 70 | 80 | 100 | - | - | - |
| 50 | 65 | 80 | 100 | 125 | 80 | 100 | 125 | - | - | - |
| 60 | 77 | 100 | 125 | 150 | 100 | 125 | 150 | - | - | - |
| 75 | 96 | 125 | 150 | 175 | 125 | 150 | 175 | - | - | - |
| 100 | 124 | 175 | 200 | 225 | 175 | 200 | 225 | - | - | - |
| 125 | 156 | 200 | 225 | 300 | 200 | 225 | 300 | - | - | - |
| 150 | 180 | 225 | 250 | 350 | 225 | 250 | 350 | - | - | - |
| 200 | 240 | 300 | 350 | 450 | 300 | 350 | 450 | - | - | - |
| 250 | 302 | 400 | 450 | 600 | 400 | 450 | 600 | - | - | - |
| 300 | 361 | 450 | 600 | - | 450 | 600 | - | - | - | - |

**Minimum** Fuses are sized near 125% of motor full load current and may not coordinate with some NEMA 20 overload relays.
**Typical** Suggested for most applications. Will coordinate with NEMA Class 20 overload relays.
**Heavy Load** Not applicable for motors marked with code letter A. Applies to high efficiency motors.

## FUSE SELECTION TABLES FOR PROTECTION OF 575 VOLT THREE PHASE MOTORS

| Motor HP | Full Load Amperes | Recommended Fuse Ampere Rating — Motor Acceleration Times | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs | Min. 2 Secs | Typical 5 Secs | Heavy > 5 Secs |
| 575V | | RK5-TRS (Tri-onic)/RK1-A6D | | | J-AJT | | | UL Class CC ATDR | | |
| 1/2 | .9 | 1-1/8 | 1-4/10 | 1-6/10 | 1-1/4 | 1-1/2 | 1-6/10 | 2-1/2 | 2-8/10 | 3-1/2 |
| 3/4 | 1.3 | 1-6/10 | 2 | 2-1/2 | 1-6/10 | 2 | 2-1/2 | 3 | 4 | 5-6/10 |
| 1 | 1.7 | 2-1/4 | 2-1/2 | 3 | 2-1/4 | 2-1/2 | 3 | 4 | 5-6/10 | 6-1/4 |
| 1-1/2 | 2.4 | 3 | 3-1/2 | 4-1/2 | 3 | 3-1/2 | 4-1/2 | 5 | 8 | 10 |
| 2 | 2.7 | 3-2/10 | 4 | 5 | 3-2/10 | 4 | 5 | 6 | 8 | 10 |
| 3 | 3.9 | 5 | 6 | 7 | 5 | 6 | 7 | 9 | 12 | 15 |
| 5 | 6.1 | 8 | 9 | 12 | 8 | 10 | 12 | 15 | 17-1/2 | 20 |
| 7-1/2 | 9 | 12 | 15 | 17-1/2 | 12 | 15 | 17-1/2 | 20 | 30 | - |
| 10 | 11 | 15 | 17-1/2 | 20 | 15 | 17-1/2 | 20 | 25 | 30 | - |
| 15 | 17 | 20 | 25 | 30 | 20 | 25 | 30 | - | - | - |
| 20 | 22 | 30 | 35 | 40 | 30 | 35 | 40 | - | - | - |
| 25 | 27 | 35 | 40 | 50 | 35 | 40 | 50 | - | - | - |
| 30 | 32 | 40 | 50 | 60 | 40 | 50 | 60 | - | - | - |
| 40 | 41 | 50 | 60 | 75 | 50 | 60 | 75 | - | - | - |
| 50 | 52 | 70 | 80 | 100 | 70 | 80 | 100 | - | - | - |
| 60 | 62 | 75 | 90 | 110 | 80 | 90 | 110 | - | - | - |
| 75 | 77 | 100 | 125 | 150 | 100 | 125 | 150 | - | - | - |
| 100 | 99 | 125 | 150 | 175 | 125 | 150 | 175 | - | - | - |
| 125 | 125 | 150 | 175 | 225 | 150 | 200 | 225 | - | - | - |
| 150 | 144 | 175 | 225 | 300 | 175 | 225 | 300 | - | - | - |
| 200 | 192 | 250 | 300 | 350 | 250 | 300 | 350 | - | - | - |
| 250 | 240 | 300 | 350 | 500 | 300 | 350 | 500 | - | - | - |
| 300 | 289 | 350 | 450 | 600 | 350 | 450 | 600 | - | - | - |

**Minimum** Fuses are sized near 125% of motor full load current and may not coordinate with some NEMA 20 overload relays.
**Typical** Suggested for most applications. Will coordinate with NEMA Class 20 overload relays.
**Heavy Load** Not applicable for motors marked with code letter A. Applies to high efficiency motors.

# FIELD CURRENT IN D.C. GENERATORS

It has been found that a fair average for the field amperes of different sized generators is as follows:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| K.W. ................ | 1 | 5 | 10 | 20 | 30 | 50 | 75 | 100 |
| Percent ............ | 8 | 6 | 5 | 4 | 3.5 | 3 | 3 | 2.75 |

The field current, expressed as a percentage of full load current on lines, is determined with all of the resistance out.

## D.C. GENERATORS

| Kilowatts | Output Current Amperes | | | Efficiency % | | |
|---|---|---|---|---|---|---|
| Capacity | 125 Volts | 250 Volts | 500 Volts | 1/2 Load | 3/4 Load | Full Load |
| 5 | 40 | 20 | 10 | 77.0 | 81.0 | 82.5 |
| 10 | 80 | 40 | 20 | 82.0 | 85.0 | 86.0 |
| 15 | 120 | 60 | 30 | 82.5 | 86.5 | 86.5 |
| 20 | 160 | 80 | 40 | 84.0 | 86.5 | 87.5 |
| 25 | 200 | 100 | 50 | 85.0 | 88.0 | 89.0 |
| 35 | 280 | 140 | 70 | 87.0 | 89.0 | 89.5 |
| 50 | 400 | 200 | 100 | 88.0 | 89.5 | 90.5 |
| 60 | 480 | 240 | 120 | 88.5 | 90.5 | 91.0 |
| 75 | 600 | 300 | 150 | 88.5 | 90.5 | 91.0 |
| 90 | 720 | 360 | 180 | 88.5 | 90.5 | 91.0 |
| 100 | 800 | 400 | 200 | 89.0 | 90.5 | 91.0 |
| 125 | 1,000 | 500 | 250 | 90.5 | 91.0 | 91.0 |
| 150 | 1,200 | 600 | 300 | 90.5 | 91.3 | 91.5 |
| 200 | 1,600 | 800 | 400 | 91.0 | 91.5 | 92.0 |
| 300 | 2,400 | 1,200 | 600 | 91.3 | 91.8 | 92.0 |
| 400 | 3,200 | 1,600 | 800 | 91.8 | 92.3 | 92.5 |
| 500 | 4,000 | 2,000 | 1,000 | 91.8 | 92.2 | 92.5 |
| 750 | 6,000 | 3,000 | 1,500 | 92.0 | 92.3 | 92.5 |
| 1,000 | 8,000 | 4,000 | 2,000 | 92.5 | 93.0 | 93.5 |

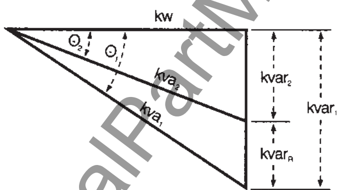
## Application of Power Factor Capacitators

Power factor capacitors can be connected across electric lines to neutralize the effect of lagging power-factor loads, thereby reducing the current drawn for a given kilowatt load. In a distribution system, small capacitor units may be connected at the individual loads or the total capacitor kilovolt-amperes may be grouped at one point and connected to the main. Although the total kvar of capacitors is the same, the use of small capacitors at the individual loads reduces current all the way from the loads back to the source and thereby has greater PF corrective effect than the one big unit on the main, which reduces current only from its point of installation back to the source.

**Calculating Size of Capacitor:**

Assume it is desired to improve the power factor a given amount by the addition of the capacitors to the circuit.

Then $kvar_R = kw \times (\tan \theta_1 - \tan \theta_2)$




where $kvar_R$ = Rating of required capacitor
$kvar_1$ = reactive kilovolt-amperes at original PF
$kvar_2$ = reactive kilovolt-amperes at improved PF
$\theta_1$ = original phase angle
$\theta_2$ = phase angle at improved PF
kw = load at which original PF was determined

NOTE: The phase angle $\theta_1$ and $\theta_2$ can be determined from a table of trigonometric functions using the following relationships:

$\theta_1$ = The angle which has its cosine equal to the decimal value of the original power factor.(eg. 0.70 for 70% PF; 0.65 for 65% PF, etc.)

$\theta_2$ = The angle which has its cosine equal to the decimal value of the improved power factor.

-Electrical Construction and Maintenance Magazine

## TABLE FOR CALCULATING NECESSARY CAPACITOR

### Desired Power Factor in Percentage

| | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 |
|---|---|---|---|---|---|---|---|---|---|---|
| 50 | .982 | 1.008 | 1.034 | 1.060 | 1.086 | 1.112 | 1.139 | 1.165 | 1.192 | 1.220 |
| 51 | .936 | .962 | .988 | 1.014 | 1.040 | 1.066 | 1.093 | 1.119 | 1.146 | 1.174 |
| 52 | .894 | .920 | .946 | .972 | .998 | 1.024 | 1.041 | 1.077 | 1.104 | 1.132 |
| 53 | .850 | .876 | .902 | .928 | .954 | .980 | 1.007 | 1.033 | 1.060 | 1.088 |
| 54 | .809 | .835 | .861 | .887 | .913 | .939 | .966 | .992 | 1.019 | 1.047 |
| 55 | .769 | .795 | .821 | .847 | .873 | .899 | .926 | .952 | .979 | 1.007 |
| 56 | .730 | .756 | .782 | .808 | .834 | .860 | .887 | .913 | .940 | .968 |
| 57 | .692 | .718 | .744 | .770 | .796 | .822 | .849 | .875 | .902 | .930 |
| 58 | .655 | .681 | .707 | .733 | .759 | .785 | .812 | .838 | .865 | .893 |
| 59 | .618 | .644 | .670 | .696 | .722 | .748 | .775 | .801 | .828 | .856 |
| 60 | .584 | .610 | .636 | .662 | .688 | .714 | .741 | .767 | .794 | .822 |
| 61 | .549 | .575 | .601 | .627 | .653 | .679 | .706 | .732 | .759 | .787 |
| 62 | .515 | .541 | .567 | .593 | .619 | .645 | .672 | .698 | .725 | .753 |
| 63 | .483 | .509 | .535 | .561 | .587 | .613 | .640 | .666 | .693 | .721 |
| 64 | .450 | .476 | .502 | .528 | .554 | .580 | .607 | .633 | .660 | .688 |
| 65 | .419 | .445 | .471 | .497 | .523 | .549 | .576 | .602 | .629 | .657 |
| 66 | .388 | .414 | .440 | .466 | .492 | .518 | .545 | .571 | .598 | .626 |
| 67 | .358 | .384 | .410 | .436 | .462 | .488 | .515 | .541 | .568 | .596 |
| 68 | .329 | .355 | .381 | .407 | .433 | .459 | .486 | .512 | .539 | .567 |
| 69 | .209 | .325 | .351 | .377 | .403 | .429 | .456 | .482 | .509 | .537 |
| 70 | .270 | .296 | .322 | .348 | .374 | .400 | .427 | .453 | .480 | .508 |
| 71 | .242 | .268 | .294 | .320 | .346 | .372 | .399 | .425 | .452 | .480 |
| 72 | .213 | .239 | .265 | .291 | .317 | .343 | .370 | .396 | .423 | .451 |
| 73 | .186 | .212 | .238 | .264 | .290 | .316 | .343 | .369 | .396 | .424 |
| 74 | .159 | .185 | .211 | .237 | .263 | .289 | .316 | .342 | .369 | .397 |
| 75 | .132 | .158 | .184 | .210 | .236 | .262 | .289 | .315 | .342 | .370 |
| 76 | .105 | .131 | .157 | .183 | .209 | .235 | .262 | .288 | .315 | .343 |
| 77 | .079 | .105 | .131 | .157 | .183 | .209 | .236 | .262 | .289 | .317 |
| 78 | .053 | .079 | .105 | .131 | .157 | .183 | .210 | .236 | .263 | .291 |
| 79 | .026 | .052 | .078 | .104 | .130 | .156 | .183 | .209 | .236 | .264 |
| 80 | .000 | .026 | .052 | .078 | .104 | .130 | .157 | .183 | .210 | .238 |
| 81 | -- | .000 | .026 | .052 | .078 | .104 | .131 | .157 | .184 | .212 |
| 82 | -- | -- | .000 | .026 | .052 | .078 | .105 | .131 | .158 | .186 |
| 83 | -- | -- | -- | .000 | .026 | .052 | .079 | .105 | .132 | .160 |
| 84 | -- | -- | -- | -- | .000 | .026 | .053 | .079 | .106 | .134 |
| 85 | -- | -- | -- | -- | -- | .000 | .027 | .053 | .080 | .108 |

Example: Total kw input of plant from wattmeter reading 100 kw at power factor of 60%. The leading reactive kva, necessary to raise the power factor

## KVAR TO CORRECT LOAD TO DESIRED POWER FACTOR
**(Cornell Dubilier)**

**Desired Power Factor in Percentage**

| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | Existing Power Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.248 | 1.276 | 1.303 | 1.337 | 1.369 | 1.403 | 1.441 | 1.481 | 1.529 | 1.590 | 1.732 | 50 |
| 1.202 | 1.230 | 1.257 | 1.291 | 1.323 | 1.357 | 1.395 | 1.435 | 1.483 | 1.544 | 1.686 | 51 |
| 1.160 | 1.188 | 1.215 | 1.249 | 1.281 | 1.315 | 1.353 | 1.393 | 1.441 | 1.502 | 1.644 | 52 |
| 1.116 | 1.144 | 1.171 | 1.205 | 1.237 | 1.271 | 1.309 | 1.349 | 1.397 | 1.458 | 1.600 | 53 |
| 1.075 | 1.103 | 1.130 | 1.164 | 1.196 | 1.230 | 1.268 | 1.308 | 1.356 | 1.417 | 1.559 | 54 |
| 1.035 | 1.063 | 1.090 | 1.124 | 1.156 | 1.190 | 1.228 | 1.268 | 1.316 | 1.377 | 1.519 | 55 |
| .996 | 1.024 | 1.051 | 1.085 | 1.117 | 1.151 | 1.189 | 1.229 | 1.277 | 1.338 | 1.480 | 56 |
| .958 | .986 | 1.013 | 1.047 | 1.079 | 1.113 | 1.151 | 1.191 | 1.239 | 1.300 | 1.442 | 57 |
| .921 | .949 | .976 | 1.010 | 1.042 | 1.076 | 1.114 | 1.154 | 1.202 | 1.263 | 1.405 | 58 |
| .884 | .912 | .939 | .973 | 1.005 | 1.039 | 1.077 | 1.117 | 1.165 | 1.226 | 1.368 | 59 |
| .849 | .878 | .905 | .939 | .971 | 1.005 | 1.043 | 1.083 | 1.131 | 1.192 | 1.334 | 60 |
| .815 | .843 | .870 | .904 | .936 | .970 | 1.008 | 1.048 | 1.096 | 1.157 | 1.299 | 61 |
| .781 | .809 | .836 | .870 | .902 | .936 | .974 | 1.014 | 1.062 | 1.123 | 1.265 | 62 |
| .749 | .777 | .804 | .838 | .870 | .904 | .942 | .982 | 1.030 | 1.091 | 1.233 | 63 |
| .716 | .744 | .771 | .805 | .837 | .871 | .909 | .949 | .997 | 1.058 | 1.200 | 64 |
| .685 | .713 | .740 | .774 | .806 | .840 | .878 | .918 | .966 | 1.027 | 1.169 | 65 |
| .654 | .682 | .709 | .743 | .775 | .809 | .847 | .887 | .935 | .996 | 1.138 | 66 |
| .624 | .652 | .679 | .713 | .745 | .779 | .817 | .857 | .905 | .966 | 1.108 | 67 |
| .595 | .623 | .650 | .684 | .716 | .750 | .788 | .828 | .876 | .937 | 1.079 | 68 |
| .565 | .593 | .620 | .654 | .686 | .720 | .758 | .798 | .840 | .907 | 1.049 | 69 |
| .536 | .564 | .591 | .625 | .657 | .691 | .729 | .769 | .811 | .878 | 1.020 | 70 |
| .508 | .536 | .563 | .597 | .629 | .663 | .701 | .741 | .783 | .850 | .992 | 71 |
| .479 | .507 | .534 | .568 | .600 | .634 | .672 | .712 | .754 | .821 | .963 | 72 |
| .452 | .480 | .507 | .541 | .573 | .607 | .645 | .685 | .727 | .794 | .936 | 73 |
| .425 | .453 | .480 | .514 | .546 | .580 | .618 | .658 | .700 | .767 | .909 | 74 |
| .398 | .426 | .453 | .487 | .519 | .553 | .591 | .631 | .673 | .740 | .882 | 75 |
| .371 | .399 | .426 | .460 | .492 | .526 | .564 | .604 | .652 | .713 | .855 | 76 |
| .345 | .373 | .400 | .434 | .466 | .500 | .538 | .578 | .620 | .687 | .829 | 77 |
| .319 | .347 | .374 | .408 | .440 | .474 | .512 | .552 | .594 | .661 | .803 | 78 |
| .292 | .320 | .347 | .381 | .413 | .447 | .485 | .525 | .567 | .634 | .776 | 79 |
| .266 | .294 | .321 | .355 | .387 | .421 | .459 | .499 | .541 | .608 | .750 | 80 |
| .240 | .268 | .295 | .329 | .361 | .395 | .433 | .473 | .515 | .582 | .724 | 81 |
| .214 | .242 | .269 | .303 | .335 | .369 | .407 | .447 | .489 | .556 | .698 | 82 |
| .188 | .216 | .243 | .277 | .309 | .343 | .381 | .421 | .463 | .530 | .672 | 83 |
| .162 | .190 | .217 | .251 | .283 | .317 | .355 | .395 | .437 | .504 | .645 | 84 |
| .136 | .164 | .191 | .225 | .257 | .291 | .329 | .369 | .417 | .478 | .620 | 85 |

to 90% is found by multiplying the 100 kw by the factor found in the table, which is .849. Then 100 kw x 0.849 = 84.9 kva. Use 85 kva.

# TRANSFORMER PROTECTION

Article 450-3 of the National Electrical Code and Rule 26-254 of the Canadian Electrical Code cover overcurrent protection of transformers. Some of the requirements are summarized here.

**Transformers - Primary 600 Volts or Less**
If secondary fuse protection is not provided, primary fuses are to be selected according to Table 1. If both primary and secondary fuses are used, they are to be selected according to Table 2.

### Table 1 - Primary Fuse Only

| Transformer Primary Amperes | Maximum Primary Fuse % Rating |
|---|---|
| 9 or More | 125* (NEC) / 150* (CEC) |
| 2 to 9 | 167 |
| Less than 2 | 300 |

* May be increased to next higher std. fuse size.

### Table 2 - Primary and Secondary Fuses

| Transformer Secondary Amperes | Maximum % Rating | | |
|---|---|---|---|
| | Primary Fuse | | Secondary Fuse |
| | NEC | CEC | |
| 9 or More | 250 | 300 | 125* |
| Less than 9 | 250 | 300 | 167 |

*May be increased to next higher std. fuse size

**Transformer Magnetizing Inrush Currents**
When voltage is switched on to energize a transformer, the transformer core normally saturates. This results in a large inrush (magnetizing) current which is greatest during the first half cycle (approx. .01 second) and becomes progressively less severe over the next several cycles (approx. 0.1 second) until the transformer reaches its normal current.

To accommodate this inrush current, fuses are often selected which have time-current withstand values of at least 12 times transformer primary rated current for 0.1 second and 25 times for 0.01 second. Recommended primary fuses for popular, low-voltage 3-phase transformers are shown on the next page. Control circuit transformers may have substantially greater inrush currents. For these applications, the fuse should be selected to withstand 40 times transformer primary rated current for 0.01 second.

## SECONDARY FUSES

Selecting fuses for the secondary is simple once rated secondary current is known. Fuses are sized at 125% secondary FLA or next higher rating of at 167% of secondary FLA depending on secondary current. (See NEC and CEC guidelines on pervious page). The preferred sizing is 125% of rated secondary Icurrent (Isec) or next higher fuse rating. Determine transformer rating (VA or kVA), secondary voltage (Vsec) and whether it is single or three phase.

1. Single Phase: $Isec = \frac{\text{Transformer VA}}{\text{Vsec}}$ or $\frac{\text{Transformer KVA x 1000}}{\text{Vsec}}$

2. Three Phase: $Isec = \frac{\text{Transformer VA}}{\text{1.73 x Vsec}}$ or $\frac{\text{Transformer KVA x 1000}}{\text{1.73 Vsec}}$

When Isec is determined, multiply it by 1.25 and choose that fuse rating or the next higher rating. (Isec x 1.25 = Fuse Rating).
For transformers with primary over 600 volts, consult the Application Section in the Ferraz Shawmut Advisor.

## RECOMMENDED PRIMARY FUSES FOR 240 VOLT THREE PHASE TRANSFORMERS

| Trans-former Rating KVA | Primary Full Load Amps | Primary Fuse Rating | | | | |
|---|---|---|---|---|---|---|
| | | TR-R | AJT* or A2D-R* | A4BQ* | A4BY* | A4BT* |
| 3 | 7.2 | 9 | 15 | -- | -- | -- |
| 5 | 12 | 15 | 25 | -- | -- | -- |
| 7-1/2 | 18 | 25 | 40 | -- | -- | -- |
| 9 | 22 | 30 | 45 | -- | -- | -- |
| 15 | 36 | 45 | 60 | -- | -- | -- |
| 30 | 72 | 90 | 150 | -- | -- | -- |
| 45 | 108 | 150 | 225 | -- | -- | -- |
| 75 | 180 | 225 | 400 | -- | -- | -- |
| 100 | 241 | 300 | 450 | -- | -- | -- |
| 112.5 | 271 | 350 | 500 | -- | -- | -- |
| 150 | 361 | 450 | 600 | -- | -- | -- |
| 225 | 541 | 600 | -- | 1200 | 900 | 800 |
| 300 | 722 | -- | -- | 1600 | 1200 | 1200 |
| 500 | 1203 | -- | -- | 2500 | 2000 | 1800 |
| 750 | 1804 | -- | -- | 4000 | 3000 | -- |
| 1000 | 2406 | -- | -- | 5000 | 5000 | -- |
| 1500 | 3608 | -- | -- | -- | 6000 | -- |

* When using these fuses, transformer secondary must also be fused to comply with NEC 450-3 and CEC 26-254.

# RECOMMENDED PRIMARY FUSES FOR 480 VOLT THREE PHASE TRANSFORMERS

| Trans-former Rating KVA | Primary Full Load Amps | Primary Fuse Rating | | | | |
|---|---|---|---|---|---|---|
| | | TRS-R | AJT* or A6D-R* | A4BQ* | A4BY* | A4BT* |
| 3 | 3.6 | 4-1/2 | 6 | -- | -- | -- |
| 5 | 6.0 | 8 | 12 | -- | -- | -- |
| 7-1/2 | 9.0 | 12 | 15 | -- | -- | -- |
| 9 | 11 | 15 | 25 | -- | -- | -- |
| 15 | 18 | 25 | 35 | -- | -- | -- |
| 30 | 36 | 45 | 60 | -- | -- | -- |
| 45 | 54 | 70 | 100 | -- | -- | -- |
| 75 | 90 | 125 | 175 | -- | -- | -- |
| 100 | 120 | 150 | 225 | -- | -- | -- |
| 112.5 | 135 | 175 | 300 | -- | -- | -- |
| 150 | 180 | 225 | 400 | -- | -- | -- |
| 225 | 271 | 350 | 500 | -- | -- | -- |
| 300 | 361 | 450 | 600 | -- | -- | -- |
| 500 | 601 | -- | -- | 1200 | 1000 | 1000 |
| 750 | 902 | -- | -- | 2000 | 1600 | 1400 |
| 1000 | 1203 | -- | -- | 2500 | 2000 | 1800 |
| 1500 | 1804 | -- | -- | 4000 | 3000 | -- |
| 2000 | 2406 | -- | -- | 5000 | 4000 | -- |
| 2500 | 3007 | -- | -- | 6000 | 5000 | -- |

* When using these fuses, transformer secondary must also be fused to comply with NEC 450-3 and CEC 26-254.

# RECOMMENDED PRIMARY FUSES FOR 600 VOLT THREE PHASE TRANSFORMERS

| Transformer Rating KVA | Primary Full Load Amps | Primary Fuse Rating | | | | |
|---|---|---|---|---|---|---|
| | | TRS-R | AJT* or A6D-R* | A4BQ* | A4BY* | A4BT* |
| 3 | 2.9 | 4 | 5 | -- | -- | -- |
| 5 | 4.8 | 6 | 10 | -- | -- | -- |
| 7-1/2 | 7.2 | 9 | 15 | -- | -- | -- |
| 9 | 9 | 12 | 17-1/2 | -- | -- | -- |
| 15 | 14 | 20 | 25 | -- | -- | -- |
| 30 | 29 | 35 | 45 | -- | -- | -- |
| 45 | 43 | 60 | 80 | -- | -- | -- |
| 75 | 72 | 90 | 150 | -- | -- | -- |
| 100 | 96 | 125 | 200 | -- | -- | -- |
| 112.5 | 108 | 150 | 225 | -- | -- | -- |
| 150 | 144 | 200 | 300 | -- | -- | -- |
| 225 | 217 | 300 | 450 | -- | -- | -- |
| 300 | 289 | 350 | 500 | -- | -- | -- |
| 500 | 481 | 600 | -- | 1000 | 900 | 700 |
| 750 | 722 | -- | -- | 1600 | 1400 | 1200 |
| 1000 | 962 | -- | -- | 2000 | 1800 | 1600 |
| 1500 | 1443 | -- | -- | 3000 | 2500 | 2000 |
| 2000 | 1925 | -- | -- | 4000 | 4000 | -- |
| 2500 | 2406 | -- | -- | 5000 | 5000 | -- |

* When using these fuses, transformer secondary must also be fused to comply with NEC 450-3 and CEC 26-254.

## CONTROL CIRCUIT TRANSFORMERS

Control circuit transformers used as part of a motor control circuit are to be protected as outlined in NEC 450-3 and CEC 25-256 with one important exception. The NEC allows primary fuses to be sized up to 500% of transformer rated primary current if the rated current is less than 2 amperes.

When a control circuit transformer is energized, the typical magnetizing inrush will be 25-40 times rated primary full load current (FLA) for the first 1/2 cycle and dissipates to rated current in a few cycles. Fuses must be sized so they do not open during this inrush. We recommend that fuses be selected to withstand 40 x FLA for 0.01 second and to stay within the guidelines specified above.

For example: 300VA Transformer, 600V primary

$$I_{pri} = \frac{\text{Transformer VA}}{\text{Primary V}} = \frac{300}{600} = 1/2A$$

The fuse time-current curve must lie to the right of the point 40 x (1/2A) = 20A @ .01 second.

## RECOMMENDED ATQR CLASS CC PRIMARY FUSES FOR SINGLE PHASE CONTROL TRANSFORMERS

| Trans-former VA | 240V Primary | | 480V Primary | | 600V Primary | |
|---|---|---|---|---|---|---|
| | Pri. FLA | ATQR | Pri. FLA | ATQR | Pri. FLA | ATQR |
| 25 | 0.10 | 2/10 | 0.052 | 1/10 | 0.042 | 1/10 |
| 50 | 0.21 | 4/10 | 0.10 | 1/4 | 0.08 | 1/4 |
| 75 | 0.31 | 1/2 | 0.16 | 3/10 | 0.13 | 1/4 |
| 100 | 0.42 | 6/10 | 0.21 | 4/10 | 0.17 | 3/10 |
| 130 | 0.54 | 1 | 0.27 | 1/2 | 0.22 | 4/10 |
| 150 | 0.63 | 1 | 0.31 | 1/2 | 0.25 | 1/2 |
| 200 | 0.83 | 1-1/2 | 0.42 | 6/10 | 0.33 | 1/2 |
| 250 | 1.04 | 2 | 0.52 | 8/10 | 0.42 | 6/10 |
| 500 | 2.08 | 4* | 1.04 | 2 | 0.83 | 1-1/2 |
| 750 | 3.13 | 7* | 1.56 | 3 | 1.25 | 2-1/2 |
| 1000 | 4.16 | 10* | 2.08 | 4* | 1.67 | 3 |
| 1500 | 6.25 | 15* | 3.13 | 7* | 2.50 | 5* |
| 2000 | 8.3 | 20* | 4.17 | 10* | 3.33 | 8* |

* When using these fuses, transformer secondary must also be fused to comply with NEC 450-3 and CEC 26-256.

## CONVERSION FACTORS - KVA TO AMPERES

| Three-Phase Volts Line-to-line | Amperes per Phase per kVA | Two-wire Volts | | Amperes per per kVA or KW |
|---|---|---|---|---|
| | | AC | DC | |
| 110 | 5.25 | 100 | -- | 10.0 |
| 115 | 5.02 | -- | 110 | 9.10 |
| 120 | 4.81 | 115 | 115 | 8.70 |
| 180 | 3.21 | 120 | -- | 8.33 |
| 199 | 2.90 | -- | 125 | 8.00 |
| -- | -- | 220 | -- | 4.55 |
| 208 | 2.78 | -- | -- | -- |
| 220 | 2.63 | 230 | -- | 4.35 |
| 230 | 2.51 | 240 | -- | 4.17 |
| 240 | 2.41 | 250 | 250 | 4.00 |
| 416 | 1.39 | 265 | -- | 3.77 |
| 440 | 1.31 | -- | 275 | 3.64 |
| -- | -- | 277 | -- | 3.61 |
| 460 | 1.25 | -- | 300 | 3.33 |
| 480 | 1.20 | -- | -- | -- |
| 550 | 1.05 | 416 | -- | 2.41 |
| 575 | 1.00 | 440 | -- | 2.27 |
| 600 | 0.96 | 460 | -- | 2.17 |
| -- | -- | 480 | -- | 2.08 |
| -- | -- | 550 | 550 | 1.82 |
| -- | -- | 575 | -- | 1.74 |
| -- | -- | 600 | 600 | 1.67 |

**How to convert kVA to amperes.**
For example, determine the necessary busway rating to carry the full current from a 750 kVA, 3-phase transformer at 220 volts. From the table, one kVA at 220 volts is 2.63 amp per phase. Hence, the full-load current is 2.63 times 750 or 1972.5 amp per phase, requiring, at the minimum, a 2000 amp, 3-phase, 3-conductor feeder busway.



When you need fuses for any purpose, always ask about the latest SHAWMUT fuse for that purpose. SHAWMUT engineering is never satisfied with merely making better product; it is alert at all times to the most exacting requirements of circuit protection and consequently to the most exacting requirements for fuses.

# AMPERES FOR ONE KW AT VARIOUS VOLTAGES AND POWER FACTORS

## SINGLE-PHASE CIRCUITS

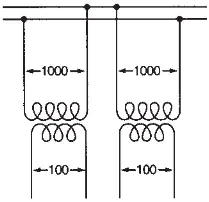
| | Amperes per Kilowatt @ Power Factor | | | | | |
|---|---|---|---|---|---|---|
| Volts | 100% | 90% | 80% | 70% | 60% | 50% |
| 115 | 8.70 | 9.67 | 10.9 | 12.4 | 14.5 | 17.4 |
| 230 | 4.38 | 4.87 | 5.48 | 6.23 | 7.30 | 8.76 |
| 460 | 2.17 | 2.41 | 2.71 | 3.10 | 3.62 | 4.34 |
| 575 | 1.74 | 1.93 | 2.18 | 2.49 | 2.90 | 3.48 |
| 2300 | 0.435 | 0.483 | 0.544 | 0.621 | 0.725 | 0.870 |

## TWO-PHASE CIRCUITS

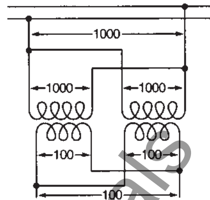
| | Amperes per Kilowatt @ Power Factor | | | | | |
|---|---|---|---|---|---|---|
| Volts | 100% | 90% | 80% | 70% | 60% | 50% |
| 115 | 4.35 | 4.83 | 5.44 | 6.21 | 7.25 | 8.70 |
| 230 | 2.17 | 2.41 | 2.71 | 3.10 | 3.62 | 4.34 |
| 460 | 1.09 | 1.21 | 1.36 | 1.56 | 1.82 | 2.18 |
| 575 | 0.870 | 0.966 | 1.09 | 1.24 | 1.45 | 1.74 |
| 2300 | 0.217 | 0.242 | 0.271 | 0.310 | 0.362 | 0.434 |

## THREE-PHASE CIRCUITS

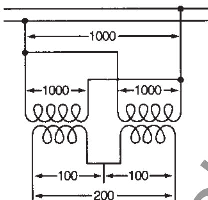
| | Amperes per Kilowatt @ Power Factor | | | | | |
|---|---|---|---|---|---|---|
| Volts | 100% | 90% | 80% | 70% | 60% | 50% |
| 115 | 5.02 | 5.58 | 6.28 | 7.17 | 8.37 | 10.0 |
| 208 | 2.78 | 3.08 | 3.48 | 3.97 | 4.63 | 5.56 |
| 230 | 2.51 | 2.79 | 3.18 | 3.59 | 4.18 | 5.02 |
| 460 | 1.26 | 1.39 | 1.58 | 1.80 | 2.10 | 2.52 |
| 575 | 1.00 | 1.12 | 1.25 | 1.43 | 1.67 | 2.00 |
| 2400 | 0.241 | 0.268 | 0.301 | 0.344 | 0.402 | 0.482 |
| 4160 | 0.139 | 0.154 | 0.174 | 0.199 | 0.232 | 0.278 |
| 7200 | .0802 | .0891 | 0.100 | 0.115 | 0.134 | 0.160 |



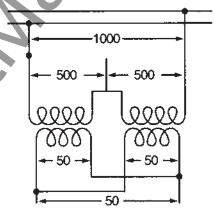

Single-phase transformers on a single phase system.



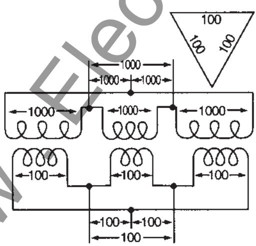

Single-phase transformers, secondaries in parallel.



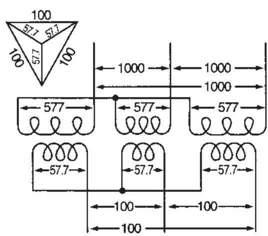

Single-phase transformers secondaries in series.




Single-phase transformers primaries in series, secondaries in parallel.

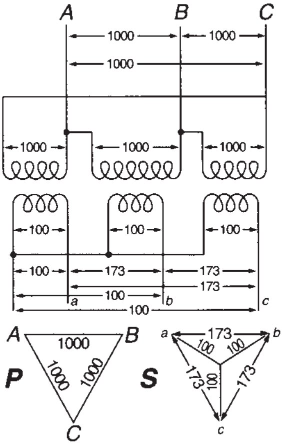



Three single-phase transformers connected delta-delta in a three-phase system

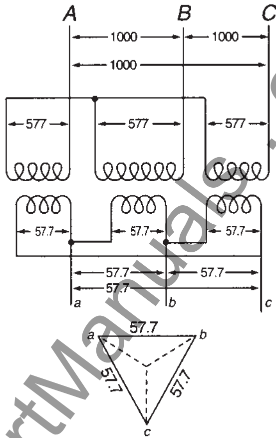



Three single-phase transformers connected star-star in a three-phase system

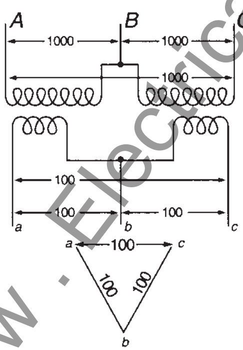
# CONNECTION DIAGRAMS
## For Transformers



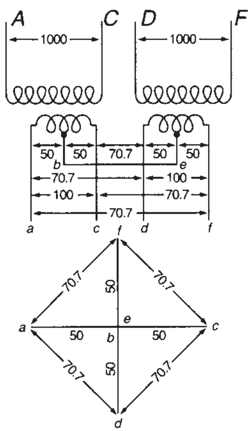

Three single-phase transformers connected delta-star in a three-phase system




Three single-phase transformers connected star-delta in a three-phase system

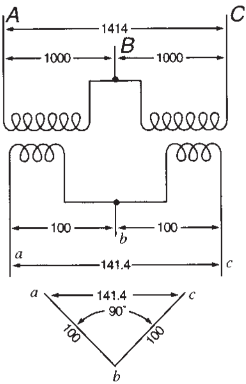



Two single-phase transformers connected open delta in a three phase system

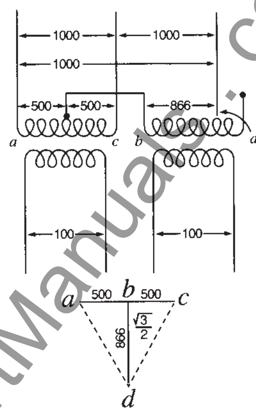



Two single-phase transformers connected star in a four-wire two-phase system

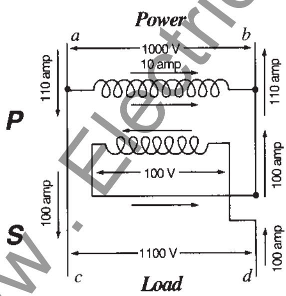
# CONNECTION DIAGRAMS
## For Transformers



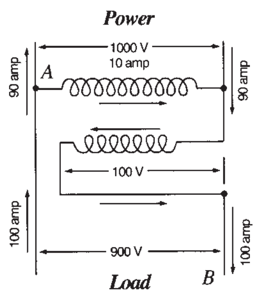

Two single-phase transformers
connected in a three-wire
two-phase system




Two single-phase transformers
connected in a three phase
two-phase system. Scott Connection



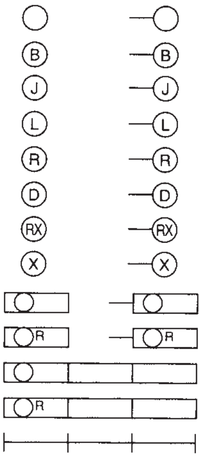

Single phase transformer
used as a booster.




Single phase transformer
connected to lower the E.M.F.

## GRAPHIC SYMBOLS FOR ELECTRICAL WIRING
### Lighting outlets

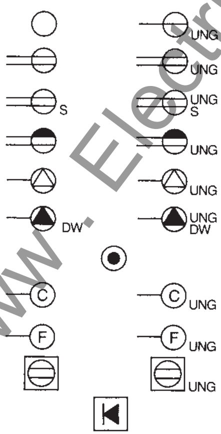
*Ceiling* *Wall*




Outlet
Blanked Outlet
Junction Box
Lamp Fixture Holder
Recessed Lamp Fixture
Drop Cord
Recessed Exit Light
Surface or Pendant Exit Light
Surface or Pendant Fluorescent Fixture
Recessed Fluorescent Fixture
Surface/Pendant Continuous-Row Fluorescent Fixture
Recessed Continuous -Row Fluorescent Fixture
Bare-Lamp Fluorescent Strip

### Receptacle Outlets

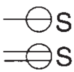
*Grounded* *Ungrounded*




Single Receptacle Outlet
Duplex Receptacle Outlet
Switched Receptacle & Convenience Outlet
Duplex Receptacle Outlet - Split Wired
Single Special-Purpose Receptacle Outlet
Special-Purpose Connection - Subscript Letters Indicate Function (DW - Dishwasher, etc.)
Floor Receptacle
Clock Hanger Receptacle
Fan Hanger Receptacle
Floor Duplex Receptacle Outlet
Floor Telephone Outlet - Public

## Switch Outlets

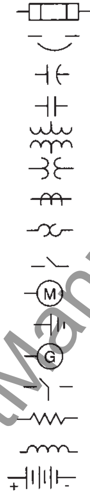
| | |
|---|---|
| S | Single-Pole Switch |
| $S_2$ | Double-Pole Switch |
| $S_3$ | Three-Way Switch |
| $S_4$ | Four-Way Switch |
| $S_F$ | Fused Switch |
| $S_{WPF}$ | Weather-Proof Fused Switch |
| $S_K$ | Key-Operated Switch |
| $S_P$ | Switch and Pilot Lamp |
| $S_L$ | Switch for Low-Voltage System |
| $S_{RC}$ | Remote Control Switch |



- Switch and Single Receptacle
- Switch and Double Receptacle

| | |
|---|---|
| $S_{WP}$ | Weatherproof Switch |
| $S_D$ | Door Switch |
| $S_T$ | Time Switch |
| $S_{MC}$ | Momentary Contact Switch |
| $S_{CB}$ | Circuit Breaker Switch |
| $S_{WCB}$ | Weatherproof Circuit Breaker Switch |

## Power Circuits

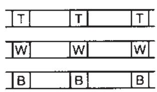


- Fuse
- Circuit Breaker
- Capacitor
- Contactor
- Transformer
- Potential Transformer
- Current Transformer
- Overload Relay
- Line Switch
- Motor
- Ground
- Generator
- Transfer Switch
- Resistor
- Inductor
- Battery

## Residential Occupancies

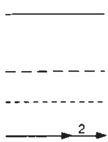

- Push-button
- Buzzer
- Bell
- Chime
- Annunciator
- Electric Door Opener
- Interconnection Box
- Outside Telephone
- Interconnecting Telephone
- Radio Outlet
- Television Outlet

## Bus Duct and Wireway




- Trolley Duct
- Wireway
- Busway (Service, Feeder or Plug-in)

## Circuiting



- Wiring Concealed in Ceiling or Wall
- Wiring Concealed in Floor
- Wire Exposed
- Branch Circuit Home Run to Panel Board

## APPROXIMATE COST OF OPERATING AVERAGE ELECTRICAL APPLIANCES ON A 10-CENT RATE

| Appliance | Typical Average Annual Power Consumption - KWH | Annual Cost at 10 Cents/KWH |
|---|---|---|
| Hot Water Heater | 4,000 | $400.00 |
| Air Conditioner (Room) | 300 | 30.00 |
| Air Conditioner (House) | 1,300 | 130.00 |
| Swimming Pool | 1,900 | 190.00 |
| Room Heater | 720 | 72.00 |
| Refrigerator: Manual (12 Cu. Ft.) | 600 | 60.00 |
| Automatic Defrost (14 Cu. Ft.) | 950 | 95.00 |
| Automatic Defrost (19 Cu. Ft.) | 1,400 | 140.00 |
| Freezer: Manual (16 Cu. Ft.) | 950 | 95.00 |
| Automatic Defrost (16 Cu. Ft.) | 1,100 | 110.00 |
| Water Bed | 1,000 | 100.00 |
| Lighting: 4 - 5 Rooms | 550 | 55.00 |
| 6 - 8 Rooms | 670 | 67.00 |
| 9 - 12 Rooms | 1,300 | 130.00 |
| Attic Fan | 375 | 37.50 |
| Clothes Dryer | 1,000 | 100.00 |
| Furnace Fan | 400 | 40.00 |
| Range/Oven | 460 | 46.00 |
| Well Pump | 500 | 50.00 |
| Dishwasher (Not Incl. Hot Water | 360 | 36.00 |
| Dehumidifier | 540 | 54.00 |
| Window Fan | 300 | 30.00 |
| Colour Television | 300 | 30.00 |
| Microwave Oven | 250 | 25.00 |
| Sump Pump | 240 | 24.00 |
| Toaster Oven | 160 | 16.00 |
| Personal Computer | 160 | 16.00 |
| Coffee Maker | 120 | 12.00 |
| Slow Cooker | 120 | 12.00 |
| Frying Pan | 120 | 12.00 |
| Washing Machine (Not Hot Water) | 150 | 15.00 |
| Iron | 110 | 11.00 |
| Electric Blanket | 100 | 10.00 |
| Black & White Television | 85 | 8.50 |
| Stereo | 85 | 8.50 |
| Radio | 85 | 8.50 |
| Broiler | 70 | 7.00 |
| Trash Compactor | 70 | 7.00 |
| Vacuum Cleaner | 35 | 3.50 |
| Toaster | 25 | 2.50 |
| Sandwich Grill | 25 | 2.50 |

Note - For different rates,multiply the new rate times the annual usage. Example: The annual cost of running a hot water heater at $.08/KWH would be .08 × 4000 = $320.00

Source: Massachusetts Electric Company

# THERMOMETER SCALE
## Celsius - Fahrenheit

| Celsius = 5/9 (F - 32) | | | | Fahrenheit = 9/5 C + 32 | | | |
|---|---|---|---|---|---|---|---|
| C | F | C | F | C | F | C | F |
| -35 | -31.0 | 13 | 55.4 | 49 | 120.2 | 85 | 185.0 |
| -30 | -22.0 | 14 | 57.2 | 50 | 122.0 | 86 | 186.8 |
| -25 | -13.0 | 15 | 59.0 | 51 | 123.8 | 87 | 188.6 |
| -20 | -4.0 | 16 | 60.8 | 52 | 125.6 | 88 | 190.4 |
| -19 | -2.2 | 17 | 62.6 | 53 | 127.4 | 89 | 192.2 |
| -18 | -.4 | 18 | 64.4 | 54 | 129.2 | 90 | 194.0 |
| -17 | 1.4 | 19 | 66.2 | 55 | 131.0 | 91 | 195.8 |
| -16 | 3.2 | 20 | 68.0 | 56 | 132.8 | 92 | 197.6 |
| -15 | 5.0 | 21 | 69.8 | 57 | 134.6 | 93 | 199.4 |
| -14 | 6.8 | 22 | 71.6 | 58 | 136.4 | 94 | 201.2 |
| -13 | 8.6 | 23 | 73.4 | 59 | 138.2 | 95 | 203.0 |
| -12 | 10.4 | 24 | 75.2 | 60 | 140.0 | 96 | 204.8 |
| -11 | 12.2 | 25 | 77.0 | 61 | 141.8 | 97 | 206.6 |
| -10 | 14.0 | 26 | 78.8 | 62 | 143.6 | 98 | 208.4 |
| -9 | 15.8 | 27 | 80.6 | 63 | 145.4 | 99 | 210.2 |
| -8 | 17.6 | 28 | 82.4 | 64 | 147.2 | 100 | 212.0 |
| -7 | 19.4 | 29 | 84.2 | 65 | 149.0 | 105 | 221.0 |
| -6 | 21.2 | 30 | 86.0 | 66 | 150.8 | 110 | 230.0 |
| -5 | 23.0 | 31 | 87.8 | 67 | 152.6 | 115 | 239.0 |
| -4 | 24.8 | 32 | 89.6 | 68 | 154.4 | 120 | 248.0 |
| -3 | 26.6 | 33 | 91.4 | 69 | 156.2 | 130 | 266.0 |
| -2 | 28.4 | 34 | 93.2 | 70 | 158.0 | 140 | 284.0 |
| -1 | 30.2 | 35 | 95.0 | 71 | 159.8 | 150 | 302.0 |
| 0 | 32.0 | 36 | 96.8 | 72 | 161.6 | 160 | 320.0 |
| 1 | 33.8 | 37 | 98.6 | 73 | 163.4 | 170 | 338.0 |
| 2 | 35.6 | 38 | 100.4 | 74 | 165.2 | 180 | 356.0 |
| 3 | 37.4 | 39 | 102.2 | 75 | 167.0 | 190 | 374.0 |
| 4 | 39.2 | 40 | 104.0 | 76 | 168.8 | 200 | 392.0 |
| 5 | 41.0 | 41 | 105.8 | 77 | 170.6 | 250 | 482.0 |
| 6 | 42.8 | 42 | 107.6 | 78 | 172.4 | 300 | 572.0 |
| 7 | 44.6 | 43 | 109.4 | 79 | 174.2 | 350 | 662.0 |
| 8 | 46.4 | 44 | 111.2 | 80 | 176.0 | 400 | 752.0 |
| 9 | 48.2 | 45 | 113.0 | 81 | 177.8 | 500 | 932.0 |
| 10 | 50.0 | 46 | 114.8 | 82 | 179.6 | 600 | 1112.0 |
| 11 | 51.8 | 47 | 116.0 | 83 | 181.4 | 800 | 1472.0 |
| 12 | 53.6 | 48 | 118.4 | 84 | 183.2 | 1000 | 1832.0 |

## GENERAL CONVERSION TABLE

BTU x 777.5 = Foot pounds
BTU x 1055 = Joules
BTU x 0.000293 = Kilowatt hours
BTU per minute x 13.0 = Foot pounds per second
BTU per minute x 0.0176 = Kilowatts
BTU per hour x 0.000293 = Kilowatts
Cubic feet x 0.02832 = Cubic meters
Cubic feet per minute x 7.48 = US Gallons per minute
Cubic inches x 16.387 = Cubic centimeters
Cycles per second = Hertz
Degrees x 0.01745 = Radians
Degrees Celsius x 1.8 + 32 = Degrees Fahrenheit
Degrees Celsius = (Degrees Fahrenheit - 32) ÷ 1.8
Feet x 30.48 = Centimeters
Feet x 0.3048 = Meters
Feet of water x 0.883 = Inches of Mercury
Feet of water X 63.43 = Pounds per square foot
Feet of water X 0.43135 = Pounds per square inch
Feet per minute X 0.0114 = Miles per hour
Feet per second x 0.682 = Miles per hour
Feet per second x 0.3048 = Meters per second
Foot-pounds x 0.0229 = BTU
Foot-pounds x 5.05/10,000,000 = Horsepower hours
Foot-pounds x 3.77/10,000,000 = Kilowatt hours
Foot-pounds x 1.356 = Joules
Foot-pounds x 1.356 = Newton meters
Foot-pounds per minute x 0.00129 = BTU per minute
Foot-pounds per minute x 3.03/100,000 = Horsepower
Foot-pounds per second x 0.00182 = Horsepower
Foot-pounds per second x 1.356 = Watts
Gallons (US) x 3.785 = Liters
Gallons (US) x 0.134 = Cubic feet
Gallons (Imperial) x 1.2 = US Gallons
Horsepower x 746 = Watts
Horsepower x 42.4 = BTU per minute
Horsepower x 33,000 = Foot-pounds per minute
Horsepower x 550 = Foot-pounds per second

## GENERAL CONVERSION TABLE CONT.

Horsepower Boiler x 33,520 = BTU per hour
Horsepower Boiler x 9.80 = Kilowatts
Horsepower hours x 2550 = BTU
Horsepower hours X 1,980,000 = Foot-pounds
Inches x 2.54 = Centimeters
Inches of mercury x 1.133 = feet of water
Inches of mercury x 70.7 = Pounds per square foot
Inches of mercury x 0.491 = Pounds per square inch
Inches of mercury x 3.374 = Kilopascals
Inches of water x 0.0735 = Inches of Mercury
Inches of water x 5.2 = Pounds per square foot
Inches of water x 0.2486 = Kilopascals
Inch pounds x 0.1130 = Newton meters
Kilowatts x 56.9 = BTU per minute
Kilowatts x 3412 = BTU per hour
Kilowatts x 1.341 = Horsepower
Kilowatt hours x 3412 = BTU
Kilowatt hours x 1.34 = Horsepower hours
Miles per hour x 1.47 = Feet per second
Miles per hour x 0.447 = Meters per second
Miles per hour x 1.609 = Kilometers per hour
Minutes x 0.000291 = Radians
Pounds mass x 0.4536 = Kilograms
Pounds force x 4.448 = Newtons
Pounds per cubic foot x 16.02 = Kilograms per cubic meter
Pounds per cubic foot x 16.02 = Grams per liter
Pounds per square foot x 0.016 = Feet of water
Pounds per square inch x 2.31 = Feet of water
Pounds per square inch x 144 = pounds per square foot
Pounds per square inch x 6.895 = Kilopascals
Radians x 57.3 = Degrees
Radians x 3438 = Minutes
Revolutions x 6.28 = Radians
Revolutions per minute x 0.105 = Radians per second
Square inches x 1,273,000 Circular Mills
Square inches x 6.452 = Square centimeters
Square feet x 0.0929 = Square meters

# WEIGHTS AND MEASURES

### Troy Weight

24 grains = 1 penny weight
20 pennyweights = 1 ounce
12 ounces = 1 pound
3.168 grains = 1 carat

Used for weighing gold, silver and jewels

### Apothecaries' Weight

20 grains = 1 scruple
3 scruples = 1 dram
8 drams = 1 ounce
12 ounces = 1 pound

The ounce and pound in this are the same as in Troy weight

### Avoirdupois Weight

27-11/32 grains = 1 dram
16 drams = 1 ounce
16 ounces = 1 pound
25 pounds = 1 quarter
4 quarters = 1 hundredweight
2000 pounds = 1 short ton
2240 pounds = 1 long ton

### Dry Measure

2 pints = 1 quart
8 quarts = 1 peck
4 pecks = 1 bushel
36 bushels = 1 chaldron

### Liquid Measure

4 gills = 1 pint
2 pints = 1 quart
4 quarts = 1 gallon
31-1/2 gallons = 1 barrel
2 barrels = 1 hogshead
1 gallon = 231 cubic inches

### Mariners' Measure

6 feet = 1 fathom
120 fathoms = 1 cable length
7-1/2 cable lengths = 1 mile
5280 feet = 1 statute mile
6086 feet = 1 nautical mile

### Miscellaneous

3 inches = 1 palm
4 inches = 1 hand
6 inches = 1 span
18 inches = 1 cubit
21.8 inches = 1 Bible cubit
2-1/2 feet = 1 military pace

### Square Measure

144 square inches = 1 square foot
9 square feet = 1 square yard
30-1/4 square yards = 1 square rod
40 square rods = 1 rood
4 roods = 1 acre
640 acres = 1 square mile

### Surveyors' Measure

7.92 inches = 1 link
25 links = 1 rod
10 square chains or 160 square rods = 1 acre
36 square miles (6 miles square) = 1 township
4 rods = 1 chain
640 acres = 1 square mile

### Cubic Measure

1728 cubic inches = 1 cubic foot
27 cubit feet = 1 cubic yard
2150.42 cubic inches = 1 standard bushel
268.8 cubic inches = 1 standard gallon
1 cubic foot = about four-fifths of a bushel
128 cubic feet = 1 cord (wood)
40 cubic feet = ton (shipping

### Long Measure

12 inches = 1 foot
3 feet = 1 yard
5-1/2 yards = 1 rod
40 rods = 1 furlong
8 furlongs = 1 statute mile
3miles = 1 league

## METRIC AND DECIMAL EQUIVALENTS OF FRACTIONS OF AN INCH

**(Bureau of Standards)**

| Fractions of an inch | Decimal Equiv. | Milli-meters | Fractions of an inch | Decimal Equiv. | Milli-meters | Fractions of an inch | Decimal Equiv. | Milli-meters | Fractions of an inch | Decimal Equiv. | Milli-meters |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/32 | .0313 | 0.794 | 9/32 | .2813 | 7.144 | 17/32 | .5313 | 13.494 | 25/32 | .7813 | 19.844 |
| 3/64 | .0469 | 1.191 | 19/64 | .2969 | 7.541 | 35/64 | .5469 | 13.891 | 51/64 | .7969 | 20.241 |
| 1/16 | .0625 | 1.588 | 5/16 | .3125 | 7.938 | 9/16 | .5625 | 14.288 | 13/16 | .8125 | 20.638 |
| 5/64 | .0781 | 1.985 | 21/64 | .3281 | 8.334 | 37/64 | .5781 | 14.684 | 53/64 | .8281 | 21.034 |
| 3/32 | .0938 | 2.381 | 11/32 | .3438 | 8.731 | 19/32 | .5938 | 15.081 | 27/32 | .8438 | 21.431 |
| 7/64 | .1094 | 2.778 | 23/64 | .3594 | 9.128 | 39/64 | .6094 | 15.478 | 55/64 | .8594 | 21.828 |
| 1/8 | .1250 | 3.175 | 3/8 | .3750 | 9.525 | 5/8 | .6250 | 15.785 | 7/8 | .8750 | 22.225 |
| 9/64 | .1406 | 3.572 | 25/64 | .3906 | 9.922 | 41/64 | .6406 | 16.272 | 57/64 | .8906 | 22.622 |
| 5/32 | .1563 | 3.969 | 13/32 | .4063 | 10.319 | 21/32 | .6563 | 16.669 | 29/32 | .9063 | 23.019 |
| 11/64 | .1719 | 4.366 | 27/64 | .4219 | 10.716 | 43/64 | .6719 | 17.066 | 59/64 | .9219 | 23.416 |
| 3/16 | .1875 | 4.763 | 7/16 | .4375 | 11.113 | 11/16 | .6875 | 17.463 | 15/16 | .9375 | 23.813 |
| 13/64 | .2031 | 5.159 | 29/64 | .4531 | 11.509 | 45/64 | .7031 | 17.859 | 61/64 | .9531 | 24.209 |
| 7/32 | .2188 | 5.556 | 15/32 | .4688 | 11.906 | 23/32 | .7188 | 18.256 | 31/32 | .9688 | 24.606 |
| 15/64 | .2344 | 5.953 | 31/64 | .4844 | 12.303 | 47/64 | .7344 | 18.653 | 63/64 | .9844 | 25.003 |
| 1/4 | .2500 | 6.350 | 1/2 | .5000 | 12.700 | 3/4 | .7500 | 19.050 | 1 | 1.0000 | 25.400 |

**On all electrical installations that require fuses, specify SHAWMUT fuses.**
**You will then be in no doubt that the fullest requirements in fusing have been met.**

# DECIMAL EQUIVALENTS, SQUARES, CUBES, SQUARE AND CUBE ROOTS, CIRCUMFERENCES AND AREAS OF CIRCLES, FROM 1/64 TO 1/2 INCH

| Fraction | Decimal Equiv. | Square | Square Root | Cube | Cube Root | Circle* Circum. | Circle* Area |
|---|---|---|---|---|---|---|---|
| 1/64 | .015625 | .0002441 | .125 | .000003815 | .25 | .04909 | .000192 |
| 1/32 | .03125 | .0009766 | .176777 | .000030518 | .31498 | .09817 | .000767 |
| 3/64 | .046875 | .0021973 | .216506 | .000102997 | .36056 | .14726 | .001726 |
| 1/16 | .0625 | .0039063 | .25 | .00024414 | .39685 | .19635 | .003068 |
| 5/64 | .078125 | .0061035 | .279508 | .00047684 | .42749 | .24544 | .004794 |
| 3/32 | .09375 | .0087891 | .306186 | .00082397 | .45428 | .29452 | .006903 |
| 7/64 | .109375 | .0119629 | .330719 | .0013084 | .47823 | .34361 | .009396 |
| 1/8 | .125 | .015625 | .353553 | .0019531 | .5 | .39270 | .012272 |
| 9/64 | .140625 | .0197754 | .375 | .0027809 | .52002 | .44179 | .015532 |
| 5/32 | .15625 | .0244141 | .395285 | .0038147 | .53861 | .49087 | .019175 |
| 11/64 | .171875 | .0295410 | .414578 | .0050774 | .55600 | .53996 | .023201 |
| 3/16 | .1875 | .0351563 | .433013 | .0065918 | .57236 | .58905 | .027611 |
| 13/64 | .203125 | .0412598 | .450694 | .0083809 | .58783 | .63814 | .032405 |
| 7/32 | .21875 | .0478516 | .467707 | .010468 | .60254 | .68722 | .037583 |
| 15/64 | .234375 | .0549316 | .484123 | .012875 | .61655 | .73631 | .043143 |
| 1/4 | .25 | .0625 | .5 | .015625 | .62996 | .78540 | .049087 |
| 17/64 | .265625 | .0705566 | .515388 | .018742 | .64282 | .83449 | .055415 |
| 9/32 | .28125 | .0791016 | .530330 | .022247 | .65519 | .88357 | .062126 |
| 19/64 | .296875 | .0881348 | .544862 | .026165 | .66710 | .93266 | .069221 |
| 5/16 | .3125 | .0976562 | .559017 | .030518 | .67860 | .98175 | .076699 |
| 21/64 | .328125 | .107666 | .572822 | .035328 | .68973 | 1.03084 | .084561 |
| 11/32 | .34375 | .118164 | .586302 | .040619 | .70051 | 1.07992 | .092806 |
| 23/64 | .359375 | .129150 | .599479 | .046413 | .71097 | 1.12901 | .101434 |
| 3/8 | .375 | .140625 | .612372 | .052734 | .72112 | 1.17810 | .110445 |
| 25/64 | .390625 | .1525879 | .625 | .059605 | .73100 | 1.22718 | .119842 |
| 13/32 | .40625 | .1650391 | .637377 | .067047 | .74062 | 1.27627 | .129621 |
| 27/64 | .421875 | .1779785 | .649519 | .075085 | .75 | 1.32536 | .139784 |
| 7/16 | .4375 | .1914063 | .661438 | .083740 | .75915 | 1.37445 | .150330 |
| 29/64 | .453125 | .2053223 | .673146 | .093037 | .76808 | 1.42353 | .161260 |
| 15/32 | .46875 | .2197266 | .684653 | .102997 | .77681 | 1.47262 | .172573 |
| 31/64 | .484375 | .2346191 | .695971 | .113644 | .78535 | 1.52171 | .184269 |
| 1/2 | .5 | .25 | .707107 | .125 | .79370 | 1.57080 | .196350 |

*Fraction represents diameter

# DECIMAL EQUIVALENTS, SQUARES, CUBES, SQUARE AND CUBE ROOTS, CIRCUMFERENCES AND AREAS OF CIRCLES, FROM 33/64 TO 1/2 INCH

| Fraction | Decimal Equiv. | Square | Square Root | Cube | Cube Root | Circle* Circum. | Circle* Area |
|---|---|---|---|---|---|---|---|
| 33/64 | .515625 | .265869 | .718070 | .137089 | .80188 | 1.61988 | .208813 |
| 17/32 | .53125 | .282227 | .728869 | .149933 | .80990 | 1.66897 | .221660 |
| 35/64 | .546875 | .299072 | .739510 | .163555 | .81777 | 1.71806 | .234891 |
| 9/16 | .5625 | .316406 | .75 | .177979 | .82548 | 1.76715 | .248505 |
| 37/64 | .578125 | .334229 | .760345 | .193226 | .83306 | 1.81623 | .262502 |
| 19/32 | .59375 | .352539 | .770552 | .209320 | .84049 | 1.86532 | .276884 |
| 39/64 | .609375 | .371338 | .780625 | .226284 | .84780 | 1.91441 | .291648 |
| 5/8 | .625 | .390625 | .790569 | .244141 | .85499 | 1.96350 | .306796 |
| 41/64 | .640625 | .410400 | .800391 | .262913 | .86205 | 2.01258 | .322328 |
| 21/32 | .65625 | .430664 | .810093 | .282623 | .86901 | 2.06167 | .338243 |
| 43/64 | .671875 | .451416 | .819680 | .303295 | .87585 | 2.11076 | .354541 |
| 11/16 | .6875 | .472656 | .829156 | .324951 | .88259 | 2.15984 | .371223 |
| 45/64 | .703125 | .494385 | .838525 | .347614 | .88922 | 2.20893 | .388289 |
| 23/32 | .71875 | .516602 | .847791 | .371307 | .89576 | 2.25802 | .405737 |
| 47/64 | .734375 | .539307 | .856957 | .396053 | .90221 | 2.30711 | .423570 |
| 3/4 | .75 | .5625 | .866025 | .421875 | .90856 | 2.35619 | .441786 |
| 49/64 | .765625 | .586182 | .875 | .448795 | .91483 | 2.40528 | .460386 |
| 25/32 | .78125 | .610352 | .883883 | .476837 | .92101 | 2.45437 | .479369 |
| 51/64 | .796875 | .635010 | .892679 | .506023 | .92711 | 2.50346 | .498736 |
| 13/16 | .8125 | .660156 | .901388 | .536377 | .93313 | 2.55254 | .518486 |
| 53/64 | .828125 | .685791 | .910014 | .567921 | .93907 | 2.60163 | .538619 |
| 27/32 | .84375 | .711914 | .918559 | .600677 | .94494 | 2.65072 | .559136 |
| 55/64 | .859375 | .738525 | .927024 | .634670 | .95074 | 2.69981 | .580036 |
| 7/8 | .875 | .765625 | .935414 | .669922 | .95647 | 2.74889 | .601320 |
| 57/64 | .890625 | .793213 | .943729 | .706455 | .96213 | 2.79798 | .622988 |
| 29/32 | .90625 | .821289 | .951972 | .744293 | .96772 | 2.84707 | .645039 |
| 59/64 | .921875 | .849854 | .960143 | .783459 | .97325 | 2.89616 | .667473 |
| 15/16 | .9375 | .878906 | .968246 | .823975 | .97872 | 2.94524 | .690291 |
| 61/64 | .953125 | .908447 | .976281 | .865864 | .98412 | 2.99433 | .713493 |
| 31/32 | .96875 | .938477 | .984251 | .909149 | .98947 | 3.04342 | .737078 |
| 63/64 | .984375 | .968994 | .992157 | .953854 | .99476 | 3.09251 | .761046 |
| 1 | 1 | 1 | 1 | 1 | 1 | 3.14159 | .785398 |

*Fraction represents diameter

## AREAS AND CIRCUMFERENCES OF CIRCLES

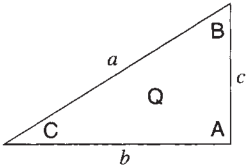
| Diam. | Circum. | Area | Diam. | Circum. | Area |
|---|---|---|---|---|---|
| 1/64 | .049087 | .00019 | 2. | 6.28319 | 3.1416 |
| 1/32 | .098175 | .00077 | 1/16 | 6.47953 | 3.3410 |
| 3/64 | .147262 | .00173 | 1/8 | 6.67588 | 3.5466 |
| 1/16 | .196350 | .00307 | 3/16 | 6.87223 | 3.7583 |
| 3/32 | .294524 | .00690 | 1/4 | 7.06858 | 3.9761 |
| 1/8 | .392699 | .01227 | | | |
| | | | 5/16 | 7.26493 | 4.2000 |
| 5/32 | .490874 | .01917 | 3/8 | 7.46128 | 4.4301 |
| 3/16 | .589049 | .02761 | 7/16 | 7.65763 | 4.6664 |
| 7/32 | .687223 | .03758 | 1/2 | 7.85398 | 4.9087 |
| 1/4 | .785398 | .04909 | | | |
| | | | 9/16 | 8.05033 | 5.1572 |
| 9/32 | .883573 | .06213 | 5/8 | 8.24668 | 5.4119 |
| 5/16 | .981748 | .07670 | 11/16 | 8.44303 | 5.6727 |
| 11/32 | 1.07992 | .09281 | 3/4 | 8.63938 | 5.9396 |
| 3/8 | 1.17810 | .11045 | | | |
| | | | 13/16 | 8.83573 | 6.2126 |
| 13/32 | 1.27627 | .12962 | 7/8 | 9.03208 | 6.4918 |
| 7/16 | 1.37445 | .15033 | 15/16 | 9.22843 | 6.7771 |
| 15/32 | 1.47262 | .17257 | 3. | 9.42478 | 7.0686 |
| 1/2 | 1.57080 | .19635 | | | |
| | | | 1/16 | 9.62113 | 7.3662 |
| 17/32 | 1.66897 | .22166 | 1/8 | 9.81748 | 7.6699 |
| 9/16 | 1.76715 | .24850 | 3/16 | 10.0138 | 7.9798 |
| 19/32 | 1.86532 | .27688 | 1/4 | 10.2102 | 8.2958 |
| 5/8 | 1.96350 | .30680 | | | |
| | | | 5/16 | 10.4065 | 8.6179 |
| 21/32 | 2.06167 | .33824 | 3/8 | 10.6029 | 8.9462 |
| 11/16 | 2.15984 | .37122 | 7/16 | 10.7992 | 9.2806 |
| 23/32 | 2.25802 | .40574 | 1/2 | 10.9956 | 9.6211 |
| 3/4 | 2.35619 | .44179 | | | |
| | | | 9/16 | 11.1919 | 9.9678 |
| 25/32 | 2.45437 | .47937 | 5/8 | 11.3883 | 10.321 |
| 13/16 | 2.55254 | .51849 | 11/16 | 11.5846 | 10.680 |
| 27/32 | 2.65072 | .55914 | 3/4 | 11.7810 | 11.045 |
| 7/8 | 2.74889 | .60132 | | | |
| | | | 13/16 | 11.9773 | 11.416 |
| 29/32 | 2.84707 | .64504 | 7/8 | 12.1737 | 11.793 |
| 15/16 | 2.94524 | .69029 | 15/16 | 12.3700 | 12.177 |
| 31/32 | 3.04342 | .73708 | 4. | 12.5664 | 12.566 |
| 1. | 3.14159 | .78540 | | | |
| | | | 1/16 | 12.7627 | 12.962 |
| 1/16 | 3.33794 | .88664 | 1/8 | 12.9591 | 13.364 |
| 1/8 | 3.53429 | .99402 | 3/16 | 13.1554 | 13.772 |
| 3/16 | 3.73064 | 1.1075 | 1/4 | 13.3518 | 14.186 |
| 1/4 | 3.92699 | 1.2272 | | | |
| | | | 5/16 | 13.5481 | 14.607 |
| 5/16 | 4.12334 | 1.3530 | 3/8 | 13.7445 | 15.033 |
| 3/8 | 4.31969 | 1.4849 | 7/16 | 13.9408 | 15.466 |
| 7/16 | 4.51604 | 1.6230 | 1/2 | 14.1372 | 15.904 |
| 1/2 | 4.71239 | 1.7671 | | | |
| | | | 9/16 | 14.3335 | 16.349 |
| 9/16 | 4.90874 | 1.9175 | 5/8 | 14.5299 | 16.800 |
| 5/8 | 5.10509 | 2.0739 | 11/16 | 14.7262 | 17.257 |
| 11/16 | 5.30144 | 2.2365 | 3/4 | 14.9226 | 17.721 |
| 3/4 | 5.49779 | 2.4053 | | | |
| | | | 13/16 | 15.1189 | 18.190 |
| 13/16 | 5.69414 | 2.5802 | 7/8 | 15.3153 | 18.665 |
| 7/8 | 5.89049 | 2.7612 | 15/16 | 15.5116 | 19.147 |
| 15/16 | 6.08684 | 2.9483 | 5. | 15.7080 | 19.635 |

## TRIGONOMETRIC FUNCTIONS

| Angle- Deg. | Sine | Cos | Tan | Cot | Angle-Deg. |
|---|---|---|---|---|---|
| 0 | .0000 | 1.0000 | .0000 | Infinite | 90 |
| 1 | .0175 | .9998 | .0175 | 57.29 | 89 |
| 2 | .0349 | .9994 | .0349 | 28.64 | 88 |
| 3 | .0523 | .9986 | .0524 | 19.08 | 87 |
| 4 | .0698 | .9976 | .0699 | 14.30 | 86 |
| 5 | .0872 | .9962 | .0875 | 11.43 | 85 |
| 6 | .1045 | .9945 | .1051 | 9.514 | 84 |
| 7 | .1219 | .9925 | .1228 | 8.144 | 83 |
| 8 | .1392 | .9903 | .1405 | 7.115 | 82 |
| 9 | .1564 | .9877 | .1584 | 6.314 | 81 |
| 10 | .1736 | .9848 | .1763 | 5.671 | 80 |
| 11 | .1908 | .9816 | .1944 | 5.145 | 79 |
| 12 | .2079 | .9781 | .2126 | 4.705 | 78 |
| 13 | .2250 | .9744 | .2309 | 4.332 | 77 |
| 14 | .2419 | .9703 | .2493 | 4.011 | 76 |
| 15 | .2588 | .9659 | .2679 | 3.732 | 75 |
| 16 | .2756 | .9613 | .2867 | 3.487 | 74 |
| 17 | .2924 | .9563 | .3057 | 3.271 | 73 |
| 18 | .3090 | .9511 | .3249 | 3.078 | 72 |
| 19 | .3256 | .9455 | .3433 | 2.904 | 71 |
| 20 | .3420 | .9397 | .3640 | 2.748 | 70 |
| 21 | .3584 | .9336 | .3839 | 2.605 | 69 |
| 22 | .3746 | .9272 | .4040 | 2.475 | 68 |
| 23 | .3907 | .9205 | .4245 | 2.356 | 67 |
| 24 | .4067 | .9135 | .4452 | 2.246 | 66 |
| 25 | .4226 | .9063 | .4663 | 2.146 | 65 |
| 26 | .4384 | .8988 | .4877 | 2.050 | 64 |
| 27 | .4540 | .8910 | .5095 | 1.963 | 63 |
| 28 | .4695 | .8829 | .5317 | 1.881 | 62 |
| 29 | .4848 | .8746 | .5543 | 1.804 | 61 |
| 30 | .5000 | .8660 | .5774 | 1.732 | 60 |
| 31 | .5150 | .8572 | .6009 | 1.664 | 59 |
| 32 | .5299 | .8480 | .6249 | 1.600 | 58 |
| 33 | .5446 | .8337 | .6494 | 1.540 | 57 |
| 34 | .5592 | .8290 | .6745 | 1.483 | 56 |
| 35 | .5736 | .8192 | .7002 | 1.428 | 55 |
| 36 | .5878 | .8090 | .7265 | 1.376 | 54 |
| 37 | .6018 | .7986 | .7536 | 1.327 | 53 |
| 38 | .6157 | .7880 | .7813 | 1.280 | 52 |
| 39 | .6293 | .7771 | .8098 | 1.235 | 51 |
| 40 | .6428 | .7660 | .8391 | 1.192 | 50 |
| 41 | .6561 | .7547 | .8693 | 1.150 | 49 |
| 42 | .6691 | .7431 | .9004 | 1.111 | 48 |
| 43 | .6820 | .7314 | .9325 | 1.072 | 47 |
| 44 | .6947 | .7193 | .9657 | 1.036 | 46 |
| 45 | .7071 | .7071 | 1.0000 | 1.000 | 45 |
| **Angle-Deg.** | **Cos** | **Sine** | **Cot** | **Tan** | **Angle-Deg.** |

For angles over 45°, use titles at bottom of page.

## TRIGNOMETRIC FORMULAE
## (SUPLEE)
### Right-Angled Triangles




1. $a = \sqrt{b^2 + c^2}$

2. $a = \dfrac{c}{\sin C}$

3. $a = \dfrac{b}{\cos C}$

4. $a = 2\sqrt{\dfrac{Q}{\sin 2C}}$

5. $b = a \cos C$

6. $b = c \cot C$

7. $b = a \sin B$

8. $b = c \tan B$

9. $b = \sqrt{\dfrac{2Q}{\tan C}}$

10. $Q = \sqrt{\dfrac{a^2 \sin 2C}{4}}$

11. $Q = 1/2\, b^2 \tan C$

12. $Q = 1/2\, c^2 \cot C$

13. $Q = 1/2\, c \sqrt{(a+c)(a-c)}$

14. $\sin C = \dfrac{c}{a}$

15. $\cos C = \dfrac{b}{a}$

16. $\tan C = \dfrac{c}{b}$

17. $\sin 2C = \dfrac{4Q}{a^2}$

18. $\tan C = \dfrac{2Q}{b^2}$

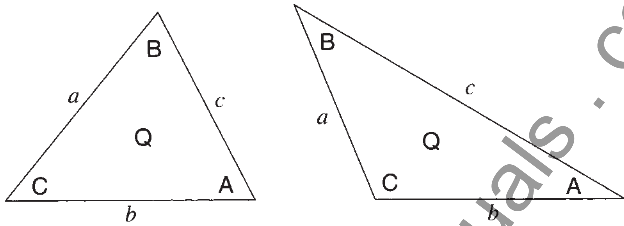
In a triangle the functions of an angle have a certain relation to the opposite side; it is this relationship which enables us to solve the triangle by the application of simple arithmetic.

In triangles the sides are denoted by the letters *a, b,* and *c*; their respective opposite angles are denoted by *A, B,* and *C,* and the area by Q.

Example: The side *c* in a right-angled triangle being 365 feet, and the angle *C* = 39˚20', how long is the side *a* = ?

Formula 2. $a = \dfrac{c}{\sin C} = \dfrac{365}{\sin 39^\circ 20'} = \dfrac{365}{0.63383} = 575.86$ feet.

# TRIGNOMETRICAL FORMULAE
## (SUPLEE)
### Oblique-Angled Triangles




a : b = sin A: sin B, and b : c = sin B : sin C.
a: c = sin A : sin C, and Q : ab = sin C : 2.

1. $a = \dfrac{c \sin A}{\sin C}$
2. $a = \dfrac{c \sin A}{\sin (A + B)}$
3. $a = \dfrac{2Q}{b \sin C}$
4. $b = \dfrac{c \sin B}{\sin C}$
5. $b = \dfrac{2Q}{c \sin A}$
6. $\sin C = \dfrac{c \sin B}{b}$
7. $\sin C = \dfrac{c \sin A}{a}$
8. $\sin A = \dfrac{2Q}{bc}$
9. $\sin A = \dfrac{a \sin C}{c}$
10. $a = \sqrt{b^2 + c^2 - 2\,bc \cos A}$
11. $a = \sqrt{\dfrac{2Q \sin A}{\sin B \sin (A+B)}}$
12. $S = 1/2\,(a + b + c)$
13. $\sin 1/2\,A = \sqrt{\dfrac{(s - b)(s - c)}{bc}}$
14. $\sin 1/2\,B = \sqrt{\dfrac{(s - a)(s - c)}{ac}}$
15. $\cos 1/2\,A = \sqrt{\dfrac{s(s - a)}{bc}}$
16. $\cos 1/2\,B = \sqrt{\dfrac{s(s - b)}{ac}}$
17. $Q = \dfrac{bc \sin A}{2}$
18. $Q = \dfrac{ab \sin C}{2}$
19. $Q = \dfrac{c^2 \sin A \sin B}{2 \sin (A + B)}$
20. $Q = \sqrt{(S - a)(S - b)(S - c)\,S}$
21. $b = \sqrt{\dfrac{2Q \sin (A + C)}{\sin A \sin C}}$
22. $c = \sqrt{\dfrac{2Q \sin C}{\sin A \sin (A + C)}}$

## WEIGHTS OF VARIOUS SUBSTANCES AND METALS

| Substances | Weight per Cubic Foot,Lbs. |
|---|---|
| Asbestos | 125-175 |
| Asphaltum | 87 |
| Brick | 125-137 |
| Brick, Fire | 144 |
| Brickwork, in mortar | 100 |
| Brickwork, in cement | 112 |
| Cement, Set | 178 |
| Chalk | 163 |
| Charcoal, Oak | 35 |
| Charcoal, Pine | 17.5-27.5 |
| Concrete | 137 |
| Earth, loose | 75 |
| Earth, rammed | 120 |
| Emery | 250 |
| Glass, common | 163 |
| Granite | 166 |
| Gravel | 110 |
| Gypsum | 140 |
| Gypsum, Burnt | 113 |
| Ice | 56 |
| Ivory | 117 |
| Kaolin | 137 |
| Lead acetate | 150 |
| Lime, Slaked | 81-87 |
| Limestone | 166 |
| Litharge, Artificial | 583 |
| Magnetite | 315 |
| Marble | 157-177 |
| Masonry | 116-144 |
| Mortar | 109 |
| Plaster of Paris | 112 |
| Pyrites | 306-324 |
| Pyrolusite | 231-287 |
| Sand, dry | 100 |
| Sandstone | 145 |
| Slate | 165 |
| Soapstone | 170 |
| Tile | 115 |
| Trap | 185 |

| Metals and Alloys | Weight per Cubic Foot, Lbs. |
|---|---|
| Aluminum, cast | 160 |
| Antimony, solid | 418 |
| Barium | 242 |
| Bismuth, solid | 617 |
| Boron | 162 |
| Brass, yellow, 70 Cu. + 30 Zn. cast | 527 |
| Brass, red 90 Cu + 10 Zn | 536 |
| Brass, white, 50 Cu. + 50 Zn. | 511 |
| Bronze, 90 Cu. + 10 Sn. | 548 |
| Bronze, 85 Cu. + 15 Sn. | 555 |
| Bronze, 75 Cu. + 25 Sn. | 551 |
| Cadmium | 536 |
| Calcium | 98 |
| Chromium | 410 |
| Cobalt, wrought | 563 |
| Copper, cast | 555 |
| Gold | 1207 |
| German Silver | 523 |
| Iridium | 1380 |
| Iron, grey, cast | 442 |
| Iron,white, cast | 478 |
| Iron, wrought | 490 |
| Lead | 709 |
| Magnesium | 107 |
| Manganese | 428-500 |
| Mercury | 848 |
| Molybdenum | 530 |
| Nickel | 517-555 |
| Platinum | 1338 |
| Potassium, solid | 54 |
| Silver | 655 |
| Sodium | 612 |
| Steel | 486 |
| Strontium | 160 |
| Tin | 455 |
| Titanium | 341 |
| Tungsten | 1193 |
| Vanadium | 342 |
| Zinc, cast | 447 |

# COMPARATIVE PHYSICAL AND MECHANICAL PROPERTIES OF METALS
## Physical Properties (Approximate)
## (Whitehead Metal Products Company, Inc.)

| | Density | Melting Point Degrees C | Melting Point Degrees F | Specific Heat | Heat Expansion Per °C | Heat Cond'y % of Cu | Elec Cond'y %of Cu | Coef. of Elec. Res Per °C | Modulas of Elast'y psi |
|---|---|---|---|---|---|---|---|---|---|
| Monel | 8.80 | 1300-1350 | 2370-2460 | 0.127 | .000014 | 6.6 | 4 | .0019 | 26,000,000 |
| Nickel | 8.85 | 1440 | 2625 | 0.130 | .000013 | 15.5 | 16 | .0041 | 30,000,000 |
| Inconel | 8.55 | 1370 | 2500 | ---- | .000013 | 3.5 | ---- | ---- | 31,000,000 |
| Copper | 8.89 | 1083 | 1980 | 0.093 | .000017 | 100 | 100 | .0040 | 16,000,000 |
| Brass | 8.46 | 900 | 1650 | 0.088 | .000020 | 28 | 28 | .0015 | 13,800,000 |
| Phosphor Bronze | 8.66 | * | ---- | 0.104 | .000018 | ---- | 36 | .0039 | 16,000,000 |
| Everdur | 8.30 | 1050 | 1920 | ---- | .000017 | 30 | 6 | ---- | 15,000,000 |
| Nickel Silver | 8.75 | * | ---- | 0.095 | .000018 | 7.6 | 5.2 | .0003 | 17,000,000 |
| Iron | 7.7 | 1535 | 2795 | 0.110 | .000013 | 15 | 15 | .0062 | 25,000,000 |
| Steel | 7.9 | 1400 | 2550 | ---- | .000013 | 6-12 | 3-15 | ---- | 30,000,000 |
| Cast Iron | 7.2 | 1000-1200 | 1830-2190 | ---- | .000010 | 10-12 | 2-12 | ---- | 12-27,000,000 |
| Duriron | 7.0 | 1260 | 2300 | ---- | .000028 | 17.4 | 2.5 | ---- | ------- |
| 14% Cr Iron | 7.7 | 1490 | 2715 | ---- | .000011 | 5 | 2.8 | ---- | 30,000,000 |
| !7% Cr Iron | 7.6 | 1400 | 2550 | ---- | .000010 | 5 | ---- | .0015 | ------- |
| 18/8 Cr/Ni Iron | 7.9 | 1400 | 2550 | 0.118 | .000017 | 3.6 | 2.8 | ---- | 28,600,000 |
| Zinc | 7.14 | 420 | 760 | 0.094 | .000029 | 29 | 28.2 | .0040 | 13,700,000 |
| Lead | 11.38 | 327 | 620 | 0.031 | .000029 | 9 | 7.8 | .0041 | 800,000 |
| Aluminum | 2.7 | 660 | 1220 | 0.218 | .000024 | 52 | 56-59 | .0042 | 10,000,000 |
| Duralumin | 2.8 | 600 | 1110 | ---- | .000022 | 40 | 32 | ---- | 10,000,000 |
| Silver | 10.51 | 960 | 1760 | 0.056 | .000019 | 110 | 106 | .0040 | 9,000,000 |
| Platinum | 21.5 | 1755 | 3190 | 0.032 | .000008 | 18 | 15 | .0036 | 23,000,000 |

* Varies according to Grade

# MECHANICAL PROPERTIES (APPROXIMATE)

| | | Tensile Strength psi | Yield Point psi | Elastic Limit psi | Endurance Limit psi | Elong. in 2" % | Reduct. In Area % | Brinell Hardness | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 500 kg. | 3,000 kg. |
| | Anealed | 70-85,000 | 25-35,000 | 20-30,000 | 35,000 | 50-35 | 65-75 | 80-105 | 118-135 |
| Monel | Hot-Worked | 80-105,000 | 40-85,000 | 25-65,000 | 35-40,000 | 45-20 | 50-65 | 125-150 | 150-175 |
| | Cold-Worked | 75-175,000 | 40-150,000 | 30-100,000 | 35-50,000 | 35-1 | 45-75 | 110-240 | 115-250 |
| Nickel | Annealed | 65-75,000 | 20-30,000 | 17-23,000 | 30,000 | 53-43 | 65-75 | 85-105 | 115-130 |
| Inconel | Annealed | 80-95,000 | 30-40,000 | 20-30,000 | ------- | 55-45 | 65-75 | ------- | ------- |
| | Cold-Worked | to 200,000 | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| Copper | Annealed | 30,000 | ------- | 3,000 | 10,000 | 75-70 | 50-55 | 30-40 | ------- |
| | Cold-Worked | ------- | ------- | ------- | 16,500 | 15 | 55 | ------- | ------- |
| Brass | Annealed | 45,000 | ------- | 8,500 | 18,000 | 70 | 70 | 50-60 | ------- |
| | Cold-Worked | 80-85,000 | ------- | 36-38,000 | 25,000 | 15 | 60 | ------- | ------- |
| Phosphor Bronze | Annealed | 50,000 | ------- | 14,000 | 20,000 | 70 | 80 | 60 | ------- |
| | Cold-Worked | to 145,000 | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| Everdur | Annealed | 65-70,000 | 25-30,000 | ------- | 25,000 | 60-50 | 55-65 | ------- | ------- |
| | Cold-Worked | 85-110,000 | 60-70,000 | ------- | ------- | 30-13 | 22-49 | ------- | ------- |
| Nickel Silver | Annealed | 50,000 | ------- | 6,500 | 20,000 | 50-40 | 70 | 75-85 | ------- |
| | Cold-Worked | 70,000 | ------- | 30,000 | 23,000 | 25 | 50 | ------- | ------- |
| Wrought Iron | Annealed | 40-50,000 | 28-34,000 | 21-26,00 | 24,000 | 45-40 | 40-45 | 85-95 | ------- |
| Mild Steel | Heat-Treated | 75,000 | ------- | 45,000 | 35,000 | 30 | 65 | ------- | 140-170 |
| Alloy Steel(3120) | Heat-Treated | 116,000 | ------- | 85,000 | ------- | 23 | 48 | ------- | 270 |
| 14% Cr Iron | Annealed | 80,000 | ------- | 45,000 | ------- | 35 | 75 | ------- | 160 |
| | Hot-Worked | 100-115,000 | 75-85,000 | ------- | ------- | ------- | ------- | ------- | ------- |
| 17% Cr Iron | Annealed | 70-75,000 | 45-55,000 | ------- | ------- | 35-30 | 70-75 | ------- | 140-175 |
| | Hot-Worked | 85-95,000 | 65-75,000 | ------- | ------- | 25-20 | 45-50 | ------- | ------- |
| 18/8 Cr/Ni Iron | Annealed | 80-90,000 | 35-40,000 | 20-25,000 | 45,000 | 60-35 | 60-70 | 130-140 | ------- |
| | Cold-Worked | to 300,000 | ------- | ------- | ------- | ------- | ------- | ------- | ------- |
| Aluminum | Annealed | 12-15,000 | 4-7,000 | 2-3,000 | 6,000 | 45-30 | 75-80 | 30-35 | ------- |
| | Cold-Worked | 20,000 | ------- | 12,000 | 8,000 | 18 | 65 | ------- | ------- |
| Duralumin | Annealed | 25-35,000 | 7-10,000 | 7-10,000 | 14,000 | 20-15 | 40-45 | ------- | ------- |
| | Heat-Treated | 55-65,000 | ------- | 30-44,000 | 18,000 | 25-18 | 20-25 | 90-105 | ------- |
| Lead | ------- | 2,800 | ------- | <21,000 | ------- | ------- | ------- | ------- | ------- |

# PROPERTIES OF METALS AS CONDUCTORS

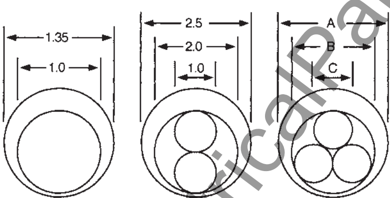
| Metal | Resistivity Microhm-Cm 20°C | Temp. Coeff. of Resistivity per °C | Specific Gravity | Tensile Strength lbs./in.$^2$ | Melting Point °C |
|---|---|---|---|---|---|
| Aluminum | 2.824 | 0.0039 | 2.7 | 30.000 | 659 |
| Antimony | 41.7 | 0.0036 | 6.6 | -- | 630 |
| Bismuth | 120 | 0.004 | 9.8 | -- | 271 |
| Brass | 7 | 0.002 | 8.6 | 70,000 | 900 |
| Cadmium | 7.6 | 0.0038 | 8.6 | -- | 321 |
| Climax | 87 | 0.0007 | 8.1 | 150,000 | 1250 |
| Cobalt | 9.8 | 0.0033 | 8.71 | -- | 1480 |
| Constantan | 49 | 0.00001 | 8.9 | 120,000 | 1190 |
| Copper-annealed | 1.7241 | 0.00393 | 8.89 | 30,000 | 1083 |
| -hand-drawn | 1.771 | 0.00382 | 8.89 | 60,000 | 1083 |
| German Silver, 18%Ni | 33 | 0.0004 | 8.4 | 150,000 | 1100 |
| Gold | 2.44 | 0.0034 | 19.3 | 20,000 | 1063 |
| Iron | 10 | 0.005 | 7.8 | 50,000 | 1530 |
| Lead | 22 | 0.0039 | 11.4 | 3,000 | 327 |
| Magnesium | 4.6 | 0.004 | 1.74 | 33,000 | 651 |
| Manganin | 44 | 0.00001 | 8.4 | 150,000 | 910 |
| Mercury | 95.783 | 0.00089 | 13.546 | 0 | -38.9 |
| Molybdenum, drawn | 5.7 | 0.004 | 9 | 100,000 | 25.00 |
| Monel | 42 | 0.002 | 8.9 | 160,000 | 1300 |
| Nichrome | 100 | 0.0004 | 8.2 | 150,000 | 1500 |
| Nickel | 7.8 | 0.006 | 8.9 | 120,000 | 1452 |
| Palladium | 11 | 0.0033 | 12.2 | 39,000 | 1550 |
| Phosphor Bronze | 7.8 | 0.0018 | 8.9 | 25,000 | 750 |
| Platinum | 10 | 0.003 | 21.4 | 50,000 | 1755 |
| Silver | 1.59 | 0.0038 | 10.5 | 42,000 | 960 |
| Steel, E.B.B. | 10.4 | 0.005 | 7.7 | 53,000 | 1510 |
| Steel, maganese | 70 | 0.001 | 7.5 | 230,000 | 1260 |
| Tantalum | 15.5 | 0.0031 | 16.6 | -- | 2850 |
| Tin | 11.5 | 0.0042 | 7.3 | 4,000 | 232 |
| Tungsten, drawn | 5.6 | 0.0045 | 19 | 500,000 | 3400 |
| Zinc | 5.8 | 0.0037 | 7.1 | 10,000 | 419 |

## CONDUIT AND TUBING DIMENSIONS AND AREAS

(National Electric Products Corp.)

| Conduit Size | Internal Diameter | Internal Area Sq. In. | | | |
|---|---|---|---|---|---|
| | | 100% | 60% | 50% | 40% |
| 1/2” | .622” | .304 | .182 | .152 | .122 |
| 3/4” | .824” | .533 | .320 | .267 | .213 |
| 1” | 1.049” | .864 | .518 | .432 | .346 |
| 1 1/4” | 1.380” | 1.496 | .898 | .748 | .598 |
| 1 1/2” | 1.610” | 2.036 | 1.222 | 1.018 | .814 |
| 2” | 2.067” | 3.356 | 2.014 | 1.678 | 1.342 |
| 2 1/2” | 2.469” | 4.788 | 2.873 | 2.394 | 1.915 |
| 3” | 3.068” | 7.393 | 4.436 | 3.697 | 2.957 |
| 3 1/2 | 3.548” | 9.887 | 5.932 | 4.944 | 3.955 |
| 4” | 4.026” | 12.73 | 7.638 | 6.365 | 5.092 |
| 4 1/2” | 4.506” | 15.95 | 9.570 | 7.975 | 6.380 |
| 5” | 5.047” | 20.00 | 12.000 | 10.000 | 8.000 |
| 6” | 6.065” | 28.89 | 17.334 | 14.445 | |

## CALCULATION OF CONDUIT FILL




| Number of Wires | A | B |
|---|---|---|
| 3 | 2.7 | 2.15 |
| 4 | 3.1 | 2.41 |
| 5 | 3.5 | 2.7 |
| 6 | 3.9 | 3.0 |
| 7 | 4.8 | 3.73 |
| 8 | 4.9 | 3.83 |

Diagram shows smallest equivalent diameter of group of wires and diameter of conduit in terms of diameter of a single wire. Diameter of conduit is for runs of from 50 ft. with 3-90° bends to 150 ft. with 1-90° bend. For more difficult runs increase diameter of conduit to 115%; for less difficult, decrease to 87%.

A = Diameter in conduit in terms of C.

B = Smallest equivalent diameter of group of wires in terms of C.

C = Diameter of individual wire. Use conduit size with internal diameter nearest $A \times C$.

Example: 4 #10 wires require $3.1 \times .63 = 1.95$” or a 2” conduit (Assume dia. #10 wire = .63”)

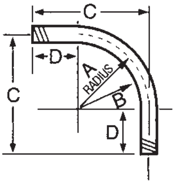
# DIMENSIONS AND WEIGHTS
## RIGID CONDUIT, PIPE, AND ELECTRICAL METALLIC TUBING
## (Garland Manufacturing Company)

| | | RIGID STEEL CONDUIT | | | STANDARD IRON PIPE | | | EXTRA STRONG IRON PIPE | | | ELECTRUNITE STEEL TUBES, ELECTRICAL METALLIC TUBING | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nominal Size in Inches | Threads per Inch | I.D. Inches | O.D. Inches | Lbs. 100 Ft. | I.D. Inches | O.D. Inches | Lbs. 100 Ft. | I.D. Inches | O.D. Inches | Lbs. 100 Ft. | I.D. Inches | O.D. Inches | Lbs. 100 Ft. |
| 1/8 | 27 | ---- | ---- | ---- | 0.269 | 0.405 | 24.5 | 0.215 | 0.405 | 31.4 | ---- | ---- | ---- |
| 1/4 | 18 | ---- | ---- | ---- | .364 | .540 | 42.5 | .302 | .540 | 53.5 | ---- | ---- | ---- |
| 3/8 | 18 | 0.493 | 0.675 | 56.8 | .493 | .675 | 56.8 | .423 | .675 | 73.8 | .493 | .577 | 25.0 |
| 1/2 | 14 | 0.622 | 0.840 | 85.2 | .622 | .840 | 85.2 | .546 | .840 | 108.7 | .622 | .706 | 32.1 |
| 3/4 | 14 | 0.824 | 1.050 | 113.4 | .824 | 1.050 | 113.4 | .742 | 1.050 | 147.3 | .824 | .922 | 48.8 |
| 1 | 11 1/2 | 1.049 | 1.315 | 168.4 | 1.049 | 1.315 | 168.4 | .957 | 1.315 | 217.1 | 1.049 | 1.163 | 71.1 |
| 1 1/4 | 11 1/2 | 1.380 | 1.660 | 228.1 | 1.380 | 1.660 | 228.1 | 1.278 | 1.660 | 299.6 | 1.380 | 1.508 | 100.0 |
| 1 1/2 | 11 1/2 | 1.610 | 1.900 | 273.1 | 1.610 | 1.900 | 273.1 | 1.500 | 1.900 | 363.1 | 1.610 | 1.738 | 118.0 |
| 2 | 11 1/2 | 2.067 | 2.375 | 367.8 | 2.067 | 2.375 | 367.8 | 1.939 | 2.375 | 502.2 | 2.067 | 2.195 | 150.0 |
| 2 1/2 | 8 | 2.469 | 2.875 | 581.9 | 2.469 | 2.875 | 581.9 | 2.323 | 2.875 | 766.1 | ---- | ---- | ---- |
| 3 | 8 | 3.068 | 3.500 | 761.6 | 3.068 | 3.500 | 761.6 | 2.900 | 3.500 | 1025. | ---- | ---- | ---- |
| 3 1/2 | 8 | 3.548 | 4.000 | 920.2 | 3.548 | 4.000 | 920.2 | 3.364 | 4.000 | 1251. | ---- | ---- | ---- |
| 4 | 8 | 4.026 | 4.500 | 1089. | 4.026 | 4.500 | 1089. | 3.826 | 4.500 | 1498. | ---- | ---- | ---- |
| 4 1/2 | 8 | 4.506 | 5.000 | 1264. | 4.506 | 5.000 | 1264. | 4.290 | 5.000 | 1761. | ---- | ---- | ---- |
| 5 | 8 | 5.047 | 5.563 | 1481. | 5.047 | 5.563 | 1481. | 4.813 | 5.563 | 2079. | ---- | ---- | ---- |
| 6 | 8 | 6.065 | 6.625 | 1919. | 6.065 | 6.625 | 1919. | 5.761 | 6.625 | 2857. | ---- | ---- | ---- |
| 8 | 8 | ---- | ---- | ---- | 7.981 | 8.625 | 2881. | 7.625 | 8.625 | 4339. | ---- | ---- | ---- |
| 10 | 8 | ---- | ---- | ---- | 10.020 | 10.750 | 4113. | 9.750 | 10.750 | 5474. | ---- | ---- | ---- |
| 12 | 8 | ---- | ---- | ---- | 12.000 | 12.750 | 5071. | 11.750 | 12.750 | 6542. | ---- | ---- | ---- |

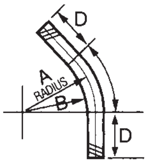
# APPROXIMATE DIMENSIONS OF CONDUIT FITTINGS

(General Electric Company)

## 90 - Degree Elbow




## 45 - Degree Elbow

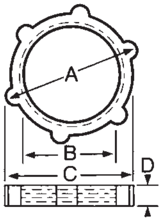



| Nominal Size Inches | A Radius | B | C (offset) | D (Tangent) | |
|---|---|---|---|---|---|
| | | | 90˚ Elbow | 90˚ Elbow | 45˚ Elbow |
| **G.E. RIGID STEEL CONDUIT** | | | | | |
| 1/2" | 4 | 3-21/32 | 6-11/16 | 2-11/16 | 4-5/16 |
| 3/4 | 4-1/2 | 3-31/32 | 7-13/32 | 2-29/32 | 4-47/64 |
| 1 | 5-3/4 | 5-3/32 | 8-27/64 | 2-43/64 | 5 |
| 1-1/4 | 7-1/4 | 6-27/64 | 9-7/8 | 2-5/8 | 3-25/32 |
| 1-1/2 | 8-1/4 | 7-11/32 | 11-3/16 | 2-15/16 | 4-9/16 |
| 2 | 9-1/2 | 8-5/16 | 13-25/32 | 4-9/32 | 6-17/64 |
| 2-1/2 | 10-1/2 | 9-1/16 | 15-1/4 | 4-3/4 | 5-1/8 |
| 3 | 13 | 11-1/4 | 19 | 6 | 7-1/64 |
| 3-1/2 | 15 | 13 | 22-13/16 | 7-13/16 | 8-7/64 |
| 4 | 16 | 13-3/4 | 23 | 7 | 7-23/32 |
| 4-1/2 | 18 | 15-1/2 | 28-11/32 | 10-11/32 | 9-15/16 |
| 5 | 24 | 21-7/32 | 34-5/16 | 10-5/16 | 11-37/64 |
| 6 | 30 | 26-11/16 | 41-7/16 | 11-7/16 | 11-21/32 |
| **ELECTRICAL METALLIC TUBING** | | | | | |
| 1 | 5.063 | | 9.438 | 4.375 | |
| 1-1/4 | 5.500 | | 10 | 4.500 | 5.500 |
| 1-1/2 | 6.875 | | 10.938 | 4.063 | 5.125 |
| 2 | 8 | | 13 | 5 | 6 |

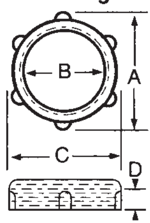
(Steel City Electric Company)

| Nominal Pipe Inches | LOCKNUT A | LOCKNUT B | LOCKNUT C | LOCKNUT D | BUSHING A | BUSHING B | BUSHING C | BUSHING D |
|---|---|---|---|---|---|---|---|---|
| 3/8 | 1-1/16 | 5/8 | 1 | 1/8 | 27/32 | 15/32 | 3/4 | 5/16 |
| 1/2 | 1-3/32 | 25/32 | 1-1/16 | 1/8 | 1-1/32 | 5/8 | 29/32 | 11/32 |
| 3/4 | 1-11/32 | 1 | 1-9/32 | 5/32 | 1-1/4 | 3/4 | 1-5/32 | 7/16 |
| 1 | 1-21/32 | 1-1/4 | 1-19/32 | 5/32 | 1-17/32 | 1-1/32 | 1-13/32 | 9/16 |
| 1-1/4 | 2-1/8 | 1-19/32 | 2-1/32 | 7/32 | 1-29/32 | 1-5/16 | 1-3/4 | 9/16 |
| 1-1/2 | 2-3/8 | 1-13/32 | 2-1/4 | 3/16 | 2-5/32 | 1-17/32 | 2-1/32 | 5/8 |
| 2 | 2-31/32 | 2-5/16 | 2-25/32 | 7/32 | 2-25/32 | 2 | 2-17/32 | 19/32 |
| 2-1/2 | 3-17/32 | 2-3/4 | 3-5/16 | 1/4 | 3-5/8 | 2-13/32 | 3 | 25/32 |
| 3 | 4-5/16 | 3-3/8 | 4-1/32 | 5/16 | 3-7/8 | 3-1/32 | 3-11/16 | 27/32 |
| 3-1/2 | 5 | 3-15/16 | 4-5/8 | 5/16 | 4-17/32 | 3-15/32 | 4-9/32 | 29/32 |
| 4 | 5-3/8 | 4-7/16 | 5-3/16 | 7/16 | 5-1/8 | 4 | 4-25/32 | 7/8 |
| 4-1/2 | 6-3/32 | 4-7/8 | 5-25/32 | 1/2 | 5-3/4 | 4-15/32 | 5-7/16 | 1-1/32 |
| 5 | 6-3/4 | 5-15/32 | 6-7/16 | 9/16 | 6-3/8 | 5-1/32 | 6-1/32 | 1-3/32 |
| 6 | 7-19/32 | 6-1/2 | 7-29/32 | 5/8 | 7-13/32 | 6-1/16 | 7-5/32 | 1-1/8 |

## Locknut




## Bushing



# HARDNESS CONVERSION TABLE (Approximate)

(Industrial Steels, Inc.)

Values vary depending on grades and conditions of material involved. Rockwell “B” Scale should not be used over B-100. The “C” Scale should not be used under C-20.

| Brinell | Rockwell | | Shore Sclero-scope | Tensile Lbs. Sq. In. | Brinell | Rock-well | Shore Sclero-scope | Tensile Lbs. Sq. In. |
|---|---|---|---|---|---|---|---|---|
| Hard No. | B Scale | C Scale | Hard No. | In 1000 Lbs | Hard No. | B Scale | Hard No. | In 1000 Lbs |
| 782 | -- | 72 | 107 | 383 | 163 | 84 | 25 | 84 |
| 744 | -- | 69 | 100 | 365 | 159 | 83 | 25 | 82 |
| 713 | -- | 67 | 96 | 350 | 156 | 82 | 24 | 80 |
| 683 | -- | 65 | 92 | 334 | 153 | 81 | 24 | 79 |
| 652 | -- | 63 | 88 | 318 | 149 | 80 | 23 | 78 |
| 627 | -- | 61 | 85 | 307 | 146 | 78 | 23 | 77 |
| 600 | -- | 59 | 81 | 294 | 143 | 77 | 22 | 76 |
| 578 | -- | 58 | 78 | 284 | 140 | 76 | -- | 74 |
| 555 | -- | 56 | 75 | 271 | 137 | 75 | -- | 73 |
| 532 | -- | 54 | 72 | 260 | 134 | 74 | -- | 71 |
| 512 | -- | 52 | 70 | 251 | 131 | 72 | -- | 70 |
| 495 | -- | 51 | 68 | 242 | 128 | 71 | -- | 69 |
| 477 | -- | 49 | 66 | 233 | 126 | 70 | -- | 67 |
| 460 | -- | 48 | 64 | 226 | 124 | 69 | -- | 66 |
| 444 | -- | 47 | 61 | 217 | 121 | 67 | -- | 65 |
| 430 | -- | 45 | 59 | 210 | 118 | 66 | -- | 63 |
| 418 | -- | 44 | 57 | 205 | 116 | 65 | -- | 62 |
| 402 | -- | 43 | 55 | 197 | 114 | 64 | -- | 61 |
| 387 | -- | 41 | 53 | 189 | 112 | 62 | -- | 60 |
| 375 | -- | 40 | 52 | 183 | 109 | 61 | -- | 59 |
| 364 | -- | 39 | 50 | 178 | 107 | 59 | -- | 58 |
| 351 | -- | 38 | 49 | 172 | 105 | 58 | -- | 57 |
| 340 | -- | 37 | 47 | 167 | 103 | 57 | -- | 56 |
| 332 | -- | 36 | 46 | 162 | 101 | 56 | -- | 55 |
| 321 | -- | 35 | 45 | 157 | 99 | 54 | -- | 54 |
| 311 | -- | 34 | 44 | 152 | 97 | 53 | -- | 53 |
| 302 | -- | 33 | 42 | 148 | 96 | 52 | -- | 53 |
| 293 | -- | 31 | 41 | 144 | 95 | 51 | -- | 52 |
| 286 | -- | 30 | 40 | 140 | 93 | 50 | -- | 52 |
| 277 | -- | 29 | 39 | 136 | 92 | 49 | -- | 51 |
| 269 | -- | 28 | 38 | 132 | 90 | 48 | -- | 50 |
| 262 | -- | 27 | 37 | 128 | 88 | 47 | -- | 49 |
| 255 | -- | 26 | 36 | 125 | 87 | 46 | -- | 48 |
| 248 | -- | 25 | 36 | 121 | 86 | 45 | -- | 48 |
| 241 | 100 | 24 | 35 | 118 | 85 | 44 | -- | 47 |
| 235 | 99 | 23 | 34 | 115 | 83 | 43 | -- | 47 |
| 228 | 98 | 22 | 33 | 113 | 82 | 42 | -- | 46 |
| 223 | 97 | 21 | 33 | 109 | 81 | 41 | -- | 46 |
| 217 | 96 | 20 | 32 | 106 | 80 | 40 | -- | 45 |
| 212 | 95 | -- | 31 | 104 | 79 | 39 | -- | 45 |
| 207 | 94 | -- | 30 | 101 | 78 | 38 | -- | 44 |
| 202 | 93 | -- | 30 | 99 | 77 | 37 | -- | 44 |
| 196 | 92 | -- | 29 | 96 | 76 | 36 | -- | 43 |
| 192 | 91 | -- | 29 | 94 | 75 | 35 | -- | 43 |
| 187 | 90 | -- | 28 | 91 | 74 | 33 | -- | 42 |
| 183 | 89 | -- | 28 | 90 | 73 | 31 | -- | 42 |
| 179 | 88 | -- | 27 | 89 | 72 | 30 | -- | 41 |
| 174 | 87 | -- | 27 | 88 | 71 | 29 | -- | 41 |
| 170 | 86 | -- | 26 | 86 | 70 | 27 | -- | 40 |
| 166 | 85 | -- | 26 | 85 | 69 | 26 | -- | 40 |

# AMERICAN NATIONAL THREAD SERIES (National Bureau of Standards, Handbook H-25)

## AMERICAN NATIONAL COARSE-THREAD SERIES

| Nominal Size | Threads per in. | Major Diameter Inches | Pitch Inch | Tap Drill Size• |
|---|---|---|---|---|
| 1 | 64 | 0.073 | 0.01562 | 0.057 |
| 2 | 56 | .086 | .01786 | 0.068 |
| 3 | 48 | .099 | .02083 | 0.078 |
| 4 | 40 | .112 | .02500 | 0.087 |
| 5 | 40 | .125 | .02500 | 0.100 |
| 6 | 32 | .138 | .03125 | 0.107 |
| 8 | 32 | .164 | .03125 | 0.133 |
| 10 | 24 | .190 | .04167 | 0.148 |
| 12 | 24 | .216 | .04167 | 0.174 |
| 1/4 | 20 | .2500 | .05000 | 0.200 |
| 5/16 | 18 | .3125 | .05556 | 0.257 |
| 3/8 | 16 | .3750 | .06250 | 0.312 |
| 7/16 | 14 | .4375 | .07143 | 0.366 |
| 1/2 | 13 | .5000 | .07692 | 0.423 |
| 9/16 | 12 | .5625 | .08333 | 0.479 |
| 5/8 | 11 | .6250 | .09091 | 0.534 |
| 3/4 | 10 | .7500 | .10000 | 0.650 |
| 7/8 | 9 | .8750 | .11111 | 0.764 |
| 1 | 8 | 1.0000 | .12500 | 0.875 |
| 1 1/8 | 7 | 1.1250 | .14286 | 0.982 |
| 1 1/4 | 7 | 1.2500 | .14286 | 1.107 |
| 1 3/8 | 6 | 1.3750 | .16667 | 1.208 |
| 1 1/2 | 6 | 1.5000 | .16667 | 1.333 |
| 1 3/4 | 5 | 1.7500 | .20000 | 1.550 |
| 2 | 4 1/2 | 2.0000 | .22222 | 1.778 |
| 2 1/4 | 4 1/2 | 2.2500 | .22222 | 2.028 |
| 2 1/2 | 4 | 2.5000 | .25000 | 2.250 |
| 2 3/4 | 4 | 2.7500 | .25000 | 2.500 |
| 3 | 4 | 3.0000 | .25000 | 2.750 |
| 3 1/4 | 4 | 3.2500 | .25000 | 3.000 |
| 3 1/2 | 4 | 3.5000 | .25000 | 3.250 |
| 3 3/4 | 4 | 3.7500 | .25000 | 3.500 |
| 4 | 4 | 4.0000 | .25000 | 3.750 |

•American Machinist

## AMERICAN NATIONAL FINE-THREAD SERIES

| Nominal Size | Threads per In. | Major Diameter Inches | Pitch Inch | Tap Drill Size• |
|---|---|---|---|---|
| 0 | 80 | 0.060 | 0.01250 | 0.048 |
| 1 | 72 | .073 | 0.01389 | 0.059 |
| 2 | 64 | .086 | 0.01562 | 0.070 |
| 3 | 56 | .099 | 0.01786 | 0.081 |
| 4 | 48 | .112 | 0.02083 | 0.091 |
| 5 | 44 | .125 | 0.02273 | 0.102 |
| 6 | 40 | .138 | 0.02500 | 0.113 |
| 8 | 36 | .164 | 0.02778 | 0.136 |
| 10 | 32 | .190 | 0.03125 | 0.159 |
| 12 | 28 | .216 | 0.03571 | 0.180 |
| 1/4 | 28 | .2500 | 0.03571 | 0.214 |
| 5/16 | 24 | .3125 | 0.04167 | 0.271 |
| 3/8 | 24 | .3750 | 0.04167 | 0.333 |
| 7/16 | 20 | .4375 | 0.05000 | 0.338 |
| 1/2 | 20 | .5000 | 0.05000 | 0.450 |
| 9/16 | 18 | .5625 | 0.05556 | 0.507 |
| 5/8 | 18 | .6250 | 0.05556 | 0.569 |
| 3/4 | 16 | .7500 | 0.06250 | 0.688 |
| 7/8 | 14 | .8750 | 0.07143 | 0.804 |
| 1 | 14 | 1.0000 | 0.07143 | 0.929 |
| 1 1/8 | 12 | 1.1250 | 0.08333 | 1.042 |
| 1 1/4 | 12 | 1.2500 | 0.08333 | 1.167 |
| 1 3/8 | 12 | 1.3750 | 0.08333 | 1.292 |
| 1 1/2 | 12 | 1.5000 | 0.08333 | 1.417 |

### CLASSIFICATION OF FITS

Class 1, Loose Fit-Includes screw-thread work of rough commercial quality, where the threads must assemble readily, and a certain amount of shake or play is not objectionable.
Class 2, Free Fit-Includes the great bulk of screw-thread work of ordinary quality, of finished and semi-finished bolts and nuts, machine screws, etc.
Class 3, Medium Fit- Includes the better grade of interchangeable screw-thread work.
Class 4, Close fit-Includes screw-thread work requiring a fine snug fit, much closer than the medium fit. In this case of fit, selective assembly of parts may be necessary.

## DRILL SIZES

| Drill Size | Dia. Inches | Drill Size | Dia. Inches | Drill Size | Dia. Inches | Drill Size | Dia. Inches | Drill Size | Dia. Inches |
|---|---|---|---|---|---|---|---|---|---|
| 80 | .0135 | 50 | .070 | 5/32 | .1562 | F | .257 | 31/64 | .4843 |
| 79 | .0145 | 49 | .073 | 22 | .157 | G | .261 | 1/2 | .500 |
| 78 | .016 | 48 | .076 | 21 | .159 | 17/64 | .2656 | 33/64 | .5156 |
| 77 | .018 | 5/64 | .0781 | 20 | .161 | H | .266 | 17/32 | .5312 |
| 76 | .020 | 47 | .0785 | 19 | .166 | I | .272 | 35/64 | .5468 |
| 75 | .021 | 46 | .081 | 18 | .1695 | K | .281 | 9/16 | .5625 |
| 74 | .0225 | 45 | .082 | 11/64 | .1718 | 9/32 | .2812 | 37/64 | .5781 |
| 73 | .024 | 44 | .086 | 17 | .173 | L | .290 | 19/32 | .5937 |
| 72 | .025 | 43 | .089 | 16 | .177 | M | .295 | 39/64 | .6093 |
| 71 | .026 | 42 | .0935 | 15 | .180 | 19/64 | .2963 | 5/8 | .625 |
| 70 | .028 | 3/32 | .0937 | 14 | .182 | N | .302 | 41/64 | .6406 |
| 69 | .0292 | 41 | .096 | 13 | .185 | 5/16 | .3125 | 21/32 | .6562 |
| 68 | .031 | 40 | .068 | 3/16 | .1875 | O | .316 | 43/64 | .6718 |
| 1/32 | .0312 | 39 | .0995 | 12 | .189 | P | .323 | 11/16 | .6875 |
| 67 | .032 | 38 | .1015 | 11 | .191 | 21/64 | .3281 | 45/64 | .7031 |
| 66 | .033 | 37 | .1040 | 10 | .1935 | R | .339 | 23/32 | .7187 |
| 65 | .035 | 36 | .1065 | 9 | .196 | 11/32 | .3437 | 47/64 | .7343 |
| 64 | .036 | 7/64 | .1093 | 8 | .199 | S | .348 | 3/4 | .750 |
| 63 | .037 | 35 | .110 | 7 | .201 | T | .358 | 49/64 | .7656 |
| 62 | .038 | 34 | .1111 | 13/64 | .2031 | 23/64 | .3593 | 25/32 | .7812 |
| 61 | .039 | 33 | .113 | 6 | .204 | U | .367 | 51/64 | .7968 |
| 60 | .040 | 32 | .116 | 5 | .2055 | 3/8 | .375 | 13/16 | .8125 |
| 59 | .041 | 31 | .120 | 4 | .209 | V | .377 | 53/64 | .8281 |
| 58 | .042 | 1/8 | .125 | 3 | .213 | W | .386 | 27/32 | .8437 |
| 57 | .043 | 30 | .1285 | 7/32 | .2187 | 25/64 | .3906 | 55/64 | .8593 |
| 56 | .0465 | 29 | .136 | 2 | .221 | X | .397 | 7/8 | .875 |
| 3/64 | .0468 | 28 | .1405 | 1 | .228 | Y | .404 | 57/64 | .8906 |
| 55 | .052 | 9/64 | .1406 | A | .234 | 13/32 | .4062 | 29/32 | .9062 |
| 54 | .055 | 27 | .144 | 15/64 | .2343 | Z | .413 | 59/64 | .9218 |
| 53 | .0595 | 26 | .147 | B | .238 | 27/64 | .4218 | 15/16 | .9375 |
| 1/16 | .0625 | 25 | .1495 | C | .242 | 7/16 | .4375 | 61/64 | .9531 |
| 52 | .0635 | 24 | .152 | D | .246 | 29/64 | .4531 | 31/32 | .9687 |
| 51 | .067 | 23 | .154 | E1/4 | .250 | 15/32 | .4687 | 63/64 | 9843 |

# SHEET METAL GAUGE

### United States Standard Gauge for Sheet and Plate Steel (USS Gauge)

#### UNCOATED SHEETS

| Gauge No. | Thickness Inch | Gauge No. | Thickness Inch |
|---|---|---|---|
| 8 | .1644 | 20 | .0359 |
| 9 | .1494 | 21 | .0329 |
| 10 | .1345 | 22 | .0299 |
| 11 | .1196 | 23 | .0269 |
| 12 | .1046 | 24 | .0239 |
| 13 | .0897 | 25 | .0209 |
| 14 | .0747 | 26 | .0179 |
| 15 | .0673 | 27 | .0164 |
| 16 | .0598 | 28 | .0149 |
| 17 | .0538 | 29 | .0135 |
| 18 | .0478 | 30 | .012 |
| 19 | .0418 | | |

#### GALVANIZED SHEETS

| Gauge No. | Thickness Inch | Gauge No. | Thickness Inch |
|---|---|---|---|
| 8 | .1681 | 20 | .0396 |
| 9 | .1532 | 21 | .0366 |
| 10 | .1382 | 22 | .0336 |
| 11 | .1233 | 23 | .0306 |
| 12 | .1083 | 24 | .0276 |
| 13 | .0934 | 25 | .0247 |
| 14 | .0785 | 26 | .0217 |
| 15 | .0710 | 27 | .0202 |
| 16 | .0635 | 28 | .0187 |
| 17 | .0575 | 29 | .0172 |
| 18 | .0516 | 30 | .0157 |
| 19 | .0456 | 31 | .0142 |

**Note:** Due to variation in manufacture a plus or minus tolerance is generally recognized, some authorities allowing a 10 percent variation.

## PULLEYS

The revolutions of any two pulleys over which a belt is run vary in inverse proportion to their diameters. The pulley that imparts motion to the belt is called the "driver," and that which receives motion is called the "driven."

From above the following formulas may be deducted:

D = diameter of driver
d = diameter of driven
N = number of revolutions in driver
n = number of revolutions in driven

$$D = \frac{dn}{N} \qquad d = \frac{DN}{n} \qquad n = \frac{DN}{d} \qquad N = \frac{dn}{D}$$

**Example 1**: Diameter of driven pulley 48-inch. Shaft speed 200 R.P.M. Motor speed 1200 R.P.M. Find diameter of motor pulley.

$D = \frac{dn}{N}$ by substitution $D = \frac{\text{48-inch} \times 200}{1200}$ = 8-inch diameter of motor pulley.

**Example 2:** Diameter of motor pulley 8-inch. Motor speed 1200 R.P.M. Shaft speed 200 R.P.M. Find diameter of pulley for shaft.

$d = \frac{DN}{n}$ by substitution $d = \frac{\text{8-inch} \times 1200}{200}$ = 48-inch diameter of pulley shaft.

**Example 3:** Diameter of motor pulley 8-inch. Motor speed 1200 R.P.M. Diameter of pulley on shaft 48-inch. Find speed of shaft.

$n = \frac{DN}{d}$ by substitution $n = \frac{\text{8-inch} \times 1200}{48}$ = 200 R.P.M. speed of shaft.

**Example 4:** Diameter of motor pulley 8-inch. Speed of shaft 200 R.P.M. Diameter of pulley on shaft 48-inch. Find speed of motor.

$N = \frac{dn}{D}$ by substitution $N = \frac{\text{48-inch} \times 200}{8}$ = 1200 R.P.M. speed of motor.

# SHAFTING

Jones & Laughlin Steel Co. gives the following for steel shafts:

| | Turned | Cold-Rolled |
|---|---|---|
| For simply transmitting power and short countershaft bearings not more than 8 ft. apart | H.P. = $d^3R \div 50$ | H.P. = $d^3R \div 40$ |
| As second movers, or line shafts, bearings 8ft. apart | H.P. = $d^3R \div 90$ | H.P. = $d^3R \div 70$ |
| As prime movers or head shafts carrying main driving pulley or gear, well supported by bearings | H.P. = $d^3R \div 125$ | H.P. = $d^3R \div 100$ |

**Horsepower Transmitted by Cold-Rolled Steel Shafting at Different Speeds as Prime Movers or Head Shafts Carrying Main Driving Pulley or Gear, Well Supported by Bearings**

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| | Revolutions per minute | | | | | | Revolutions per minute | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Diam.** | **100** | **200** | **300** | **400** | **500** | **Diam.** | **100** | **200** | **300** | **400** | **500** |
| 1-1/2 | 3.4 | 6.7 | 10.1 | 13.5 | 16.9 | 2-7/8 | 24 | 48 | 72 | 95 | 119 |
| 1-9/16 | 3.8 | 7.6 | 11.4 | 15.2 | 19.0 | 2-15/16 | 25 | 51 | 76 | 101 | 127 |
| 1-5/8 | 4.3 | 8.6 | 12.8 | 17.1 | 21 | 3 | 27 | 54 | 81 | 108 | 135 |
| 1-11/16 | 4.8 | 9.6 | 14.4 | 19.2 | 24 | 3-1/8 | 31 | 61 | 91 | 122 | 152 |
| 1-3/4 | 5.4 | 10.7 | 16.1 | 21 | 27 | 3-3/16 | 32 | 65 | 97 | 129 | 162 |
| 1-13/16 | 5.9 | 11.9 | 17.8 | 24 | 30 | 3-1/4 | 34 | 69 | 103 | 137 | 172 |
| 1-7/8 | 6.6 | 13.1 | 19.7 | 26 | 33 | 3-3/8 | 38 | 77 | 115 | 154 | 192 |
| 1-15/16 | 7.3 | 14.5 | 22 | 29 | 36 | 3-7/16 | 41 | 81 | 122 | 162 | 203 |
| 2 | 8.0 | 16.0 | 24 | 32 | 40 | 3-1/2 | 43 | 86 | 128 | 171 | 214 |
| 2-1/16 | 8.8 | 17.6 | 26 | 35 | 44 | 3-9/16 | 45 | 90 | 136 | 180 | 226 |
| 2-1/8 | 9.6 | 19.2 | 29 | 38 | 48 | 3-5/8 | 48 | 95 | 143 | 190 | 238 |
| 2-3/16 | 10.5 | 21 | 31 | 42 | 52 | 3-11/16 | 50 | 100 | 150 | 200 | 251 |
| 2-1/4 | 11.4 | 23 | 34 | 45 | 57 | 3-3/4 | 55 | 105 | 158 | 211 | 264 |
| 2-5/16 | 12.4 | 25 | 37 | 49 | 62 | 3-7/8 | 58 | 116 | 174 | 233 | 291 |
| 2-3/8 | 13.4 | 27 | 40 | 54 | 67 | 3-15/16 | 61 | 122 | 183 | 244 | 305 |
| 2-7/16 | 14.5 | 29 | 43 | 58 | 72 | 4 | 64 | 128 | 192 | 256 | 320 |
| 2-1/2 | 15.6 | 31 | 47 | 62 | 78 | 4-3/16 | 74 | 147 | 221 | 294 | 367 |
| 2-9/16 | 16.8 | 34 | 50 | 67 | 84 | 4-1/4 | 77 | 154 | 230 | 307 | 383 |
| 2-5/8 | 18.1 | 36 | 54 | 72 | 90 | 4-7/16 | 88 | 175 | 263 | 350 | 438 |
| 2-11/16 | 19.4 | 39 | 58 | 77 | 97 | 4-1/2 | 91 | 182 | 273 | 365 | 456 |
| 2-3/4 | 21 | 41 | 62 | 83 | 104 | 4-3/4 | 107 | 214 | 322 | 429 | 537 |
| 2-13/16 | 22 | 44 | 67 | 89 | 111 | 5 | 125 | 250 | 375 | 500 | 625 |

Formula H.P. = $d^3R \div 100$

For H.P. transmitted by turned steel shafts, as prime movers, etc., multiply the figures by 0.8.

| | Cold-rolled | Turned |
|---|---|---|
| For shafts, as second movers or line shafts, bearings 8 ft. apart, multiply by............................................ | 1.43 | 1.11 |
| For simply transmitting power, short countershafts, etc., bearings not over 8ft. apart multiply by........................ | 2 | 2.50 |

The horsepower is directly proportional to the number of revolutions per minute.

| SPEED OF SHAFTING | | |
|---|---|---|
| - | Machine shops | 120 to 240 |
| - | Wood-working | 250 to 300 |
| - | Cotton and woolen mills | 300 to 400 |

**BELTING**
(Suplee)

The power which can be transmitted by a belt is measured by the pull and by the lineal velocity at which the belt travels. The pull is limited by the strength of the belt and by the friction upon the pulleys, while the lineal velocity is dependent upon the revolving speed of the pulleys and upon their diameter. If it is attempted to increase the strength by increasing the thickness, it is possible that the stiffness of the belt will prevent it from wrapping closely about the pulley, and hence the friction will be reduced. If the speed is made too high, the centrifugal force will act to throw the belt out of close contact with the pulley and the friction will again be reduced. There are, therefore, several practical limits within which satisfactory belt transmissions should be kept.

The tension which can be maintained in actual practice ranges from about 30 to 60 pounds per inch of width for single ply belts 3/16” thick, 65 to 95 pounds for double ply belts 3/8” thick, and 130 to 160 pounds for four ply belts 3/4” thick.

If a high tension is put on a belt, it will gradually diminish, owing to stretch, until stress upon it becomes low enough to check further stretching. If this tension is sufficient to transmit the power, the transmission will run well, while if the load is too heavy the belt will slip and it must be either tightened or a change made in the width or speed.

If the power to be transmitted is given in horsepower, we have 33,000 foot-pounds per minute to consider. If the belt tension is to be 30 pounds per inch of width, we must, therefore, have a speed of 1100 feet per minute. If the speed is one-half as much, the width must be twice as great, and so the given elements must be taken and the others found. Usually, the speed and the power are given and the width required.

If

| | | |
|---|---|---|
| w | = | width, in inches |
| s | = | speed, in feet, per minute |
| N | = | horsepower |
| t | = | tension, per inch width of belt |

we have

$$N = \frac{tws}{33000} \qquad w = \frac{33000\ N}{ts} \qquad s = \frac{33000\ N}{tw}$$

Or, if we have given the width, speed and horsepower, the minimum tension which can be reached before slipping will occur is

$$t = \frac{33000\ N}{ws}$$

Thus, if a belt 10 inches wide, running at 4000 feet per minute, is transmitting 50 horsepower the tension is

$$t = \quad 33000 \times 50 \quad = 41.25 \text{ pounds}$$

The tension available for transmitting power is really the difference between the tensions of the tight and slack sides, since there must always be tension enough on the slack side to secure sufficient friction on the pulley to keep the belt from slipping.

If we take the formula $N = \frac{tws}{33000}$

and write it $N = \quad t \times 12 \quad \times \frac{ws}{12}$

the last term will represent square feet per minute passing a given point. By substituting any value for t, and making N=1, we can thus find how many square feet per minute will transmit a horsepower. Good, practical belting rules are: For single belts, 60 square feet per minute equals 1 horsepower; and for double belts, 40 square feet per minute equals 1 horsepower. These correspond to 45 pounds and 68 pounds tension per inch of width, respectively - tensions which are readily maintained in practice.

These values are based on the assumption that the belt embraces 180° of each pulley. If the arc of contact is less, the power transmitted may be taken in the following proportions:

**Percentage of Efficiency for Various Arcs of Contact**

| 90° | 100° | 110° | 120° | 130° | 140° | 150° | 160° | 170° | 180° |
|---|---|---|---|---|---|---|---|---|---|
| 0.65 | 0.70 | 0.75 | 0.79 | 0.83 | 0.87 | 0.91 | 0.94 | 0.97 | 1.00 |

The power of 180° is to be multiplied by the percentage coefficient for other arcs. Thus, for 130° only 83 percent as much power is transmitted as with 180°.

## QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS

Short circuit levels must be known before fuses can be correctly applied. For fuses, unlike circuit breakers, there are only four levels of interest. These are 10,000, 50,000, 100,000 and 200,000 RMS symmetrical amperes.

Rigorous determination of short circuit currents requires accurate reactance and resistance data for each power carrying component from the utility generating station right to the point of fault. It is impractical for a plant engineer to collect all this information and yet he is the one most affected by short circuit hazards.

There have been several approaches to “easy” short circuit calculations which have been been too cumbersome to be of practical use. The method described here is not new but it is updated and more comprehensive than before and is the simplest of all approaches.

In summary, each basic component of the industrial electrical distribution system is pre-assigned a ***single*** factor based on the impedance it adds to the system. For instance, a 1000 KVA, 480 volt, 5.75%Z transformer has a factor of 4.80. This factor corresponds with 25,000 RMS short circuit amperes. (directly read on Scale 1)

**Note:** Factors change directly with transformer impedance. If this transformer were 5.00%Z, the factor would be 5.00/5.75 x 4.80 = 4.17.

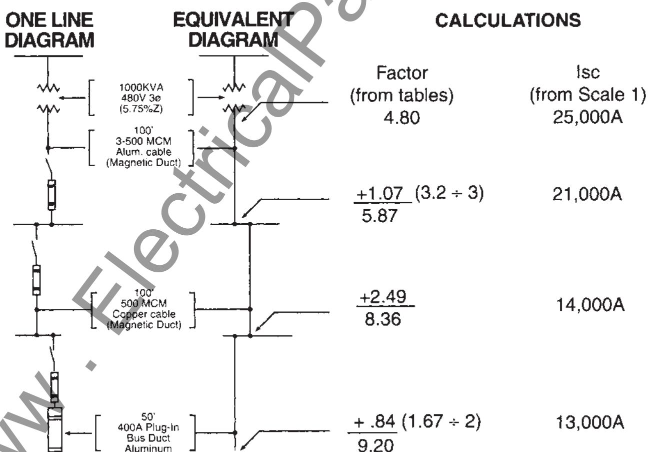
Cable and bus factors are based on 100 foot lengths. Shorter or longer lengths have proportionally smaller or larger factors (i.e. 50’ length = 1/2 factor; 200’ length = 2 x factor).

To find the short circuit current at any point in the system, simply add the factors as they appear in the system from the entrance to the fault point and read the available current on Scale 1.

**Example #1**:

What is the potential short circuit at various points in a 480V, 3-phase system fed by a 1000 KVA, 5.75%Z transformer? (Assume primary short circuit power to be 500 MVA).

**Answer:**




**Example #2:**

If the primary short circuit power were 50MVA (instead of 500MVA) in this same system. what would the Isc be at the transformer? At the end of the bus duct run?

**Answer:**

From the Primary MVA correction factor table (next page), the factor is 50MVA (at 480V) is 1.74. The new Factor at the transformer is 4.80 + 1.74 = 6.54 and Isc is reduced to 18,000A. The new factor at the bus duct is 9.20 + 1.74 = 10.94 and Isc is 11,000A.

## QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS cont.

**Factors**

**A.Transformers - 3∅ (Transformer factors are based on available primary short circuit power of 500 MVA.)**

| Transformer Size | 3∅ 208 | 240 | 480 | 600 |
|---|---|---|---|---|
| 75 KVA 1.60%Z | 9.00 | 10.00 | 20.00 | 24.00 |
| 100 KVA 1.70%Z | 7.00 | 8.00 | 16.00 | 20.00 |
| 112.5 KVA 2.00%Z | 7.40 | 8.50 | 17.00 | 21.00 |
| 150 KVA 2.00%Z | 5.40 | 6.00 | 12.00 | 15.00 |
| 225 KVA 2.00%Z | 3.70 | 4.00 | 8.00 | 10.00 |
| 300 KVA 2.00%Z | 2.70 | 3.00 | 6.00 | 7.50 |
| 500 KVA 2.50%Z | 2.15 | 2.25 | 4.50 | 5.60 |
| 750 KVA 5.75%Z | 2.78 | 3.25 | 6.50 | 8.00 |
| 1000 KVA 5.75%Z | 2.24 | 2.40 | 4.80 | 6.00 |
| 1500 KVA 5.75%Z | 1.48 | 1.60 | 3.20 | 4.00 |
| 2000 KVA 5.75%Z | N.A. | 1.20 | 2.40 | 3.00 |
| 2500 KVA %.75%Z | N.A. | .95 | 1.91 | 2.40 |

NOTES: 208 VOLT 3∅ transformer factors are calculated for 50% motor load.
240, 480 and 600 volt 3∅ transformer factors are calculated for 100% motor load.
A phase-to-phase fault is .866 times the calculated 3-phase value.

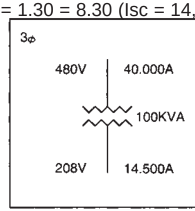
**A.1 Transformer Correction Factors**

For systems with other than 500 MVA primary short circuit power, add the appropriate correction factors in this table to the transformer factor.

| Primary MVA | 3∅ 208 | 240 | 480 | 600 |
|---|---|---|---|---|
| 15 | 2.82 | 3.24 | 6.43 | 8.05 |
| 25 | 1.65 | 1.90 | 3.78 | 4.73 |
| 50 | .78 | .90 | 1.74 | 2.24 |
| 100 | .34 | .40 | .80 | 1.00 |
| 150 | .20 | .23 | .46 | .58 |
| 250 | .08 | .10 | .20 | .25 |
| Infinite | -.08 | -.10 | -.20 | -.25 |

**A2. Second 3∅ Transformer in System**

1. Determine system factor at the second transformer primary.
   **Example:** Isc @ 480V = 40,000A. Factor is 3.00
2. Adjust factor in proportion to voltage ratio of 480/208V transformer.
   **Example:** For 208V, Factor changes to (208 ÷ 480) × 3.00 = 1.30
3. Add factor for second 3∅ transformer.
   **Example:** Factor for 100 KVA, 208V, 1.70%Z transformer is 7.00
   **Total Factor** = 7.00 = 1.30 = 8.30 (Isc = 14,500A)




2nd 3φ Transformer in 3φ system

## QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS cont.

**A3. Single Phase Transformer in 3∅ System**
Transformer connections must be known before factor can be determined. See Diagrams A and B.

1. Determine system factor at 1∅ transformer primary, with 480V pri., 120/240V sec. (Diagram A)

   **Example:** Isc @ 480V = 40,000A, 3∅
   Factor is 3.00

   $$1\varnothing \text{ Factor} = \frac{3\text{x Factor}}{.886} = \frac{3.00}{.886} = 3.45$$

2. Adjustment Factor in proportion to voltage ratio of 480/240V transformer.

   **Example:** For 240V, 1∅, factor is (240 ÷ 480) 3.45 = 1.70

3. Add Factor 1∅ transformer with Diagram A connection.
   **Example:**
   Factor for 100 KVA, 120/240V, 3%Z transformer is:
   a. 120v - Total Factor = 6.22 + 1.70 = 7.92 (Isc = 15,000A)
   b. 240v - Total Factor = 8.64 + 1.70 = 10.34 (Isc = 11,600A)

**Transformers - 1 Phase**

| Transformer Size | Single Phase Voltage | | |
|---|---|---|---|
| | Diagram A 120V | Diagram A 240V | Diagram B 120V |
| 15 KVA 2.5%Z | 34.6 | 48.0 | 24.0 |
| 25 KVA 2.5%Z | 20.7 | 28.8 | 14.4 |
| 37.5 KVA 2.8%Z | 16.6 | 23.0 | 11.5 |
| 50 KVA 3.0%Z | 12.5 | 17.3 | 8.65 |
| 75 KVA 3.0%Z | 8.28 | 11.5 | 5.75 |
| 100 KVA 3.0%Z | 6.22 | 8.64 | 4.32 |
| 150 KVA 2.5%Z | 3.46 | 4.80 | 2.40 |
| 167 KVA 2.5%Z | 3.10 | 4.31 | 2.16 |
| 225 KVA 2.5%Z | 2.30 | 3.20 | 1.60 |
| 300 KVA 3.0%Z | 2.07 | 2.88 | 1.44 |
| 500 KVA 4.5%Z | 1.86 | 2.59 | 1.30 |

NOTE: Factor varies with %Z
**Example:** 50KVA, 240V secondary with a 1.5%Z has a factor of (1.5%Z ÷ 3.0%Z) × 17.3 = 8.65

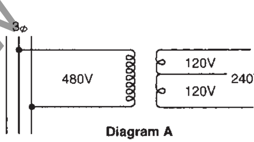


Diagram A

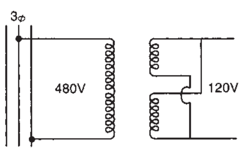


Diagram B

# QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS cont.

## B. Copper Cables in Magnetic Duct (per 100')

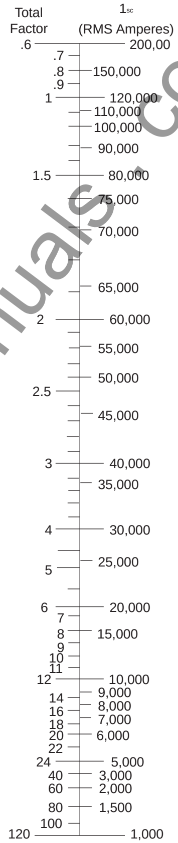
| Cable Size | 3 ∅ Voltage | | | |
|---|---|---|---|---|
| | 208 | 240 | 480 | 600 |
| 8 | 79.00 | 68.00 | 34.00 | 27.00 |
| 6 | 50.00 | 43.00 | 22.00 | 17.50 |
| 4 | 32.00 | 28.00 | 14.00 | 11.15 |
| 2 | 21.00 | 18.00 | 9.00 | 7.23 |
| 1 | 17.50 | 15.00 | 7.40 | 5.91 |
| 1/0 | 14.00 | 12.20 | 6.10 | 4.85 |
| 2/0 | 11.80 | 10.20 | 5.10 | 4.05 |
| 3/0 | 9.80 | 8.50 | 4.27 | 3.43 |
| 4/0 | 8.40 | 7.30 | 3.67 | 2.94 |
| 250MCM | 7.70 | 6.70 | 3.37 | 2.70 |
| 300MCM | 7.00 | 6.10 | 3.04 | 2.44 |
| 350MCM | 6.60 | 5.70 | 2.85 | 2.28 |
| 400MCM | 6.20 | 5.40 | 2.70 | 2.16 |
| 500MCM | 5.80 | 5.00 | 2.49 | 2.00 |
| 600MCM | 5.50 | 4.80 | 2.40 | 1.91 |
| 750MCM | 5.20 | 4.50 | 2.26 | 1.80 |

## B1. Copper Cables in Non-Magnetic Duct (per 100')

| Cable Size | 3 ∅ Voltage | | | |
|---|---|---|---|---|
| | 208 | 240 | 480 | 600 |
| 8 | 78.00 | 67.60 | 33.80 | 27.10 |
| 6 | 47.90 | 41.50 | 20.70 | 16.60 |
| 4 | 30.70 | 26.70 | 13.30 | 10.70 |
| 2 | 19.90 | 17.20 | 8.61 | 6.89 |
| 1 | 16.20 | 14.00 | 7.07 | 5.60 |
| 1/0 | 13.20 | 11.40 | 5.70 | 4.57 |
| 2/0 | 10.60 | 9.21 | 4.60 | 3.68 |
| 3/0 | 8.87 | 7.59 | 3.85 | 3.08 |
| 4/0 | 7.57 | 6.55 | 3.28 | 2.62 |
| 250MCM | 6.86 | 5.95 | 2.97 | 2.38 |
| 300MCM | 5.75 | 4.98 | 2.49 | 1.98 |
| 350MCM | 5.36 | 4.64 | 2.32 | 1.86 |
| 400MCM | 5.09 | 4.41 | 2.20 | 1.75 |
| 500MCM | 4.66 | 4.04 | 2.02 | 1.62 |
| 600MCM | 4.29 | 3.72 | 1.86 | 1.49 |
| 750MCM | 4.05 | 3.51 | 1.76 | 1.41 |

## C. Aluminum Cables in Magnetic Duct (per 100')

| Cable Size | 3 ∅ Voltage | | | |
|---|---|---|---|---|
| | 208 | 240 | 480 | 600 |
| 8 | 129.00 | 112.00 | 56.00 | 45.00 |
| 6 | 83.00 | 72.00 | 36.00 | 29.00 |
| 4 | 53.00 | 46.00 | 23.00 | 18.50 |
| 2 | 35.00 | 30.00 | 15.00 | 12.00 |
| 1 | 28.00 | 24.00 | 12.00 | 9.60 |
| 1/0 | 21.50 | 18.50 | 9.70 | 7.70 |
| 2/0 | 18.50 | 16.00 | 8.00 | 6.40 |
| 3/0 | 15.00 | 13.00 | 6.50 | 5.20 |
| 4/0 | 12.50 | 11.00 | 5.50 | 4.40 |
| 250MCM | 11.10 | 9.60 | 4.80 | 3.85 |
| 300MCM | 9.90 | 8.60 | 4.30 | 3.42 |
| 350MCM | 8.60 | 7.40 | 3.70 | 3.00 |
| 400MCM | 8.30 | 7.20 | 3.60 | 2.90 |
| 500MCM | 7.40 | 6.40 | 3.20 | 2.60 |
| 600MCM | 7.20 | 6.20 | 3.10 | 2.44 |
| 750MCM | 6.50 | 5.60 | 2.80 | 2.22 |



Scale 1

$$Isc = \frac{120{,}000}{\text{Total Factor}}$$

For parallel runs divide factor by number of conductors per phase.
**Example:** If factor for a single 500MCM conductor is 2.49 then the factor for a run having 3-500MCM per phase is 2.49 ÷ 3 = .83. (Example from Table B 480 volts.)

# QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS cont.

## C1. Aluminum Cables In Non-Magnetic Duct (Per 100')

| Cable Size | 3 ∅ Voltage | | | |
|---|---|---|---|---|
| | 208 | 240 | 480 | 600 |
| 8 | 129.75 | 112.45 | 56.20 | 45.00 |
| 6 | 80.00 | 69.10 | 34.60 | 27.70 |
| 4 | 51.10 | 44.20 | 22.10 | 17.70 |
| 2 | 33.00 | 25.70 | 14.30 | 11.40 |
| 1 | 26.30 | 22.80 | 11.40 | 9.12 |
| 1/0 | 21.20 | 18.40 | 9.20 | 7.36 |
| 2/0 | 17.00 | 14.70 | 7.34 | 5.87 |
| 3/0 | 13.80 | 12.00 | 6.02 | 4.79 |
| 4/0 | 11.50 | 9.95 | 4.98 | 3.99 |
| 250MCM | 10.10 | 8.72 | 4.36 | 3.49 |
| 300MCM | 8.13 | 7.04 | 3.52 | 2.81 |
| 350MCM | 7.49 | 6.50 | 3.07 | 2.45 |
| 400MCM | 6.87 | 5.95 | 2.98 | 2.38 |
| 500MCM | 6.12 | 5.31 | 2.66 | 2.13 |
| 600MCM | 5.30 | 4.59 | 2.29 | 1.83 |
| 750MCM | 4.85 | 4.20 | 2.10 | 1.69 |

For parallel runs, divide factors by conductors per phase.
Example: 3-500MCM per phase, 240v. New Factor = (5.31 ÷ 3) = 1.77

## D. Feeder Bus Duct Factors (per 100')

| Ampere Rating | Copper | | | | Aluminum | | | |
|---|---|---|---|---|---|---|---|---|
| | 208 | 240 | 480 | 600 | 208 | 240 | 480 | 600 |
| 600 | 2.85 | 2.48 | 1.24 | .99 | 2.54 | 2.19 | 1.10 | .88 |
| 800 | 1.61 | 1.40 | .70 | .56 | 2.54 | 2.19 | 1.10 | .88 |
| 1000 | 1.61 | 1.40 | .70 | .56 | 1.90 | 1.65 | .82 | .66 |
| 1200 | 1.21 | 1.06 | .53 | .42 | 1.60 | 1.36 | .68 | .54 |
| 1350 | 1.17 | 1.01 | .51 | .40 | 1.32 | 1.14 | .57 | .46 |
| 1600 | 1.03 | .89 | .45 | .36 | 1.19 | 1.03 | .52 | .41 |
| 2000 | .90 | .78 | .39 | .31 | .90 | .77 | .39 | .31 |
| 2500 | .63 | .54 | .27 | .22 | .70 | .60 | .30 | .24 |
| 3000 | .51 | .44 | .22 | .18 | .60 | .52 | .26 | .21 |
| 4000 | .37 | .32 | .16 | .13 | .43 | .38 | .19 | .15 |
| 5000 | .30 | .26 | .13 | .10 | -- | -- | -- | -- |

Appropriate for use with Feeder Bus Duct Manufactured by ITE, GE, Square D and Westinghouse.

## D1. Plug In Bus Duct Factors (per 100')

| Ampere Rating | Copper | | | | Aluminum | | | |
|---|---|---|---|---|---|---|---|---|
| | 208 | 240 | 480 | 600 | 208 | 240 | 480 | 600 |
| 400 | 2.53 | 2.18 | 1.09 | .89 | 3.88 | 3.34 | 1.67 | 1.36 |
| 600 | 2.53 | 2.18 | 1.09 | .89 | 2.41 | 2.07 | 1.04 | .84 |
| 800 | 1.87 | 1.61 | .81 | .66 | 2.41 | 2.07 | 1.04 | .84 |
| 1000 | 1.87 | 1.61 | .81 | .66 | 1.69 | 1.45 | .73 | .59 |
| 1200 | 1.47 | 1.26 | .63 | .51 | 1.43 | 1.22 | .61 | .50 |
| 1350 | 1.26 | 1.08 | .54 | .44 | 1.30 | 1.12 | .56 | .45 |
| 1600 | .91 | .78 | .39 | .32 | 1.09 | .94 | .47 | .38 |
| 2000 | .79 | .68 | .34 | .28 | .89 | .77 | .38 | .31 |
| 2500 | .61 | .52 | .26 | .21 | .66 | .57 | .28 | .23 |
| 3000 | .48 | .42 | .21 | .17 | .59 | .51 | .25 | .21 |
| 4000 | .43 | .37 | .18 | .15 | .46 | .40 | .20 | .16 |
| 5000 | .38 | .33 | .16 | .13 | .35 | .30 | .15 | .12 |

Appropriate for use with plug-in Bus Duct Manufactured by GE, Square D and Westinghouse.

# TRANSFORMER CHARACTERISTICS

## Three-Phase Current in Secondary on Short Circuit
## Primary Voltage Assumed to be Sustained

5 to 3000 kVA

5% Impedance

| Trans-former KVA | Secondary Short-Circuit Current in Amperes* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Secondary Volts | | | | | | | | | | |
| | 230 | 460 | 575 | 600 | 2400 | 4160 | 7200 | 12,470 | 13,800 | 23,000 | 34,500 |
| 5 | 251 | 125 | 100 | 96 | -- | -- | -- | -- | -- | -- | -- |
| 7.5 | 376 | 188 | 151 | 144 | -- | -- | -- | -- | -- | -- | -- |
| 10 | 502 | 251 | 201 | 192 | -- | -- | -- | -- | -- | -- | -- |
| 15 | 751 | 376 | 301 | 289 | 72 | -- | -- | -- | -- | -- | -- |
| 20 | 1005 | 502 | 402 | 385 | 96 | -- | -- | -- | -- | -- | -- |
| 25 | 1253 | 629 | 502 | 481 | 120 | 69 | -- | -- | -- | -- | -- |
| 37.5 | 1882 | 941 | 751 | 722 | 181 | 104 | -- | -- | -- | -- | -- |
| 50 | 2512 | 1253 | 1005 | 964 | 241 | 139 | 80 | -- | -- | -- | -- |
| 75 | 3764 | 1882 | 1507 | 1443 | 361 | 208 | 120 | 69 | 63 | -- | -- |
| 100 | 5023 | 2512 | 2009 | 1923 | 481 | 278 | 161 | 92 | 84 | -- | -- |
| 125 | 6293 | 3135 | 2512 | 2408 | 600 | 347 | 200 | 115 | 105 | 63 | -- |
| 150 | 7506 | 3764 | 3014 | 2887 | 722 | 416 | 241 | 139 | 125 | 75 | -- |
| 200 | 10046 | 5023 | 4018 | 3851 | 964 | 555 | 321 | 185 | 167 | 100 | 67 |
| 250 | 12529 | 6293 | 5023 | 4809 | 1201 | 693 | 401 | 232 | 209 | 125 | 84 |
| 300 | 15069 | 7506 | 6005 | 5774 | 1443 | 831 | 481 | 278 | 251 | 151 | 100 |
| 400 | 21824 | 10046 | 8025 | 7679 | 1923 | 1109 | 641 | 371 | 335 | 201 | 134 |
| 500 | 25115 | 12529 | 10046 | 9642 | 2408 | 1386 | 803 | 463 | 419 | 251 | 167 |
| 750 | 37644 | 18822 | 15069 | 14434 | 3609 | 2079 | 1201 | 693 | 629 | 376 | 251 |
| 1000 | 40185 | 25115 | 20092 | 19226 | 4809 | 2777 | 1605 | 924 | 837 | 502 | 345 |
| 1500 | 75058 | 37644 | 30139 | 28868 | 7217 | 4163 | 2408 | 1391 | 1253 | 751 | 502 |
| 2000 | 100462 | 50231 | 39030 | 38510 | 9642 | 5554 | 3210 | 1853 | 1674 | 1005 | 670 |
| 2500 | 125289 | 62933 | 50231 | 48095 | 12009 | 6928 | 4007 | 2315 | 2090 | 1253 | 837 |
| 3000 | 150693 | 75058 | 60046 | 57737 | 14434 | 8314 | 4809 | 2777 | 2512 | 1507 | 1005 |

***For transformers of other than 5% impedance, multiply the ampere given in the table by 5 and divide the product by the percent impedance of the transformer used.**

# SHORT CIRCUIT LANGUAGE

It is impossible to discuss short-circuit currents without some understanding of what happens during a short circuit and the terminology.



## DIRECT CURRENT

The introduction of direct current in an alternating current analysis is done to provide a relative comparison, to make the understanding of alternating current easier.

Figure 1 represents steady current of 10 amperes direct current. As can be seen, the DC value is constant and theoretically unaffected by time.

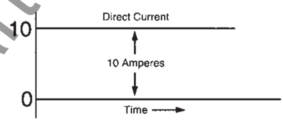



Figure 1

## ALTERNATING CURRENT

Almost everybody knows that alternating currents vary or alternate continuously. They keep changing direction and vary in the value from 0 to Maximum back to 0 in one direction and then repeating in the opposite direction.

60 cycle AC currents change direction 60 times per second and one cycle = 1/60 second = 0.0167 second.

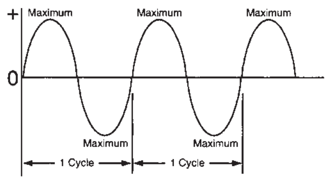



Figure 2

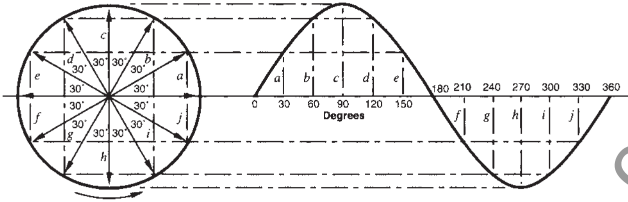



**Figure 3**

## SINE WAVE

All the alternating current circuits which we will consider have currents and voltages following a sine wave. A sine wave is generated by a revolving vector, i.e. inside a rotating machine.

## SINUSOIDAL WAVE

Same as the Sine Wave.

## EFFECTIVE CURRENT

Since an alternating current varies continuously from 0 to maximum to 0 first in one direction and then in the other, it is not readily apparent just what the true current value really is.

The current at any point on a sine wave is called the INSTANTANEOUS CURRENT. The current at the top of the wave is called the PEAK or CREST CURRENT. It is also possible to determine the ARITHMETIC AVERAGE VALUE of the alternating current, but none of these values correctly relate alternating current to direct current. It is certainly desirable to have 1 ampere of alternating current do the same work as 1 ampere of direct current. This current is called the EFFECTIVE CURRENT and 1 ampere of effective alternating current will do the same heating as 1 ampere of direct current.

## RMS CURRENT

Effective current is more commonly called RMS current. RMS means root mean square and is the square root of the average of all the instantaneous currents squared.

The RMS value of a sine wave is readily determined by calculus but can perhaps be more easily understood by old-fashioned arithmetic. Let's study a half sine wave having a 10 ampere maximum or peak value. The complete wave would be 20 amperes (Fig. 4).

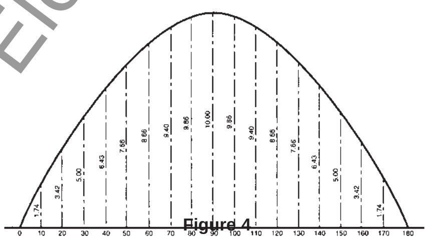



**Figure 4**

We will use instantaneous currents at 10 degree intervals. The value of the instantaneous currents can be easily measured. They have been tabulated in the following table. These values have also been squared. The average instantaneous current and the average squared instantaneous current are found by dividing the totals by 18. The square root of the average squared instantaneous current is easily found and readily understood.

**Calculation of Average and RHS Currents**

| Degrees | Instantaneous Amperes | Instantaneous Amperes Squared |
|---|---|---|
| 0 | 0 | 0 |
| 10 | 1.74 | 3.03 |
| 20 | 3.42 | 11.70 |
| 30 | 5.00 | 25.00 |
| 40 | 6.43 | 41.34 |
| 50 | 7.66 | 58.67 |
| 60 | 8.66 | 75.00 |
| 70 | 9.40 | 88.36 |
| 80 | 9.86 | 97.22 |
| 90 | 10.00 | 100.00 |
| 100 | 9.86 | 97.22 |
| 110 | 9.40 | 88.36 |
| 120 | 8.66 | 75.00 |
| 130 | 7.66 | 58.67 |
| 140 | 6.43 | 41.34 |
| 150 | 5.00 | 25.00 |
| 160 | 3.42 | 11.70 |
| 170 | 1.74 | 3.03 |
| 180 | 0 | 0 |
| **Total** | **114.34** | **900.9** |
| **Average** | **6.36** | **50.0** |

**RMS = $\sqrt{50.0}$ = 7.07 amperes**

The average current of sine wave is 0.636 of the peak current and the effective or RMS current is 0.707 of the peak current

Putting this another way we can say that the peak is 1.4 times the RMS value. Standard AC ammeters are marked in RMS amperes and unless stated otherwise all AC currents are considerd RMS currents.

When speaking of currents which flow for a few cycles or less it is necessary to specify what kind of amperes were talking about such as:

- RMS (effective)
- Peak (crest)
- Average
- Instantaneous

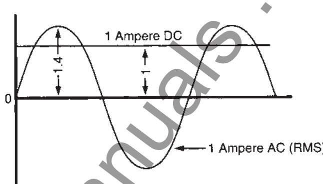



**Figure 5**

The two currents shown above have the same effective value.

**SYMMETRICAL CURRENT**

A symmetrical current wave is symmetrical about the zero axis of the wave**.** This wave has the same magnitude above and below the zero axis.

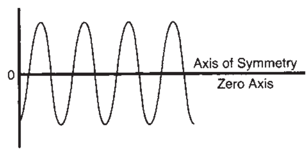



**Figure 6**

**ASYMMETRICAL CURRENT**

An asymmetrical current wave is not symmetrical about the zero axis. The axis of symmetry is displaced or offset from the zero axis, and the magnitude above and below the zero axis are not equal. See Figure 7.

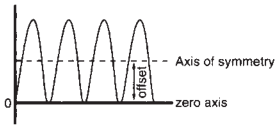



**Figure 7**

## OFFSET CURRENT

An asymmetrical wave can be partially offset. Fig. 7 shows a fully offset wave. Offset waves are sometimes called DISPLACED WAVES.

## DC COMPONENT

The axis of symmetry of an offset wave resembles a DC current and asymmetrical currents can be readily handled if considered to have an AC component and a DC component. Both of these components are theoretical. The DC component is generated within the AC system and has no external source.

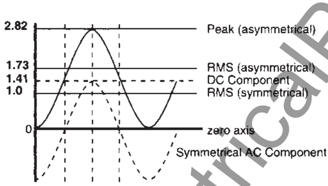



**Figure 8**

Fig. 8 shows a fully offset asymmetrical current with a steady DC component as its axis of symmetry. The symmetrical component has the zero axis as its axis of symmetry. If the RMS or effective value of the symmetrical current is 1, then the peak of the symmetrical current is 1.41. This is also the effective value of the DC component. We can add these two effective currents together by the square root of the sum of the squares and get the effective or RMS value of the asymmetrical current.

$$I_{asy} = \sqrt{I^2dc + I^2sym}$$

$$I_{asy} = \sqrt{(1.41)^2 + I^2} = \sqrt{3} = 1.73$$

The RMS value of a fully offset asymmetrical current is 1.73 times the symmetrical RMS current. It is readily apparent that the peak asymmetrical current is twice the peak symmetrical current, i.e. 2 × 1.41 = 2.82

## TOTAL CURRENT

The term total current is used to express the total or the sum of the of the AC component and the DC component of an asymmetrical current.

Total current and TOTAL ASYMMETRICAL CURRENT have the same meaning and may be expressed in peak or RMS amperes.

## DECAY

Unfortunately fault currents are neither symmetrical or fully asymmetrical but somewhere in between. The DC component is usually short lived and is said to decay.

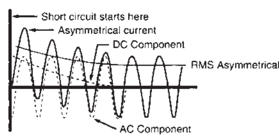



**Figure 9**

In the above diagram the DC component decays to zero in about four cycles. The rate of decay is called DECREMENT and depends upon the circuit constants. The DC components would never decay in a circuit having reactance but zero resistance, and would remain constant forever. In a circuit having resistance but zero reactance the DC component would decay instantly. These are theoretical conditions and all practical circuits have some resistance and reactance, and the DC component disappears in a few

**CLOSING ANGLE**

A short-circuit fault can occur at any point on the voltage wave of the circuit. So far we've avoided discussing voltage characteristics but the voltage wave resembles the current wave. The two waves may be in phase or out of phase and the magnitude and symmetry of the current wave on a short circuit depends on the point of the voltage wave at which the short occurs.

In laboratory tests it is possible to pick the point on the voltage wave where the fault occurs by closing the circuit at any desired angle on the voltage wave. We can say that we pick the closing angle to produce the current conditions which we wish. This is called Controlled Closing.

**RANDOM CLOSING**

In real life, faults occur at any and every point on the voltage wave and in a laboratory this can be duplicated by closing the circuit at random. This is known as random closing. The following is true of a short circuit having negligible resistance:

1.) If the fault occurs at zero voltage the current wave is fully asymmetrical, thus the maximum value of short-circuit current is obtained.

2.) If the fault occurs at maximum voltage the current wave is completely symmetrical, and a minimum value of short-circuit current is obtained.

3.) Most natural faults occur somewhere between these two extremes.

**AVAILABLE SHORT CIRCUIT CURRENT**

The first question which enters our minds when we look at Fig 9. is just what is the current value of a wave which is neither symmetrical or asymmetrical, in other words, what is the available short-circuit current. Referring again to Fig. 9 we can say that it is symmetrical after about 4 cycles, and we can properly talk about the available short-circuit current in RMS symmetrical amperes after the DC component becomes zero. We can also determine current at 1, 2, 3 cycles of any other time after the short circuit started.

**FIRST HALF CYCLE CURRENT**

The accepted practice is to use the current which is available 1/2 cycle after the short circuit starts. For a fully offset wave the maximum current does occur at the end of the first half cycle of time. Because this is the worst case, we should determine the peak and RMS currents at this point. Since the DC component has already started to decay, we cannot use the values shown in Fig. 8 where there is no decay.

As already mentioned, the rate of decay depends upon the circuit constants. A study of actual circuits of 600 volts or less indicates that the proper 1/2 cycle value for the RMS asymmetrical current is 1.4 times the RMS symmetrical current, and the peak instantaneous current is 1.7 times the RMS asymmetrical current.

$1.7 \times 1.4 = 2.4$ RMS symmetrical current

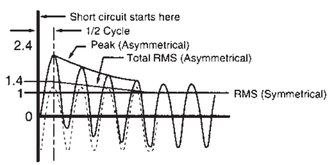



**Figure 10**

**CURRENT LIMITATION**

The significant reduction of available short-circuit current, in a circuit, by use of a device that prevents this short-circuit current from reaching its maximum value, is called Current Limitation. Fuses which perform this function are known as Current Limiting. Current Limiting fuses operate in less than 1/2 cycle, thus interrupting the short-circuit current before it can achieve its maximum value. The resultant reduction(refer to shaded segment of Fig. 11) is substantially less than the maximum value of available short-circuit current.

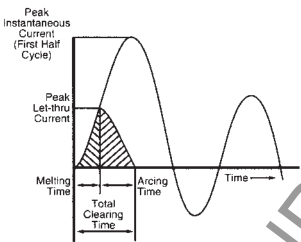



**Figure 11**

This figure shows the current-limiting action of these fuses. The MELTING TIME is the time required to melt the fusible link. The ARCING TIME is the time required for the arc to burn back the fusible link and reduce the current to zero. TOTAL CLEARING TIME is the sum of the melting and arcing times and is the time from fault initiation to extinction.

**LET-THRU CURRENT**

The maximum instantaneous or peak current which passes through the fuse is called the let-thru current. This value can be expressed in RMS amperes also. The value of let-thru current is used in determination of electrical equipment protection, as required by the NEC, Article 110-10 and CEC 14-200.

**TRIANGULAR WAVE**

The rise and fall of the current through a current-limiting fuse resembles an isosceles triangle, and can be assumed to be a triangle without introducing an appreciable error. Since this is not a sine wave, cannot determine the RMS value of the let-thru current by taking .707 of the peak value as for a sine wave. Suffice to say that the effective or RMS value of a triangular wave is equal to the peak value divided by $\sqrt{3}$.

$$I_{rms} = \frac{I\ peak}{\sqrt{3}} = \frac{I\ peak}{1.7}$$

The let-thru current of a current-limiting fuse varies with the design, ampere rating and available short-circuit current. Fuse manufacturers furnish let-thru curves for their various types of current-limiting fuses.

**THREE-PHASE SHORT CIRCUITS**

Three-phase short-circuit currents can be determined exactly the same as single-phase currents if we assume one phase is symmetrical. The three phases each have different current values at any instant. Only one can be fully asymmetrical at a given time. This is called the MAXIMUM or WORST PHASE and its RMS current value can be found by multiplying the symmetrical RMS current by the proper factor. The currents in the three phases can be averaged and the AVERAGE 3-PHASE RMS AMPERES can be determined by multiplying the symmetrical RMS current by the proper factor. The common factor is 1.25 times the RMS symmetrical current which corresponds with an 8.5% power factor. The Short Circuit Power Factor Relationships table includes multiplying factors for various power factors.

**X/R RATIO**
Every practical circuit contains resistance (R) and inductive reactance (X). These are electrically in series. Their combined effect is called IMPEDANCE (Z). When current flows thru an inductance (coil) the voltage leads the current by 90° and when current flows thru a resistance the voltage and current are in phase. This means that X and R must be combined vectorially to obtain impedance

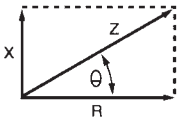



**Figure 12**

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

$$\frac{X}{R} = \tan\theta$$

The resultant $\theta$ angle is between the voltage and current waves and is called the PHASE ANGLE. The voltage leads the current or the current lags the voltage by an amount equal to the phase angle.

The X/R value is determinant as to how long a short-circuit current will remain on a circuit if uninterrupted by an overcurrent protective device.

**POWER FACTOR**
Power factor is defined as a ratio of real power (KW) to apparent power (KVA).

$$PF = \frac{KW}{KVA} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

KW are measured with a watt-meter. KVA are calculated with a voltmeter and ammeter readings since the voltage and current waves may be in phase or out of phase.

Without going into a lot of detail, KW and KVA can be represented by a right angle relationship as shown:

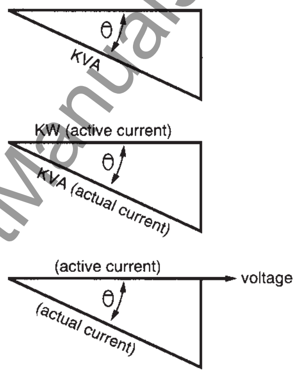



**Figure 13**

The active current is in phase with the voltage. The actual current, as read on an ammeter, lags the voltage by an amount equal to the phase angle.

$$\text{Power Factor} = \cos\theta$$

$$X/R = \tan\theta$$

The power factor is said to be 1 or unity or 100% when the current and the voltage are in phase i.e. when $\theta$ = 0 degrees. ($\cos\theta° = 1$). The power factor is 0 when $\theta$ is 90 degrees. ($\cos 90° = 0$).

The X/R ratio determines the power factor of a circuit and the table on the

## SHORT CIRCUIT POWER FACTOR RELATIONSHIPS

| Short Circuit Power Factor Percent | Short Circuit X/R Ratio | Multiplying Factor | | |
|---|---|---|---|---|
| | | Maximum 1 Phase RMS Amperes at 1/2 Cycle | Average 3 Phase RMS Amperes at 1/2 Cycle | Maximum Peak Amperes at 1/2 Cycle |
| 0 | Infinite | 1.732 | 1.394 | 2.828 |
| 5 | 19.974 | 1.568 | 1.301 | 2.625 |
| 10 | 9.9501 | 1.436 | 1.229 | 2.455 |
| 20 | 4.8990 | 1.247 | 1.127 | 2.183 |
| 30 | 3.1798 | 1.130 | 1.066 | 1.978 |
| 50 | 1.7321 | 1.026 | 1.013 | 1.694 |
| 100 | 0.0000 | 1.000 | 1.000 | 1.414 |

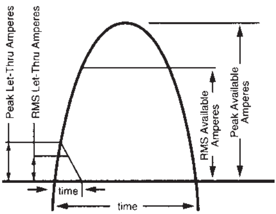



Figure 14

The small triangle shows current and time variation when a current-limiting fuse interrupts a high fault current. The current starts to rise but the fuse element melts before the available current can get through. The current drops to zero in the duration marked as “time”. The peak of the triangle shows the peak current which the fuse lets through. This current can also be expressed in RMS amperes. It should be noted that current-limiting fuses limit both current and time. Current limiting fuses could be called time limiting fuses.

$I^2$ is a measure of the Mechanical Force caused by peak current (Ip). This is the electro-magnetic force which mechanically damages bus structures, cable supports and equipment enclosures.

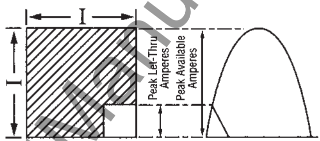



Figure 15

Squaring the available peak current of the circuit gives a very large number in comparison to the square of the peak let-thru current of the current-limiting fuse. The difference in the size of the two squares (Fig. 15) illustrates the great difference in $Ip^2$, or mechanical force, exhibited with or without a current-limiting fuse.

$I^2t$ is a measure of the heating effect or Thermal Energy of a fault current. $I^2t$ uses RMS amperes instead of peak amperes, used for mechanical forces. The difference in size of the large cube-like figure and the small cube-like figure (Fig. 16) represents the difference in heating effect between having and not having a current-limiting fuse in the circuit. $I^2t$ is a measure of the heating effect which burns off conductors such as pigtails in breakers and heater coils in motor controllers. It also welds butt contacts in contactors and breakers. $I^2t$ units are ampere squared seconds.

FERRAZ SHAWMUT

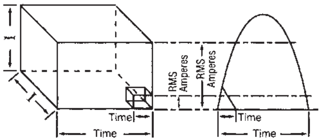



**Figure 16**

These values of Mechanical force ($I^2$) and Thermal Energy ($I^2t$) are valuable in determining the protection of electrical equipment. At any point in a distribution system the equipment must be capable of handling the Mechanical Force and Thermal Energy available. Should these values exceed the capabilities of equipment, either the equipment must be reinforced or a current-limiting fuse used to reduce the amount of force and energy available to the equipment. This is referred to in article 110-10 of the NEC and 14-200 of the CEC.

**WITHSTAND RATING**

The maximum specified value of Voltage and Current that equipment can safely “handle” is known as its “WITHSTAND RATING”. As previously shown short-circuit current translates into Mechanical Force ($I^2$) and Thermal Energy ($I^2t$) which can destroy equipment and create hazardous conditions. Therefore, for equipment protection, the Withstand Rating should never be less than the available short-circuit current at the equipment location. In reality such conditions cannot always be avoided. Hence, the current-limiting ability of fuses is utilized to reduce the short-circuit current of a value LESS THAN the equipment Withstand Rating.

**INTERRUPTING RATING**

The maximum specified value of short-circuit current that a overcurrent protective device (fuse or circuit breaker) can safely open or clear is known as its INTERRUPTING RATING. For circuit beakers there are numerous ratings ranging from 10,000 up (i.e 10,000, 14,000, 22,000, 42,000, 65,000 etc.) In the case of modern current-limiting fuses (Class R,J and L) there is one rating 200,000 amperes RMS. Older fuse types (Class H and K) have 10,000, 50,000 or 100,000 ampere ratings.

The Interrupting Ratings of over-current protective devices must never be exceeded if serious damage is to be avoided. Hence, the used of One-Time or Renewable, 10,000 ampere Class H fuses can create serious concern. Extreme caution must be exercised so that there 10,000 ampere rating is not exceeded. This problem is eliminated with the application of 200,000 ampere rated fuses.

**NOTE:** For further detailed information regarding fuse back-up protection of circuit breakers, and compliance with the National Electrical Code and Canadian Electrical Code, refer to the Ferraz Shawmut application guide “Fuse Protection of Molded Case Circuit Breakers”.

## GLOBAL ELECTRICAL SYSTEMS AND STANDARDS FOR FUSES

As electrical markets expand internationally, worldwide voltages and frequencies are of interest as well as the standards for products.

For fuses, the most important standard is the harmonized IEC269, adopted by the European community and becoming recognized worldwide. In North America the harmonized CANENA Standard (U/L, CSA & Nom) 248 has been accepted by the U.S., Canada and Mexico and may eventually include Central and South America. CANENA Standard (U/L, CSA & Nom) 248 Class J and Class L fuses are now a part of IEC269, hence they are available for use in countries adopting IEC standards and including them in their local standards.

Local fuse standards still exist. Examples are:

U.S. -- UL 248
Canada -- CSA C22.1-98
Mexico -- NOM J-9
United Kingdom -- BS88
France -- NFC 60.269
Germany -- DIN 57636 & VDE 0636
Spain -- UNE 21.103
Australia -- AS 2005

Country domestic voltages and frequencies:

**100 - 120 Volts/60 Hz**
North America, Brazil, Venezuela, Columbia, Ecuador, Peru, Northern Caribbean Islands, (Cuba, Haiti, Dominican Republic, Puerto Rico, Virgin Islands, Bahamas), Liberia, Philippines, Taiwan and South Korea.

**100 Volts / 50 & 60 Hz**
Japan

**127 Volts / 50 & 60 Hz**
Mexico

**220 - 240 Volts / 50 Hz**
Most of the rest of the world

AMP-TRAP® 2000

## SUGGESTED FUSE SPECIFICATIONS



### 1.0 GENERAL

The electrical contractor shall furnish and install a complete set of fuses for all fusible equipment on the job as specified by the electrical drawings. Final tests and inspections shall be made prior to energizing the equipment. This shall include tightening all electrical connections and inspecting all ground conductors. Fuses shall be as follows:

### 2.0 MAINS, FEEDERS AND BRANCH CIRCUITS

**A.** Circuits 601 to 6000 amperes shall be protected by current-limiting Ferraz Shawmut Amp-Trap 2000 Class L time-delay **A4BQ** fuses. Fuses shall be time-delay and shall hold 500% of rated current for a minimum of 4 seconds, clear 20 times rated current in .01 second or less and be UL listed and CSA certified with an interrupting rating of 200,000 amperes rms symmetrical.

**B.** Circuits 600 amperes or less shall be protected by current-limiting Ferraz Shawmut Amp-Trap 2000 Smart Spot Class RK1 time-delay **A2D** (250V) or **A6D** (600V) or Class J time-delay **AJT** fuses. Fuses shall hold 500% of rated current for a minimum of 10 seconds (30A, 250V Class RK1 case size shall be a minimum of 8 seconds) and shall be UL listed and CSA certified with an interrupting rating of 200,000 amperes rms symmetrical.

**C. Motor Protection**

All individual motor circuits shall be protected by Ferraz Shawmut Amp-Trap 2000 Class RK1 Smart Spot, Class J Smart Spot or Class L time-delay fuses as follows:

| | |
|---|---|
| For circuits up to 480A | Class RK1 - **A2D** (250V) or **A6D** (600V) or Class J - **AJT** |
| For circuits over 480A | Class L - **A4BQ** |

Fuse sizes for motor protection shall be chosen from tables published by Ferraz Shawmut for the appropriate fuse. Heavy load and maximum fuse ratings are to be used for applications where typical ratings are not sufficient for the starting current of the motor.

**D. Motor Controllers**

Motor controllers shall be protected from short circuits by Ferraz Shawmut Amp-Trap 2000 time-delay fuses. For IEC style controllers requiring Type 2 protection, fuses shall be chosen in accordance with motor control manufacturers' published recommendations, based on Type 2 test results. The fuses shall be Class RK1 **A2D** (250V) or **A6D** (600V) Smart Spot or Class J **AJT** Smart Spot or Class CC **ATDR** (600V.)

AMP-TRAP® 2000

## SUGGESTED FUSE SPECIFICATIONS cont.

**E.** Circuit breakers and circuit breaker panels shall be protected by Ferraz Shawmut Amp-Trap 2000 Fuses Class RK1 (**A2D** or **A6D Smart Spot**), Class J (**AJT Smart Spot**) or Class L (**A4BQ**) sized in accordance with tested UL Series-Connected combinations published in the current yellow UL Recognized Component Directory.

**F.** Lighting and control circuits in the connected combinations shown up to 30A 600vac shall be protected by Ferraz Shawmut Amp-Trap 2000 Class CC time-delay **ATDR** fuses, sizes according to the electrical drawings.

**3.0 SPARES**
Spare fuses amounting to 10% (minimum three) of each type and rating shall be supplied by the electrical contractor. These shall be turned over to the owner upon project completion. Fuses shall be contained and catalogued within the appropriate number of spare fuse cabinets (no less than one), located per project drawings. Spare fuse cabinets shall be equipped with a key lock handle, be dedicated for storage of spare fuses and shall be type **GSFC**, as supplied by Ferraz Shawmut.

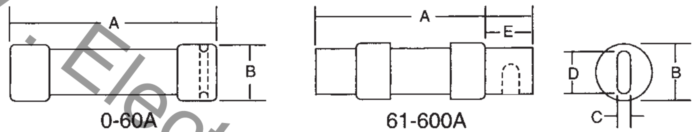
**4.0 EXECUTION**
**A.** Fuses shall not be installed until equipment is to be energized. All fuses shall be of the same manufacturer to assure selective coordination.

**B.** As-installed drawings shall be submitted to the engineer after completion of the job.

**C.** All fusible equipment rated 600 amperes or less shall be equipped with fuse clips to accept Class RK1 or Class J fuses as noted in the specifications.

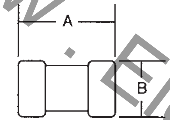
**5.0 SUBSTITUTIONS**
Fuse sizes indicated on drawings are based on Ferraz Shawmut Amp-Trap 2000 fuse current-limiting performance and selectivity ratios. Alternative submittals to furnish materials other than those specified, shall be submitted to the engineer in writing two weeks prior to bid date, along with a short circuit and selective coordination study.

# DIMENSIONS OF CLASS R,K,H, CC AND MIDGET FUSES

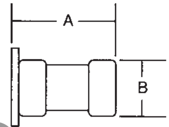



| Voltage, Class and Ampere Range | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Length Overall | | Diameter Overall | | Contact Blades | | | | | |
| | | | | | Thickness | | Width | | Length | |
| | Inches | MM | Inches | MM | Inches | MM | Inches | MM | Inches | MM |
| **250 Volt Class R,K,H** | | | | | | | | | | |
| 0 - 30 | 2 | 51 | 9/16 | 14 | -- | -- | -- | -- | -- | -- |
| 31 - 60 | 3 | 76 | 13/16 | 21 | -- | -- | -- | -- | -- | -- |
| 61 - 100 | 5-7/8 | 149 | 1-1/16 | 27 | 1/8 | 3 | 3/4 | 19 | 1 | 25 |
| 101 - 200 | 7-1/8 | 181 | 1-9/16 | 40 | 3/16 | 5 | 1-1/8 | 29 | 1-3/8 | 35 |
| 201 - 400 | 8-5/8 | 219 | 2-1/16 | 53 | 1/4 | 6 | 1-5/8 | 41 | 1-7/8 | 48 |
| 401 - 600 | 10-3/8 | 264 | 2-9/16 | 66 | 1/4 | 6 | 2 | 51 | 2-1/4 | 57 |
| **600 Volt Class R,K,H** | | | | | | | | | | |
| 0 - 30 | 5 | 127 | 13/16 | 21 | -- | -- | -- | -- | -- | -- |
| 31 - 60 | 5-1/2 | 139 | 1-1/16 | 27 | -- | -- | -- | -- | -- | -- |
| 61 - 100 | 7-7/8 | 200 | 1-5/16 | 34 | 1/8 | 3 | 3/4 | 19 | 1 | 25 |
| 101 - 200 | 9-5/8 | 244 | 1-13/16 | 46 | 3/16 | 5 | 1-1/8 | 29 | 1-3/8 | 35 |
| 201 - 400 | 11-5/8 | 295 | 2-9/16 | 66 | 1/4 | 6 | 1-5/8 | 41 | 1-7/8 | 48 |
| 401 - 600 | 13-3/8 | 340 | 3-1/8 | 80 | 1/4 | 6 | 2 | 51 | 2-1/4 | 57 |
| **Class J** | | | | | | | | | | |
| 0 - 30 | 2-1/4 | 57 | 13/16 | 21 | -- | -- | -- | -- | -- | -- |
| 31 -60 | 2-3/8 | 60 | 1-1/16 | 27 | -- | -- | -- | -- | -- | -- |
| 61 - 100 | 4-5/8 | 117 | 1-1/8 | 29 | 1/8 | 3 | 3/4 | 19 | 1 | 25 |
| 101 - 200 | 5-3/4 | 146 | 1-5/8 | 41 | 3/16 | 5 | 1-1/8 | 29 | 1-3/8 | 35 |
| 201 - 400 | 7-1/8 | 181 | 2-1/8 | 54 | 1/4 | 6 | 1-5/8 | 41 | 1-7/8 | 48 |
| 401 - 600 | 8 | 203 | 2-1/2 | 64 | 3/8 | 10 | 2 | 51 | 2-1/8 | 54 |
| **Class CC and Midget** | | | | | | | | | | |
| 0 - 30 | 1-1/2 | 38 | 13/32 | 10 | -- | -- | -- | -- | -- | -- |

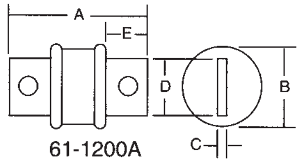
# DIMENSIONS OF CLASS T AND CLASS G FUSES




0-60A



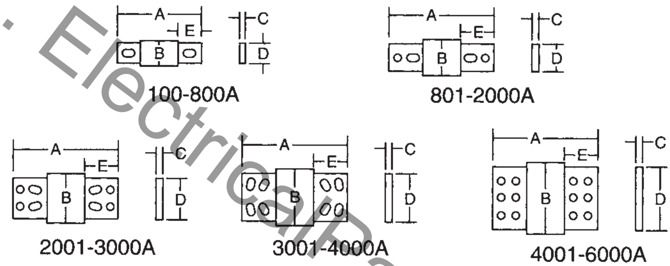

31-60A (600V only)




61-1200A

| Voltage, Class and Ampere Range | A Length Overall | | B Diameter Overall | | C Contact Blades Thickness | | D Contact Blades Width | | E Contact Blades Length | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Inches | MM | Inches | MM | Inches | MM | Inches | MM | Inches | MM |
| **300 Volts Class T** | | | | | | | | | | |
| 0 - 30 | 0.88 | 22 | 0.41 | 10 | -- | -- | -- | -- | -- | -- |
| 31 - 60 | 0.88 | 22 | 0.56 | 14 | -- | -- | -- | -- | -- | -- |
| 61 - 100 | 2.16 | 55 | 0.81 | 21 | 0.12 | 3 | 0.75 | 19 | 0.67 | 17 |
| 101 - 200 | 2.44 | 62 | 1.06 | 27 | 0.19 | 5 | 0.88 | 22 | 0.80 | 20 |
| 201 - 400 | 2.75 | 70 | 1.33 | 34 | 0.25 | 6 | 1.00 | 25 | 0.96 | 24 |
| 401 - 600 | 3.06 | 78 | 1.62 | 41 | 0.31 | 8 | 1.25 | 32 | 1.11 | 28 |
| 601 - 800 | 3.38 | 86 | 2.08 | 53 | 0.38 | 10 | 1.75 | 44 | 1.25 | 32 |
| 801 - 1200 | 4.00 | 102 | 2.52 | 64 | 0.44 | 11 | 2.00 | 51 | 1.48 | 38 |
| **600 Volt Class T** | | | | | | | | | | |
| 0 - 30 | 1.50 | 38 | 0.57 | 14 | -- | -- | -- | -- | -- | -- |
| 31 - 60 | 1.57 | 40 | 0.81 | 21 | -- | -- | -- | -- | -- | -- |
| 61 - 100 | 2.95 | 75 | 0.82 | 21 | 0.12 | 3 | 0.75 | 19 | 0.69 | 17 |
| 101 - 200 | 3.26 | 83 | 1.07 | 27 | 0.19 | 5 | 0.88 | 22 | 0.83 | 21 |
| 201 - 400 | 3.62 | 92 | 1.62 | 41 | 0.25 | 6 | 1.00 | 25 | 0.96 | 24 |
| 401 - 600 | 3.98 | 101 | 2.06 | 52 | 0.31 | 8 | 1.25 | 32 | 1.14 | 29 |
| 601 - 800 | 4.33 | 110 | 2.50 | 63 | 0.37 | 10 | 1.75 | 44 | 1.31 | 33 |
| **Class G** | | | | | | | | | | |
| 0 - 15 | 1.31 | 33.3 | 0.406 | 10.3 | -- | -- | -- | -- | -- | -- |
| 20 | 1.41 | 35.8 | 0.406 | 10.3 | -- | -- | -- | -- | -- | -- |
| 25,30 | 1.62 | 41.2 | 0.406 | 10.3 | -- | -- | -- | -- | -- | -- |
| 35 - 60 | 2.25 | 57.2 | 0.406 | 10.3 | -- | -- | -- | -- | -- | -- |

# DIMENSIONS OF CLASS L FUSES



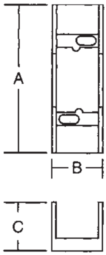

| Ampere Rating | A | | B | | C | | D | | E | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Length Overall | | Diameter Overall | | Contact Blades | | | | | |
| | | | | | Thickness | | Width | | Length | |
| | Inches | MM | Inches | MM | Inches | MM | Inches | MM | Inches | MM |
| 100 - 600* | 8-5/8 | 219 | 2 | 51 | 5/16 | 8 | 1-5/8 | 41 | 2-13/32 | 61 |
| 601 - 800 | 8-5/8 | 219 | 2-1/2 | 63 | 3/8 | 9 | 2 | 51 | 2-13/32 | 61 |
| 801 - 1200 | 10-3/4 | 273 | 2-1/2 | 63 | 3/8 | 9 | 2 | 51 | 3-15/32 | 88 |
| 1201 - 1600 | 10-3/4 | 273 | 3 | 76 | 7/16 | 11 | 2-3/8 | 60 | 3-15/32 | 88 |
| 1601 - 2000 | 10-3/4 | 273 | 3-1/2 | 89 | 1/2 | 13 | 2-3/8 | 70 | 3-15/32 | 88 |
| 2001 - 2500 | 10-3/4 | 273 | 4-1/2 | 114 | 3/4 | 19 | 3-1/2 | 89 | 3-15/32 | 88 |
| 2501 - 3000 | 10-3/4 | 273 | 5 | 127 | 3/4 | 19 | 4 | 102 | 3-15/32 | 88 |
| 3001 - 4000 | 10-3/4 | 273 | 5-3/4 | 146 | 3/4 | 19 | 4-3/4 | 121 | 3-15/32 | 88 |
| 4001 - 5000 | 10-3/4 | 273 | 6-1/4 | 159 | 1 | 25 | 5-1/4 | 133 | 3-15/32 | 88 |
| 5001 - 6000 | 10-3/4 | 273 | 7-1/8 | 181 | 1 | 25 | 5-3/4 | 146 | 3-15/32 | 88 |

* Not UL listed or CSA Certified.

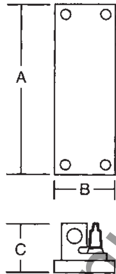
## DIMENSIONS OF FUSEHOLDERS

**FOR CLASS H, J, K, R, CC AND MIDGET FUSES**

**Outline Only - 1 Pole Shown**




0-60A




61-600A

| Fuse Voltage, Class and Ampere Range | A Length Overall | | B Width Overall | | C Height Overall | |
|---|---|---|---|---|---|---|
| | Inch | MM | Inch | MM | Inch | MM |
| **250V Class R, K, H** | | | | | | |
| 0 - 30 | 3.00 | 76 | 1.25 | 32 | 1.38 | 35 |
| 31 - 60 | 4.75 | 120 | 1.46 | 37 | 2.12 | 54 |
| 61 - 100 | 8.33 | 211 | 1.68 | 43 | 2.28 | 57 |
| 101 - 200 | 8.00 | 203 | 3.00 | 76 | 2.90 | 74 |
| 201 - 400 | 11.5 | 292 | 3.50 | 89 | 3.62 | 92 |
| 401 - 600 | 13.1 | 333 | 4.00 | 101 | 4.75 | 120 |
| **600V Class R, K, H** | | | | | | |
| 0 - 30 | 7.00 | 178 | 1.63 | 41 | 2.00 | 51 |
| 31 - 60 | 7.00 | 178 | 1.63 | 41 | 2.00 | 51 |
| 61 - 100 | 10.0 | 254 | 2.10 | 53 | 2.50 | 64 |
| 101 - 200 | 10.5 | 267 | 3.00 | 76 | 2.90 | 74 |
| 201 - 400 | 14.5 | 368 | 3.50 | 89 | 3.62 | 92 |
| 401 - 600 | 16.1 | 409 | 4.00 | 101 | 4.75 | 120 |
| **Class J** | | | | | | |
| 0 - 30 | 3.9 | 99 | 1.29 | 33 | 2.12 | 54 |
| 31 - 60 | 4.00 | 102 | 1.65 | 42 | 2.12 | 54 |
| 61 - 100 | 7.00 | 178 | 2.31 | 58 | 2.36 | 60 |
| 101 - 200 | 6.12 | 156 | 3.00 | 76 | 2.90 | 51 |
| 201 - 400 | 8.00 | 203 | 4.00 | 101 | 3.75 | 95 |
| 401 - 600 | 11.0 | 279 | 4.00 | 101 | 4.75 | 121 |
| **Class CC & Midget** | | | | | | |
| 0 - 30 | 0.85 | 22 | 3.04 | 77 | 1.31 | 33 |

# Product Guide




**AMP-TRAP® 2000**

**Class J Time Delay**
**1 to 600A**
**600V AC, 200kA I.R.**
**500V DC, 100kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**
**Smart Spot Indicator**

Motor, motor controller, control transformer, and circuit breaker back-up protection. Space saving dimensions. Very current limiting.


**AMP-TRAP® 2000**

**Class L Time Delay**
**100 to 6000A**
**600V AC, 200kA I.R.**
**601 to 3000A**
**600V DC, 100kA I.R.**
**Current Limiting**
**U.L. Listed (601 to 6000A)**
**CSA Certified (601 to 6000A)**

The most current-limiting Class L fuse available today. For increased protection of AC and DC equipment.


**AMP-TRAP® 2000**

**Class RK1 Time Delay**
**1/10 to 600A**
**A2D: 250V AC, 200kA I.R.**
**A6D: 600V AC, 200kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**
**Smart Spot Indicator**

Motor controller and motor overcurrent protection. Very current limiting.


**AMP-TRAP® 2000**

**Class CC Time Delay**
**1-1/2" x 13/32"**
**UL Listed,**
**CSA Certified**
**ATDR:**
1/4 to 30A
600V AC, 200kA I.R.
300V DC, 100kA I.R.
For motor protection
**ATQR**
1/10 to 30A
600V AC, 200kA I.R.
For transformer protection.

# Product Guide




## TRI-ONIC

**Class RK5 Time Delay**
**TR: 1/10 to 600A**
**250V AC, 200kA I.R.**
**DC all ratings**
**TRS: 1/10 to 600A**
**600V AC, 200kA I.R.**
**DC all ratings**
**UL Listed**
**CSA Certified**
**Smart Spot Indicator**

Motor overcurrent, motor controller and transformer protection.


## AMP-TRAP®

**Class J Fast Acting**
**1 to 600A**
**600V AC, 200kA I.R.**
**300V DC, 20kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**

Feeder circuit, panelboard, and circuit breaker back-up protection. Space saving dimensions. Very current limiting.


## AMP-TRAP®

**Class L Time Delay**
**200 to 6000A**
**600V AC, 200kA I.R.**
**200-2500A**
**300V DC, 100kA I.R.**
**Current Limiting**
**UL Listed (601 to 6000A)**
**CSA Certified (601 to 6000A)**

Service entrance, feeder circuit, transformer, and circuit breaker back-up protection.


## AMP-TRAP®

**Class L Time Delay**
**200 to 2000A**
**600V AC, 200kA I.R.**
**500V DC, 100kA I.R.**
**Current Limiting**
**UL Listed (601-2000A)**
**CSA Certified (601-2000A)**

Motor, motor controller, and transformer protection. Also suitable for DC application.

# Product Guide




## AMP-TRAP®

**Class T Fast Acting**
**A3T: 1 to 1200A**
**300V AC, 200kA I.R.**
**160V DC, 50kA I.R.**
**A6T: 1 to 800A**
**600V AC, 200kA I.R.**
**300V DC, 100kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**

Loadcenter, metering center, panelboard, and circuit breaker back-up protection. Very current limiting. Small physical size.


## AMP-TRAP®

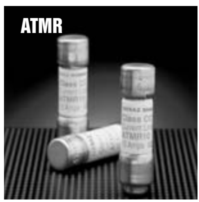
**Class RK1 Fast Acting**
**AK2: 1 to 600A**
**250V AC/DC, 200kA I.R.**
**A6K: 1 to 600A**
**600V AC, 200kA I.R.**
**300V DC, 200kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**

Feeder circuit, panelboard, and circuit breaker back-up protection. Very current limiting.


## AMP-TRAP®

**Class G Time Delay**
**1/2 to 20A**
**600V AC, 100kA I.R.**
**25 to 60A**
**480V AC, 100kA I.R.**
**Current Limiting**
**UL Listed**
**CSA Certified**

With time delay (above 5A) plus 600 and 480 volt ratings, AG fuses fit a wider variety of branch circuit protection in lighting, heating and appliances.




## AMP-TRAP®

**Class CC Fast Acting**
**1/10 to 30A**
**600V AC, 200kA I.R.**
**1-1/2" x 13/32" midget**
**Rejection style design**
**Current Limiting**
**UL Listed**
**CSA Certified**

The smallest dimension fuse suitable for branch circuit protection.

# Product Guide

North American Power Fuses


## ONE-TIME

**Class K5 General Purpose**
**OT: 1 to 600A**
**250V AC, 50kA I.R.**
**250V DC, 20kA I.R.**
**OTS: 1 to 600A**
**600V AC, 50kA I.R.**
**300V DC, 20kA I.R.**
**OTN: 15 to 60A (Canada)**
**250V AC, 50kA I.R.**
**UL Listed**
**CSA Certified**

Lowest cost protection for circuits serving heating, lighting, and other non-motor loads.


## RENEWABLE

**Class H General Purpose**
**RF: 1 to 600A**
**250V AC, 10kA I.R.**
**RFS: 1 to 600A**
**600V AC, 10kA I.R.**
**UL Listed**
**CSA Certified**

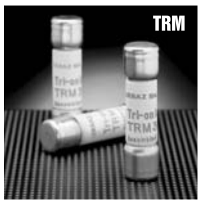
Knurled end caps unscrew for easy link replacement after fuse operates. Provides protection for non-motor loads where short circuits are 10kA or less.

Midget, Miniature & PC Mount Fuses


## AMP-TRAP®

**Midget Dimensions**
**1-1/2"x13/32"**
**ATQ Time Delay**
**1/10 to 30A, 500V AC, 10kA I.R.**
**ATM Fast Acting**
**1/10 to 30A, 600V AC, 100kA I.R.**
**35 to 50A, 600V AC, 10kA I.R.**
**1/10 to 30A, 500V DC, 100kA I.R.**
**A6Y-2B Fast Acting**
**1/4 to 3A, 600V AC, 10kA I.R.**
**3-2/10 to 15A, 500V AC, 10kA I.R.**
**A25Z-2 Extremely Fast Acting**
**1 to 30A, 300V AC, 100kA I.R.**

Supplementary overcurrent and semiconductor protection.




## MIDGET FUSES

**1-1/2" x 13/32"**
**TRM Time Delay**
**1 to 30A, 250V AC, 10kA I.R.**
**OTM Fast Acting**
**1 to 30A, 250V AC, 10kA I.R.**
**GGU Fast Acting**
**(Glass/Ceramic body)**
**3 to 30A, 125V AC, 10kA I.R.**
**GFN Time Delay, Pin Indicating**
**1/10 to 10A 250V, 12 & 15A 125V,**
**20 to 30A, 32V**
**All are U.L./CSA except GGU**

# Product Guide


## SBS

**General Purpose**
**Fast Acting**
**1-3/8" x 13/32"**
**2/10 to 30A**
**600V AC 100kA I.R.**
**UL Listed**
**CSA Certified**

SBS is the only fuse in its size to have a full 600V AC rating and 100kA I.R.. Protection of control circuits, lighting ballasts, meter circuits and electronic circuits.

## ELECTRONIC/GLASS

**Time Delay or Fast Acting**
**4.5mm x 14.5mm (2AG)**
**5mm x 20mm**
**1/4" x 1" 8AG**
**1/4" x 1-1/4" 3AG (glass)**
**1/4" x 1-1/4" 3AB (ceramic)**
**Subminiature**
**1/100 to 30A**
**32V, 125V, and 250V AC**
**Many are UL Listed and/or CSA Certified**
**Optional axial leads**

Supplementary protection in electrical and electronic circuits.

## IN-LINE FUSES/ HOLDERS

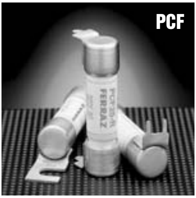
**Glass Body FSFE Fuses**
**Fast Acting**
**4A to 30A**
**32V AC/DC**

In-Line Fuse Holders for FSFE, 2AG, and 5mm x 20mm fuses.
FSFE holder max amp rating:
20A @ 32V
2AG holder max amp rating:
5A @ 32V
5mm x 20mm max amp rating:
10A @ 32V

## AUTOMOTIVE FUSES

**Fast Acting**
**1 to 30A Miniature**
**Fast Acting**
**1 to 40A Mid-size**
**Slow Acting**
**20 to 80A Max size**
**Many are U.L. Listed, Recognized and/or CSA Certified and designed to U.L. Standard for automobile blade type fuses. SAE (Society of Automotive Engineers) J1284.**

# Product Guide




## PC MOUNT FUSES

**Direct Mount PC Board Fuses**
**PCF Fast Acting Fuses**

**1 to 30A, 600V AC, 500V DC**

**PCS Semiconductor Protection Fuses**

**5 to 30A, 600V AC/DC**

**PCT Time Delay Fuses**

**1 to 30A, 500V AC**

**UL Recognized Components**

## DIN BS88 FUSES

**gRB-URB, Size: 17x49**
**12 to 100A**
**690V AC, 200kA I.R.**
**gR Class to 90A VDE 636-23**
**aR Class (100A) VDE 636-23**
**and IEC 269.4**
**Extremely high interrupting rating**
**UL & CSA Recognized**
**German std w/o BFI**
**German std w/seperate BFI**
**DIN 43623/00C**
**British std w/o BFI**
**British std w/seperate BFI**
**BS 88-4**

Semiconductor Fuses

## AMP-TRAP® PROTISTOR

**1 to 6000A**
**A15QS, A30QS, A50QS, A50P,**
**A60Q, A60X, A070gRB, A70QS,**
**A70P, A70Q, A100P, A120X, A150X**
**150V AC to 1500V AC, 200kA I.R.**
**150V DC to 1500V DC, 100kA I.R.**
**UL Recognized**

Low $I^2t$ provides protection for semiconductors and electronic equipment.

## DIN 000 FUSES

**German Standard**
**gRB-URB, Size: 000**
**20 to 400A**
**690V (660V AC, 200kA I.R. tested)**
**315A, 660V, 350 & 400A, 500V, 500V AC, 120kA I.R. tested**
**gR Class to 125A VDE 636-23**
**aR Class (100A) VDE 636-23**
**and IEC 269.4**
**Extremely high interrupting rating**
**3 Models to DIN 43653-00C are UL & CSA Recognized**
**1 Model to DIN 43620**

# Product Guide

## DIN BS88 FUSES

**Protistor Fuses**
**gRB/URB Size: 000**
**20 to 400A**
**690V (660V AC, 200kA I.R. tested)**
**315A, 660V, 350 & 400A, 500V,**
**500V AC, 120kA I.R. tested**
**gR Class to 125A VDE 636-23**
**aR Class (75 to 400A) VDE 636-23**
**and IEC 269.4**
**Extremely high interrupting rating**
**UL & CSA Recognized**
**2 Models to BS 88-4 and EN 60 269.4 std**

## DIN 00 FUSES

**Protistor Fuses**
**gRB/URB Size: 00**
**16 to 450A**
**690V AC, 200kA I.R.**
**450A, 600V**
**690V AC, 200kA I.R. (tested)**
**gR Class to 160A VDE 636-23**
**aR Class to 450A VDE 636-23**
**and IEC 269.4**
**Extremely high interrupting rating**
**DIN 43653/00C**
**DIN 43620/00 (solid blades)**

## PSC FUSES

**40 to 2500A**
**500 to 700V AC, 200kA I.R.**
**50 to 1800A**
**650 to 1300V AC, 100kA I.R.**
**UL Recognized Components**
**Current Limiting**
**Extremely Fast Acting**
**IEC 269-4 Compliance**

Protection of rectifiers, inverters, DC drives, UPS systems, reduced voltage motor starters, and other globally accepted applications.

## PROTISTOR FRENCH CYLINDRICAL

**.1 to 250A Class aR**
**500V to 1000V AC**
**Dimensions (mm)**
**10 x 38, 14 x 51, 22 x 58,**
**27 x 60**
**8 to 110A Class gR**
**800V AC**
**Dimensions (mm) 27 x 60**
**VDE 636-23**
**IEC 269-1, -4**

Extremely high interrupting rating.

# Product Guide

Medium Voltage

## AMP-TRAP®

**E Rated Current Limiting**
**A055F - AC: 5E to 450E**
**5.5kV max, 63kA I.R. Sym**
**A825X - AC: 10E to 200E**
**8.25kV max, 50kA I.R. Sym**
**A155F - AC: 5E to 200E**
**15.5kV max, 50kA I.R. Sym**
**A055C - AC: 10E to 900E**
**5.5kV max, 63kA I.R. Sym**
**A155C - AC: 10E to 300E**
**15.5kV max, 50kA I.R. Sym**
**UL Listed**

Protection for medium voltage transformers and dist. systems.


## AMP-TRAP®

**E Rated**
**For Potential Transformers**
**Current Limiting**
**A240T - AC: 1/2E to 5E**
**2.4kV max, 50kA I.R. Sym**
**A480T - AC: 1/2E to 5E**
**4.8kV max 50kA I.R. Sym**
**A500T - AC: 1/2E to 5%E**
**5.0kV max, 50kA I.R. Sym**
**A720T - AC: 1/2E to 3E**
**7.2kV max, 50kA I.R. Sym**

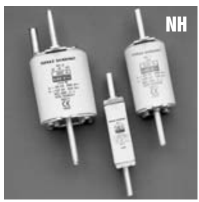
Primary protection for potential transformers.


## AMP-TRAP®

**R Rated Current Limiting**
**A240R - AC: 2R to 36R**
**2.75kV max, 45kA I.R. Sym**
**A480R - AC: 2R to 36R**
**5.5kV max, 63kA I.R. Sym**
**A072F, A072B - AC: 2R to 24R**
**7.2kV max, 50kA I.R. Sym**
**A033D1 - AC: 2R to 19R**
**3.3kV max, 65kAI.R. Sym**
**A055D1 - AC: 2R to 19R**
**5.5kV max, 65kA I.R. Sym**
**A072D1 - AC: 2R to 19R**
**7.2kV max, 65kA I.R. Sym**
**UL Recognized Component**

Short circuit protection for medium voltage motors and controllers.

International Fuses




## EURO/IEC FUSES

**Cylindrical Fuses**
**"gF", "gI-gG" & "aM" Types**
**250/380/400/500/690V AC**
**0.16 to 125A ratings**
**Screw Cap Fuses**
**DO Type - 400V AC**
**D Type - 500V AC**
**2 to 100A**
**NH Dimension Fuses**
**"gL-gG", and "aM" Types**
**400, 500 and 690V AC**
**2 to 800A**

## CANADIAN FUSES

**Class C, CA, CB**
**HRCII-Misc.**
**NRN/NRS, CRN/CRS**

# Product Guide

Special Purpose Fuses


## SURGE SUPPRESSION FUSES

**VSP - 600V AC, 200 kA I.R.**
**Surge Rating:**
**5-100kA 8 x 20 µsec**
**Special purpose MOV protector.**
**Protection of TVSS devices.**
**UL Recognized**
**TPMOV**
**150V to 550V AC, 100kA I.R.**
**Surge rating:**
**40kA 8 x 20 µsec**
**Thermally protected MOV.**
**Multiple applications**
**UL Recognized**


## AMP-TRAP®

**Cable protectors**
**Current Limiting**
**600V AC, 200kA I.R.**
**Sizes:**
**Copper: #2AWG to 750kcmil (MCM)**
**Aluminum - 4/0 to 750kcmil (MCM)**

Protect runs of multiple conductor cables by selectively isolating faulted cables. Available for copper and aluminum cable.


## AMP-TRAP®

**Welder Protectors**
**Current Limiting**
**100 to 600A**
**600V AC, 200kA I.R.**

Short circuit protection for electric welders. Class K and Class J dimensions.


## AMP-TRAP®

**Form 600 Special Purpose**
**Current Limiting**
**U.L. Recognized**
**A2Y - 1 to 600A**
**250V AC, 200kA I.R.**
**500V DC, 100kA I.R.**
**A6Y - 1 to 8A**
**500V AC, 200kA I.R.**
**500V DC, 100kA I.R.**
**A6Y - 10 to 1200A**
**600V AC, 200kA I.R.**
**A6Y - 10 to 600A**
**500V DC, 100kA I.R.**

# Product Guide



## CAPACITOR FUSES

**6A to 300A**
**600V to 5500V AC**

Cartridge type. Full range operation. Indicator for most types. Direct mtg. on capacitor. Special mtg. brackets available.

## TELECOMM. FUSES

**1 to 800A**
**170 V DC, 100kA I.R.**
**UL Recognized**
**Highly current limitng**
**Fast acting**
**Rejection style**

Protection of distribution switching panels, battery back-up systems, power supplies, switching substations, telephone switching equipment, and rectifiers.

## FORKLIFT TRUCK FUSES

**General Purpose & Time Delay**
**AC and DC rated**
**UL Recognized Components**

Cartridge type:
ACK: 1 - 400A Time Delay
ACL: 30 - 120A
ALS: 100 - 500A
125V AC/DC 10kA I.R.
Blade Type
CNN: 10 - 800A
130V AC, 2500A I.R.
80V DC, 2600A I.R.
CNL: 35 - 500A
80V AC/DC 2600A I.R.

## IN-LINE FUSES AND HOLDERS

**SLR Fuses - 1/2 to 15A**
**300V AC, 10kA I.R.**
**Fast Acting**
**UL Listed & CSA Certified**
**Intergral fuse & insulating cap**
**SMF Fuses - 3/10 to 10A**
**300V AC, 10kA I.R.**
**Time-Delay**
**UL Listed & CSA Certified**
**intergral fuse & insulating cap**
**Designed to handle ballast inrush currents.**
**SHR fuse holders**
**300V AC: 15A, 10kA I.R.**

# Product Guide

Special Purpose Fuses

## PLUG FUSES

**Edison Base and Type S**
**125V AC, 10kA I.R.**
**UL LIsted**
**CSA Certified**

Types:
Non-Time Delay - GW, G, GP
Time Delay - GTL, GT, TD, GSL*

•rejection type "s" must be used with SAG adapter

## DC RATED FUSES

**0.8 to 4000A**
**48 to 6000V DC**
**aR & gR operation.**
**Very high interupting ability**
**Current limiting**
**Round and square body designs**
**Multiple mounting available**

Protects traction and traction auxiliary circuits, filters, rectifiers, and transit industry applications.

## DC RATED FERRULE FUSES

**2 to 160A (gLB)**
**440V DC, 100kA I.R.**
**14x51, 22x58, 27x60 (mm)**
**.8 to 110A**
**660V DC, 50kA I.R.**
**27x60mm, UL Recognized**
**6 to 63A**
**1000V DC, 100kAI.R.**
**20x127mm, UL Recognized**
**25 to 100A (gRB-gRC)**
**1000V DC, 100kA I.R.**
**36x127mm, UL Recognized**

## DC RATED FERRULE FUSES

**.8 to 5A (CC 1551 CP gRB)**
**10000V DC, 100kA I.R.**
**.8 to 5A (CC 1500 CP gRB)**
**1000V DC, 30kA I.R.**
**6 to 25A (CC 1500 CP gRD)**
**1500V DC, 30kA I.R.**
**20x127mm**
**6 to 32A (CC 1591 CP gRC)**
**1500V DC, 60kA I.R.**
**6 to 32A (CC 1500 CP gRC)**
**1500V DC, 60kA I.R.**
**20x190mm**

# Product Guide



## DC RATED FERRULE FUSES

40 to 100A
(CC1591 CP gRC-gRD)
1500V DC, 60kA I.R.
36x190mm
40 to 100A
(CC1500 CP gRC-gRD)
1500V DC, 60kA I.R.
36x190mm
.8 to 20A (CC4000 CP gRC)
40000V DC, 30kA I.R.
36x400mm

## DC RATED SQUARE-BODY FUSES

50 to 160A (CC 7.5gRC)
750V DC, 100kA I.R.
900V DC, 100kA I.R.
Size: 120, UL Recognized
200 to 250A (CC 7.5gRC)
750V DC, 100kA I.R.
900V DC, 100kA I.R.
Size: 121, UL Recognized
250 to 500A (CC 7.5gRC, gRD)
750V DC, 100kA I.R.
900V DC, 100kA I.R.
Size: 122, UL Recognized

## DC RATED SQUARE-BODY FUSES

500A (CC 7.5gRC)
750V DC, 100kA I.R.
900V DC, 100kA I.R.
630 to 750A (CC 7.5gRD)
750V DC, 100kA I.R.
800A (CC 6.6gRB)
660V DC, 100kA I.R.
Size: 123
500 to 900A (CC 7.5gRC)
900V DC, 100kA I.R.
Size: 2x122


## DC RATED SQUARE-BODY FUSES

1000A (CC 7.5gRC)
750V DC, 100kA I.R.
900V DC, 100kA I.R.
1250 to 1500A (CC7.5gRB, D)
750V DC, 100kA I.R.
1600A (CC 6.6gRB)
660V DC, 100kA I.R.
Size: 2x123
160 to 420A (CC 12 SRG)
1200V DC, 100kA I.R.
Size: 72

# Product Guide



## DC RATED SQUARE-BODY FUSES

**20 to 215A (CC 20 SRC)**
**2000V DC, 100kA I.R.**
**Size: 120**
**160 to 400A (CC 20 SRD)**
**1800V DC, 100kA I.R.**
**2000V DC, 100kA I.R.**
**Size: 122**
**6 to 25A (CC 35 gRB)**
**3500V DC, 30kA I.R.**
**32 to 80 to 125A**
**(CC40 gRB, gRD)**
**4000V DC, 30kA I.R.**
**Size: 600**

## ULTRASAFE™ FUSE HOLDERS

**Finger Safe, Modular**
**Fuse Holders**
**Optional Indicators**
**Single- or Multi-pole**
**Ratings up to 125A**

USCC - For Class CC Fuses

USM - For Midget Fuses

US3J - For Class J Fuses

US6J - For Class J Fuses

US14 - For 414x51mm Fuses

US22 - For 22x58mm Fuses

## FUSE BLOCKS 250V AND 600V

**Single and Multi-Pole**

Available for Class H, J, K, R, CC and Midget fuses. A variety of clips, pole configurations and termination provisions are available. Most are UL Listed, UL Recognized or CSA Certified.


## IN-LINE FUSEHOLDERS

**For 1-1/2" x 13/32" & Class CC fuses Rated 30A, 600V AC**
**200kA withstand rating**
**Breakaway feature - standard**
**UL Recognized**
**CSA Certified**

Choice of crimp or screw connectors for solid or stranded copper cable. Rubber boots available.

# Product Guide

## GPM SERIES PANEL MOUNT FUSE HOLDERS

**Rated up to 30A, 600V AC**
**UL Recognized**
**CSA Certified**

Various sizes accommodate 5mm x 20mm, 1/4" x 1-1/4" or 1-1/2" x 13/32" Midget and Class CC fuses. Straight and right angle connections. Front or rear mounting in panel.

## CLASS T FUSE BLOCKS

**Rated 30A up to 600A**
**300V AC - Use with A3T fuses**
**600V AC - Use with A6T fuses**
**200kA withstand rating**
**Meet UL 512 requirements**
**UL Listed, UL Recognized**
**CSA Certied**

Spring reinforced 30 & 60A clips.
Full barrier design.
Unique adder-block design.

## 703, U705, U710 SEMICONDUCTOR FUSE HOLDERS

**750V AC, 200kA I.R.**
**Ratings up to 100A**
**UL Recognized**
**CSA Certified**

Blocks are open face style and accommodate 14mmx51mm and 22mmx58mm fuses. Choice of box, screw or pressure plate connector. Thermoplastic bases.

## DFC DEAD-FRONT FUSE COVERS

**Snap on to Class G, H, J, K, R, CC or Midget Fuses in fuse holders**
**Provide dead-front electrical safety**
**Fits fuses 0-100A**
**Reusable**
**Optional Open-Fuse Indicator Light**
**UL Listed or Recognized**
**CSA Certified**

# Product Guide

## CLASS G FUSE BLOCKS

**600V: 15A & 20A**
**480V: 30A & 60A**
**Withstand rating: 100kA using screw, pressure plate or box connector. 10kA using quick connects.**
**UL Listed - Meets Standard 512**
**CSA Certified**

Unique adder block design with integral DIN rail adapter. Spring reinforcing standard for 60A clips.

## 3AG FUSE BLOCKS

**TERMINATIONS/AMP RATING:**
**SOLDER - 30A, 300V**
**NEMA 3/16" QC - 20A, 300V**
**1/4" QC - 20A, 300V**
**NEMA 1/4" QC - 30A, 300V**
**Clips - tin-plated spring brass**
**Base - Glass reinforced thermoplastic**
**1 to 12 poles available**
**UL 94VO flammability**
**UL Recognized**
**CSA Certified**

## AMP-TRAP FORM 101 FUSE BLOCKS

**For semiconductor fuses 1 to 1000A**
**Clip Type: 1200V or less**
**Stud Type: 1000V or less**
**Insulators are glass filled polycarbonate or laminated phenolic.**
**UL Recognized**
**CSA Certified**

## MODULAR FUSE BLOCKS

**For semiconductor fuses 100 to 800A, 600 to 5000V**
**UL Recognized 600 & 1000V**
**Modular 2-piece design**
**Stud type & box connector**
**Phenolic insulators**
**Mounting hardware included**
**Heat dissipating box connect.**
**Accomodates a large range of semiconductor fuses.**

# Product Guide

## FERRULE FUSE HOLDERS/NO-LOAD DISCONNECTORS

For 20x127mm ferrule fuses 50 to 125A
1500V w/o terminal cover
2500V w/ terminal covers
and only salt spray proof model.
Fuse mounting in holders or no-load disconnectors with or without open fuse
indicating microswitches.

## EURO/IEC FUSE BASES

NH Dimension
690V Ceramic bases
Silver plated contacts
Screw mount

690V Polyester bases
Silver plated contacts
Screw or rail mount

1 to 4 pole holders available for NH - 0, 1, 2, and 3 size fuse links.

## EURO/IEC FUSE BASES

Modular Fuse Bases
CC Series: 4 size ranges:
will accept 8x31mm, 10x38mm, 14x51mm & 22x58mm, Class CC, Midget, 20A/250V Class H/K/R fuse links.
MSC Series: 2 size ranges
will accept 8x31mm, 10x38mm, Class CC and Midget fuse links.
CMS Series: 2 size ranges
will accept 14x51mm, 22x58mm & 30A/250V Class H/K/R fuse links.

## FINGER-SAFE BLOCKS

Provides DIN rail mounting capabilities in addition to being completely finger safe to an IP20 level.
Compact modularity
Snap-on DIN rail mounting
Captive termination screw
Ampere ratings 175 to 840A
600V rated
UL Recognized
CSA Certified

Power Distribution Blocks

# Product Guide



## OPEN POWER DIST. BLOCKS 600V AC

**600V, 90 to 2660A**
**Small - 62-63 series**
**Intermediate - 66-67 series**
**Large - 68-69 series**
**Copper & Aluminum available**
**Safety covers available**
**Most are UL Rec/CSA Cert**

Provides convenient means of distributing power. A variety of pole configurations, termination provisions and gauge sizes are available.

## FUSE REDUCERS

Wide choice for 30A to 400A Class H, J, K & R fuse reducers to fit 60 to 600A, 250 or 600V clips.

## FUSE PULLERS

Nylon or plastic for 30 to 600A fuses.

## FUSE CLIP CLAMPS

Steel jaws clamp fuses tightly in clips, with a turn of the cap.

## BOX COVERS

**125V AC UL Listed**
**Galvanized steel**
**Variety of plug fuse, switch and receptacle combinations**
**All standard size boxes avail**

For use with plug fuses primarily in the protection of 125V motors and motor circuits.


## BLOWN FUSE INDICATORS

**Shawmut Trigger® TI-130, TI-600, TI-1500**

Wired in parallel with fuse

**Trigger Actuator® (TA)**

Optionally mounted on many Amp-trap fuses

**Add-On-Switch (AOS)**

AOS-Q quick connectors
AOS-S screw terminals

**IL - indicator**

Provides blown fuse indication

**EI-700 and EI-1000**

Externally mounted 700 and 1000V indicators

# Product Guide

## MICROSWITCHES AND STUDS

**PSC Fuse Type**
**3 to 10A**
**1000 & 1500V AC**
**Watertight & resettable available**
**Protistor Type**
**3 & 5A**
**1250 to 6000V**
**Watertight & resettable available**

Disconnect Swtiches

## FUSIBLE, NON-FUSIBLE AND LOAD BREAK

**LBS - load break disconnect switches, from 16 to 100A-UL 508**
**SIRCO - non-fusible disconnect switches, from 30 to 1200A-UL 98**
**FUSERBLOC - fusible dosconnect switches, from 30 to 800A-UL 98**
Front or side operated disconnect switches with direct or external handles including flange style.

## SURGE SWITCH

**600V AC**
**200kA 8x20 $\mu$s waveform**
**3 & 4 pole switches available**
**Extremely reliable**
**Defeatable handles standard automatic re-latch when door is closed; no tool necessary**
**Direct mount handles optional**
**Compact footprint**
**UL Recognized & CSA Certified Pending**
**Only surge rated switch available today**
**Application: TVSS Panels**

## ENGINEERED SWITCHES

**Fusible Shunt Trip Disconnect Switches**
**Ensclosure - NEMA 1 (std)**
**NEMA 12, 3R, 4 or 4X available**
**120V AC Shunt Trip**
**3-Pole Fused Switch**
**Modular Components**
**Many optional features available**
**600V AC: 30A, 60A, 100A, 200A, and 400A (w/stand rating: 200kA I.R.) Applications:**
**elevators, emergency bldg systems, misc fusible shunt trip applications**

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FERRAZ SHAWMUT

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