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 2π 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		
	Skin Effect Factor	
Frequency x Area in C.M.	Copper u = 1. p = 1.72	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	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:

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

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 Number	STRANDS Diameter	Diameter Overall Inches	Area Square Inches	DC RESISTANCE Copper Ohms/kFt	DC RESISTANCE 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.

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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.

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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*

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	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.

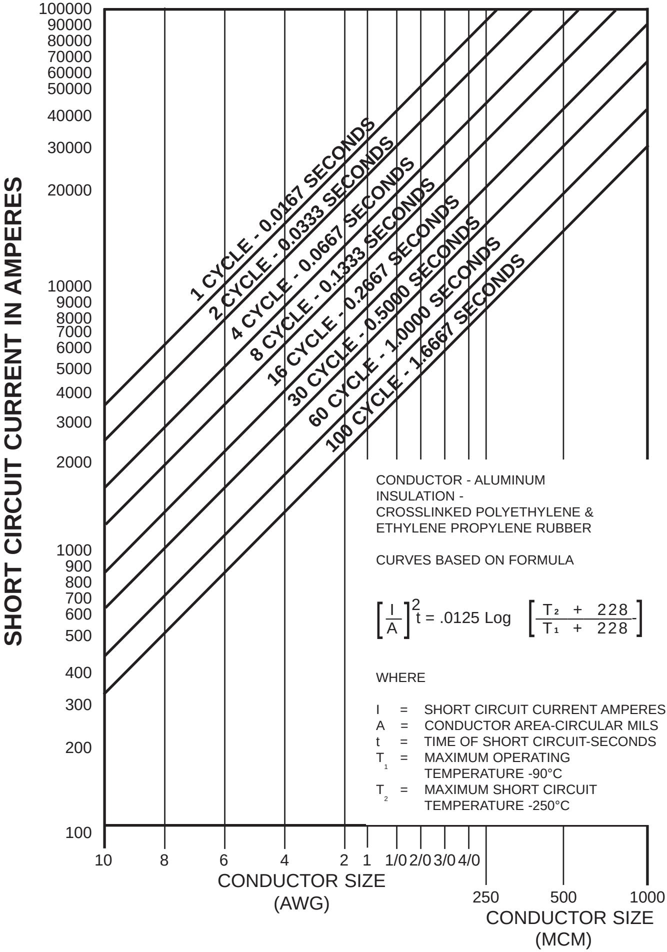
‡ These are maximum allowable conductor temperatures for 1, 2 or 3 conductors run in a raceway, or 2 or 3 conductors run in a cable and may be used in determining the ampacity of other conductor types in Table 19, which are so run as follows: From Table 19 determine the maximum allowable conductor temperature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

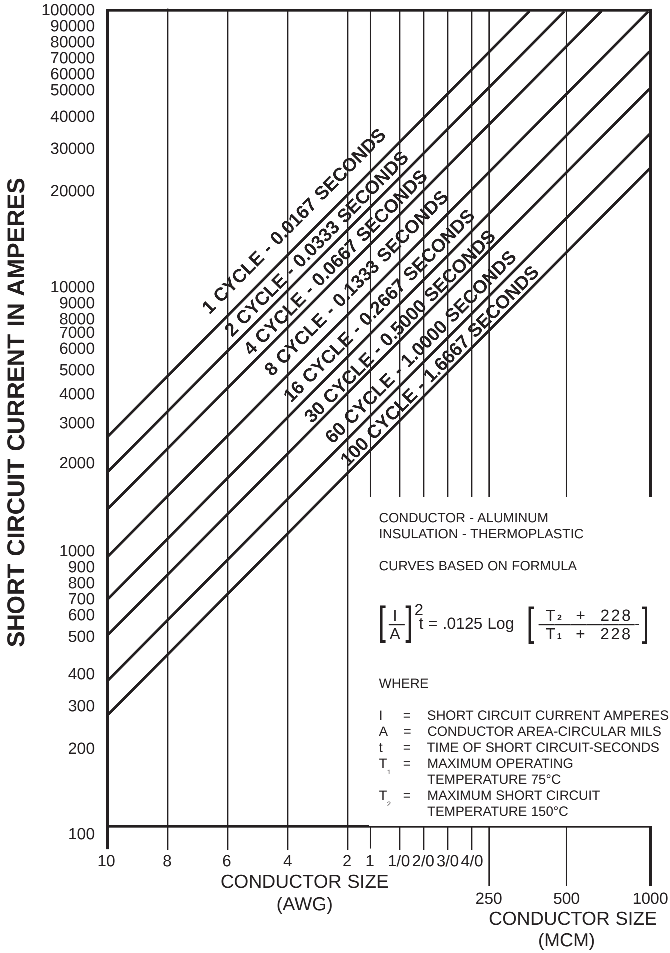
NOTES: (1) These ampacities are only applicable under special circumstances where the use of insulated conductors having this temperature rating are acceptable.

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



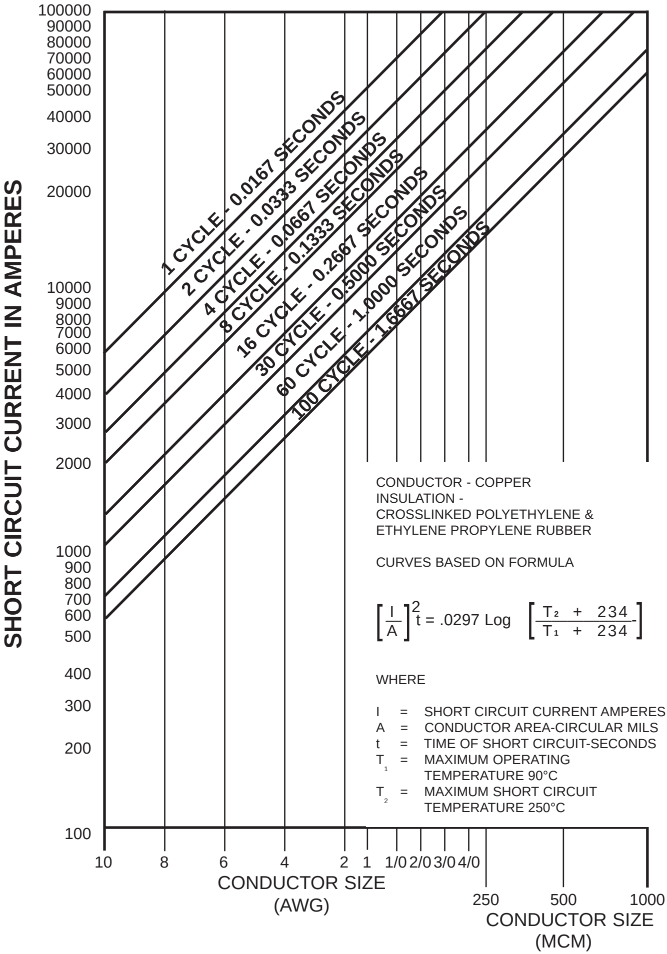
Source: Insulated Cable Engineers Association

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



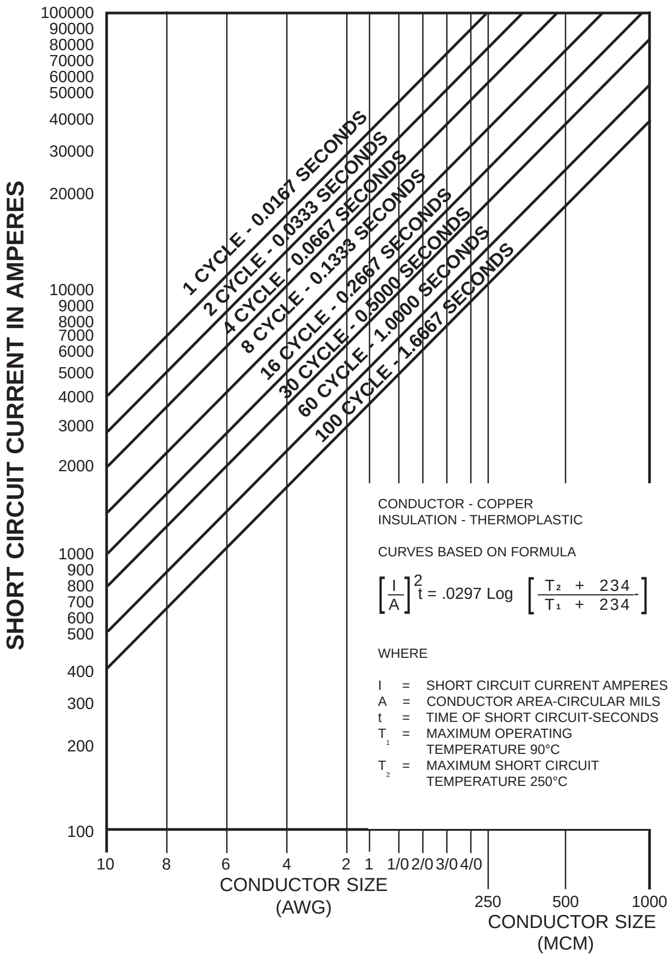
Source: Insulated Cable Engineers Association

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



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?

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

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

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

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

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

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:

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

The kilo-ampere feet would equal:

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

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	Wire Size (AWG or kcmil) 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*
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

V_o = $E'_o - E_o$ = 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

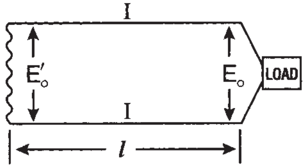
W = watts delivered

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

θ = 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.

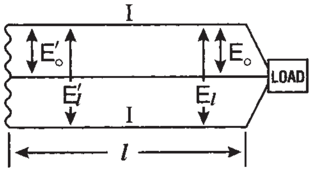
D.C - 2 WIRE



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

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

D.C - 3 WIRE - BALANCED LOAD

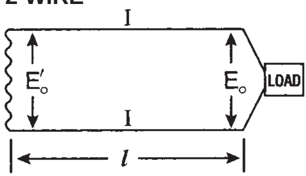


$$I = \frac{W}{2E_o} = \frac{W}{E_l} \text{ amps.}$$

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

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

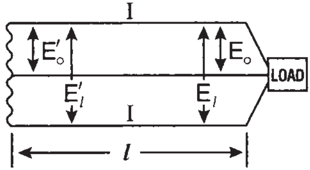


$$I = \frac{W}{E_o \times p.f.} \text{ amps.}$$

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

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

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



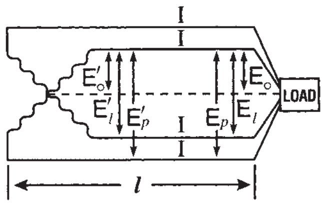
$$I = \frac{W}{2E_o \times p.f.} = \frac{W}{E_l \times p.f.} \text{ amps.}$$

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

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

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

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



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

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

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

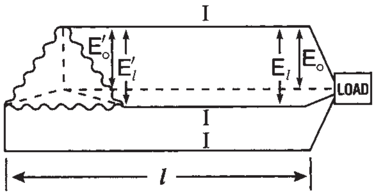
$$= \frac{I \times Z \times l}{1000} \text{ volts drop to neutral (approx.)}$$

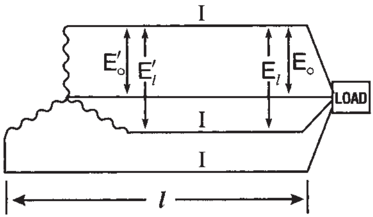
$$V_l = E'_l - E_l = \frac{I \times Z \times \sqrt{2}\, l}{1000} \text{ volts drop between lines (approx.)}$$

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

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





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

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

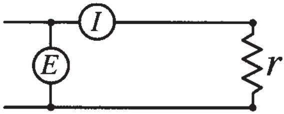
$$V_o = E'_o - E_o = \left[\sqrt{(E_o \cos\theta + IR)^2 + (E_o \sin\theta + IX)^2} - E_o\right] \times \frac{l}{1000} \text{ volts drop to neutral}$$

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

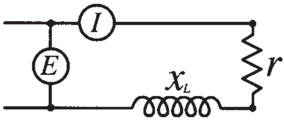
$$V_l = E'_l - E_l = \frac{I \times Z \times \sqrt{3}\, l}{1000} \text{ volts drop between lines (approx.)}$$

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).

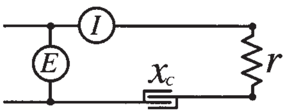
FORMULAE FOR DETERMINING CURRENT IN ALTERNATING CURRENT CIRCUITS



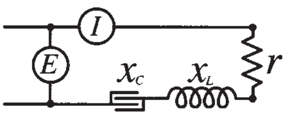
$$I = \frac{E}{r}$$



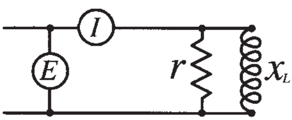
$$I = \frac{E}{\sqrt{r^2 + X_L^2}} = \frac{E}{Z}$$



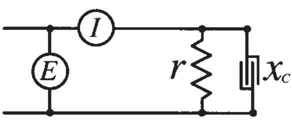
$$I = \frac{E}{\sqrt{r^2 + X_C^2}} = \frac{E}{Z}$$



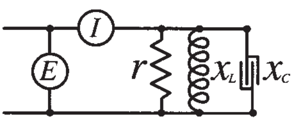
$$I = \frac{E}{\sqrt{r^2 + (X_L - X_C)^2}} = \frac{E}{Z}$$



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



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



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

r = Resistance in ohms

X_L = Inductive reactance in ohms

X_C = Capacitive reactance in ohms

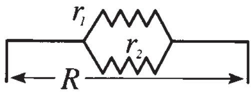
Z = Impedance in ohms

I = Current in amperes

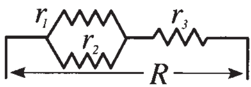
E = Voltage in volts

FORMULAE FOR COMBINING RESISTANCE AND REACTANCE

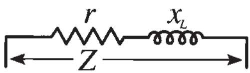
$$R = r$$



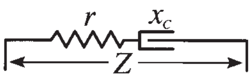
$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{r_1\, r_2}{r_1 + r_2}$$



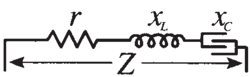
$$R = \frac{1}{\frac{1}{r_1} + \frac{1}{r_2}} + r_3 = \frac{r_1\, r_2}{r_1 + r_2} + r_3$$



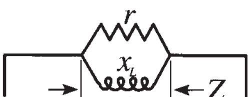
$$Z = \sqrt{r^2 + x_L^2}$$



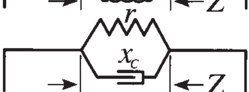
$$Z = \sqrt{r^2 + x_c^2}$$



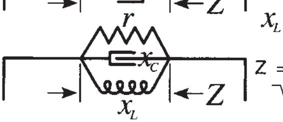
$$Z = \sqrt{r^2 + (x_L - x_C)^2}$$



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



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



$$Z = \frac{1}{\sqrt{\left(\frac{1}{r}\right)^2 + \left(\frac{1}{x_L} - \frac{1}{x_C}\right)^2}} = \frac{r\, x_L\, x_C}{\sqrt{x_L^2\, x_C^2 + r^2\, (x_L - x_C)^2}}$$

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
2π	=	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	$\frac{\text{H.P.} \times 746}{\text{E} \times \text{EFF.}}$	$\frac{\text{H.P.} \times 746}{\text{E} \times \text{EFF.} \times \text{P.F.}}$	$\frac{\text{H.P.} \times 746}{2 \times \text{E} \times \text{EFF.} \times \text{P.F.}}$	$\frac{\text{H.P.} \times 746}{1.73 \times \text{E} \times \text{EFF.} \times \text{P.F.}}$
Amperes when Kilowatts are Known	$\frac{\text{K.W.} \times 1000}{\text{E}}$	$\frac{\text{K.W.}\ \ 1000}{\text{E} \times \text{P.F.}}$	$\frac{\text{K.W.} \times 1000}{2 \times \text{E} \times \text{P.F.}}$	$\frac{\text{K.W.} \times 1000}{1.73 \times \text{E} \times \text{P.F.}}$
Amperes when K.V. A. is known		$\frac{\text{K.V.A.} \times 1000}{\text{E}}$	$\frac{\text{K.V. A.} \times 1000}{2 \times \text{E}}$	$\frac{\text{K.V. A.} \times 1000}{1.73 \times \text{E}}$
Kilowatts	$\frac{\text{I} \times \text{E}}{1000}$	$\frac{\text{I} \times \text{E} \times \text{P.F.}}{1000}$	$\frac{\text{I} \times \text{E} \times 2 \times \text{P.F.}}{1000}$	$\frac{\text{I} \times \text{E} \times 1.73 \times \text{P.F.}}{1000}$
K.V.A.		$\frac{\text{I} \times \text{E}}{1000}$	$\frac{\text{I} \times \text{E} \times 2}{1000}$	$\frac{\text{I} \times \text{E} \times 1.73}{1000}$
Horsepower (Output)	$\frac{\text{I} \times \text{E} \times \text{EFF.}}{746}$	$\frac{\text{I} \times \text{E} \times \text{EFF.} \times \text{P.F.}}{746}$	$\frac{\text{I} \times \text{E} \times 2 \times \text{EFF.} \times \text{P.F.}}{746}$	$\frac{\text{I} \times \text{E} \times 1.73 \times \text{EFF.} \times \text{P.F.}}{746}$

I = Amperes; E = Volts; EFF. = 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.

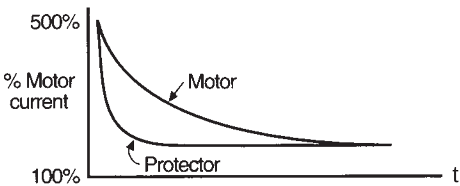
MOTOR OVERCURRENT PROTECTION

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

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

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

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				THREE PHASE			
	115V	230V	460V	575V	115V	230V	460V	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

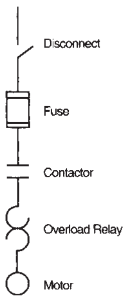
SYNCHRONOUS SPEEDS - ALTERNATING CURRENT GENERATORS AND MOTORS

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

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



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 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.

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.

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.

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			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	1.3	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	25	-	-	-
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 Capacity	Output Current Amperes			Efficiency %		
	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

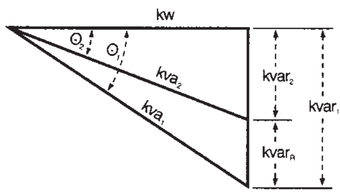
Application of Power Factor Capacitators

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
	θ_1 =	original phase angle
	θ_2 =	phase angle at improved PF
	kw =	load at which original PF was determined

NOTE: The phase angle θ_1 and θ_2 can be determined from a table of trigonometric functions using the following relationships:

θ_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.)

θ_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: $\text{Isec} = \dfrac{\text{Transformer VA}}{\text{Vsec}}$ or $\dfrac{\text{Transformer KVA x 1000}}{\text{Vsec}}$

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

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

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

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.

AMPERES FOR ONE KW AT VARIOUS VOLTAGES AND POWER FACTORS

SINGLE-PHASE CIRCUITS

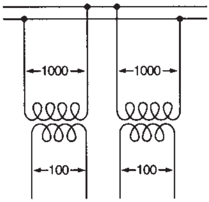
	Amperes per Kilowatt @ Power Factor					
Volts	100%	90%	80%	70%	60%	50%
115	8.70	9.67	10.9	12.4	14.5	17.4
230	4.38	4.87	5.48	6.23	7.30	8.76
460	2.17	2.41	2.71	3.10	3.62	4.34
575	1.74	1.93	2.18	2.49	2.90	3.48
2300	0.435	0.483	0.544	0.621	0.725	0.870

TWO-PHASE CIRCUITS

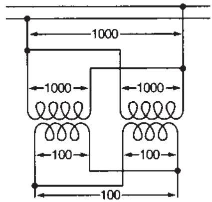
	Amperes per Kilowatt @ Power Factor					
Volts	100%	90%	80%	70%	60%	50%
115	4.35	4.83	5.44	6.21	7.25	8.70
230	2.17	2.41	2.71	3.10	3.62	4.34
460	1.09	1.21	1.36	1.56	1.82	2.18
575	0.870	0.966	1.09	1.24	1.45	1.74
2300	0.217	0.242	0.271	0.310	0.362	0.434

THREE-PHASE CIRCUITS

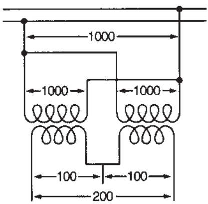
	Amperes per Kilowatt @ Power Factor					
Volts	100%	90%	80%	70%	60%	50%
115	5.02	5.58	6.28	7.17	8.37	10.0
208	2.78	3.08	3.48	3.97	4.63	5.56
230	2.51	2.79	3.18	3.59	4.18	5.02
460	1.26	1.39	1.58	1.80	2.10	2.52
575	1.00	1.12	1.25	1.43	1.67	2.00
2400	0.241	0.268	0.301	0.344	0.402	0.482
4160	0.139	0.154	0.174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



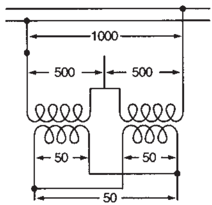
Single-phase transformers on
a single phase system.



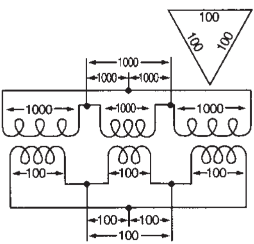
Single-phase transformers,
secondaries in parallel.



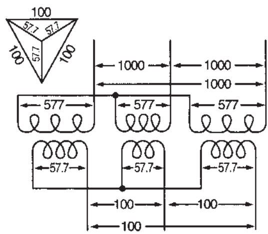
Single-phase transformers
secondaries in series.



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

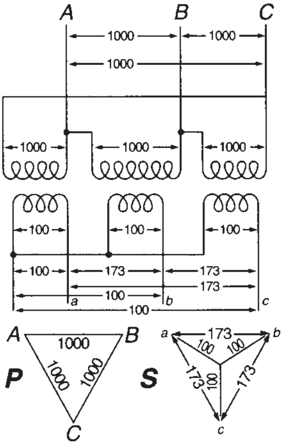


Three single-phase transformers
connected delta-delta in
a three-phase system

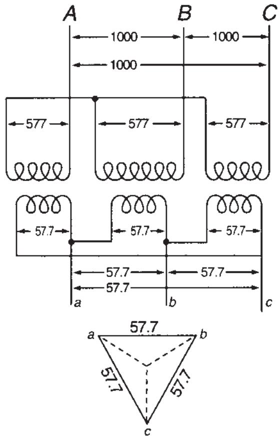


Three single-phase transformers
connected star-star in
a three-phase system

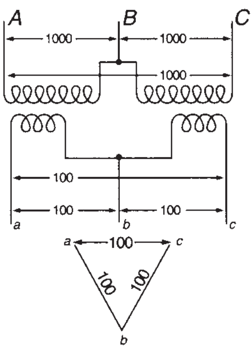
CONNECTION DIAGRAMS
For Transformers



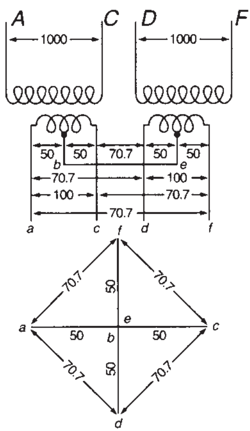
Three single-phase transformers
connected delta-star in
a three-phase system



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

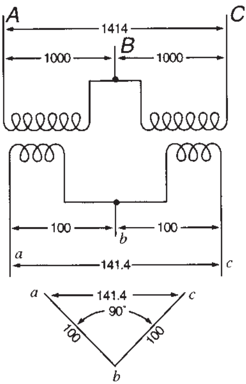


Two single-phase transformers
connected open delta in a three phase
system

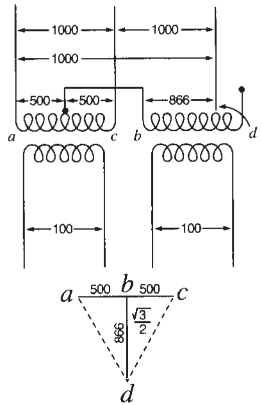


Two single-phase transformers
connected star in a four-wire
two-phase system

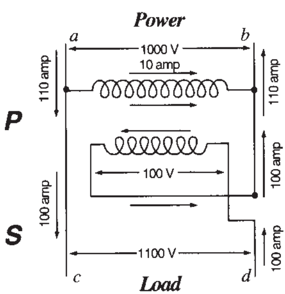
CONNECTION DIAGRAMS
For Transformers



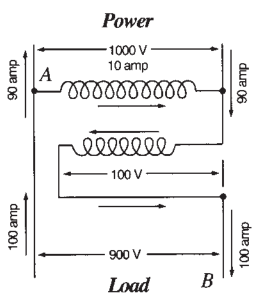
Two single-phase transformers
connected in a three-wire
two-phase system



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



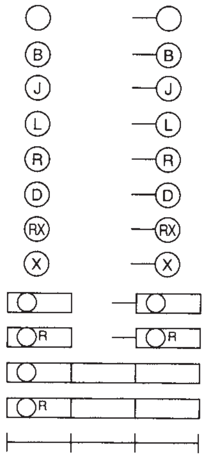
Single phase transformer
used as a booster.



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

GRAPHIC SYMBOLS FOR ELECTRICAL WIRING
Lighting outlets

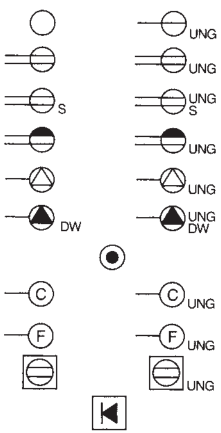
Ceiling **Wall**



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

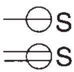
Grounded **Ungrounded**



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

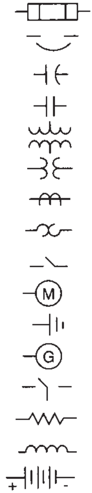
S	Single-Pole Switch
S_2	Double-Pole Switch
S_3	Three-Way Switch
S_4	Four-Way Switch
S_F	Fused Switch
S_{WPF}	Weather-Proof Fused Switch
S_K	Key-Operated Switch
S_P	Switch and Pilot Lamp
S_L	Switch for Low-Voltage System
S_{RC}	Remote Control Switch



Switch and Single Receptacle
Switch and Double Receptacle

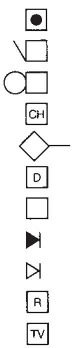
S_{WP}	Weatherproof Switch
S_D	Door Switch
S_T	Time Switch
S_{MC}	Momentary Contact Switch
S_{CB}	Circuit Breaker Switch
S_{WCB}	Weatherproof Circuit Breaker Switch

Power Circuits



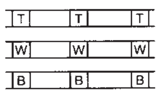
Fuse
Circuit Breaker
Capacitor
Contactor
Transformer
Potential Transformer
Current Transformer
Overload Relay
Line Switch
Motor
Ground
Generator
Transfer Switch
Resistor
Inductor
Battery

Residential Occupancies



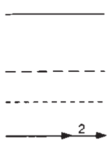
Push-button
Buzzer
Bell
Chime
Annunciator
Electric Door Opener
Interconnection Box
Outside Telephone
Interconnecting Telephone
Radio Outlet
Television Outlet

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

 FERRAZ SHAWMUT

AREAS AND CIRCUMFERENCES OF CIRCLES

Diam.	Circum.	Area
1/64	.049087	.00019
1/32	.098175	.00077
3/64	.147262	.00173
1/16	.196350	.00307
3/32	.294524	.00690
1/8	.392699	.01227
5/32	.490874	.01917
3/16	.589049	.02761
7/32	.687223	.03758
1/4	.785398	.04909
9/32	.883573	.06213
5/16	.981748	.07670
11/32	1.07992	.09281
3/8	1.17810	.11045
13/32	1.27627	.12962
7/16	1.37445	.15033
15/32	1.47262	.17257
1/2	1.57080	.19635
17/32	1.66897	.22166
9/16	1.76715	.24850
19/32	1.86532	.27688
5/8	1.96350	.30680
21/32	2.06167	.33824
11/16	2.15984	.37122
23/32	2.25802	.40574
3/4	2.35619	.44179
25/32	2.45437	.47937
13/16	2.55254	.51849
27/32	2.65072	.55914
7/8	2.74889	.60132
29/32	2.84707	.64504
15/16	2.94524	.69029
31/32	3.04342	.73708
1.	3.14159	.78540
1/16	3.33794	.88664
1/8	3.53429	.99402
3/16	3.73064	1.1075
1/4	3.92699	1.2272
5/16	4.12334	1.3530
3/8	4.31969	1.4849
7/16	4.51604	1.6230
1/2	4.71239	1.7671
9/16	4.90874	1.9175
5/8	5.10509	2.0739
11/16	5.30144	2.2365
3/4	5.49779	2.4053
13/16	5.69414	2.5802
7/8	5.89049	2.7612
15/16	6.08684	2.9483

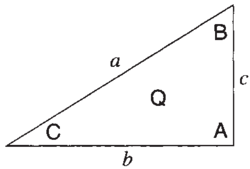
Diam.	Circum.	Area
2.	6.28319	3.1416
1/16	6.47953	3.3410
1/8	6.67588	3.5466
3/16	6.87223	3.7583
1/4	7.06858	3.9761
5/16	7.26493	4.2000
3/8	7.46128	4.4301
7/16	7.65763	4.6664
1/2	7.85398	4.9087
9/16	8.05033	5.1572
5/8	8.24668	5.4119
11/16	8.44303	5.6727
3/4	8.63938	5.9396
13/16	8.83573	6.2126
7/8	9.03208	6.4918
15/16	9.22843	6.7771
3.	9.42478	7.0686
1/16	9.62113	7.3662
1/8	9.81748	7.6699
3/16	10.0138	7.9798
1/4	10.2102	8.2958
5/16	10.4065	8.6179
3/8	10.6029	8.9462
7/16	10.7992	9.2806
1/2	10.9956	9.6211
9/16	11.1919	9.9678
5/8	11.3883	10.321
11/16	11.5846	10.680
3/4	11.7810	11.045
13/16	11.9773	11.416
7/8	12.1737	11.793
15/16	12.3700	12.177
4.	12.5664	12.566
1/16	12.7627	12.962
1/8	12.9591	13.364
3/16	13.1554	13.772
1/4	13.3518	14.186
5/16	13.5481	14.607
3/8	13.7445	15.033
7/16	13.9408	15.466
1/2	14.1372	15.904
9/16	14.3335	16.349
5/8	14.5299	16.800
11/16	14.7262	17.257
3/4	14.9226	17.721
13/16	15.1189	18.190
7/8	15.3153	18.665
15/16	15.5116	19.147
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. $\tan C = \dfrac{2Q}{b^2}$

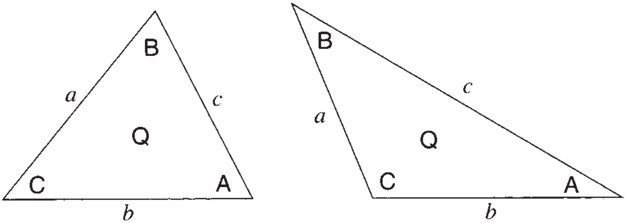
In a triangle the functions of an angle have a certain relation to the opposite side; it is this relationship which enables us to solve the triangle by the application of simple arithmetic.

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.	Metals and Alloys	Weight per Cubic Foot, Lbs.
Asbestos	125-175	Aluminum, cast	160
Asphaltum	87	Antimony, solid	418
Brick	125-137	Barium	242
Brick, Fire	144	Bismuth, solid	617
Brickwork, in mortar	100	Boron	162
Brickwork, in cement	112	Brass, yellow, 70 Cu. + 30 Zn. cast	527
Cement, Set	178	Brass, red 90 Cu + 10 Zn	536
Chalk	163	Brass, white, 50 Cu. + 50 Zn.	511
Charcoal, Oak	35	Bronze, 90 Cu. + 10 Sn.	548
Charcoal, Pine	17.5-27.5	Bronze, 85 Cu. + 15 Sn.	555
Concrete	137	Bronze, 75 Cu. + 25 Sn.	551
Earth, loose	75	Cadmium	536
Earth, rammed	120	Calcium	98
Emery	250	Chromium	410
Glass, common	163	Cobalt, wrought	563
Granite	166	Copper, cast	555
Gravel	110	Gold	1207
Gypsum	140	German Silver	523
Gypsum, Burnt	113	Iridium	1380
Ice	56	Iron, grey, cast	442
Ivory	117	Iron,white, cast	478
Kaolin	137	Iron, wrought	490
Lead acetate	150	Lead	709
Lime, Slaked	81-87	Magnesium	107
Limestone	166	Manganese	428-500
Litharge, Artificial	583	Mercury	848
Magnetite	315	Molybdenum	530
Marble	157-177	Nickel	517-555
Masonry	116-144	Platinum	1338
Mortar	109	Potassium, solid	54
Plaster of Paris	112	Silver	655
Pyrites	306-324	Sodium	612
Pyrolusite	231-287	Steel	486
Sand, dry	100	Strontium	160
Sandstone	145	Tin	455
Slate	165	Titanium	341
Soapstone	170	Tungsten	1193
Tile	115	Vanadium	342
Trap	185	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

SHAWMUT designs for protection, which is your surest economy.

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.	Brinell Hardness 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

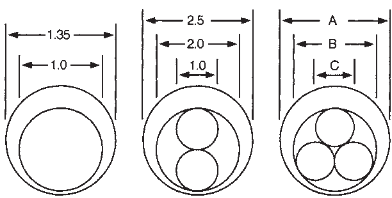
Metal	Resistivity Microhm-Cm 20°C	Temp. Coeff. of Resistivity per °C	Specific Gravity	Tensile Strength lbs./in.^{2}	Melting Point °C
Aluminum	2.824	0.0039	2.7	30.000	659
Antimony	41.7	0.0036	6.6	--	630
Bismuth	120	0.004	9.8	--	271
Brass	7	0.002	8.6	70,000	900
Cadmium	7.6	0.0038	8.6	--	321
Climax	87	0.0007	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 × C.

Example: 4 #10 wires require 3.1 × .63 = 1.95" or a 2" conduit (Assume dia. #10 wire = .63")

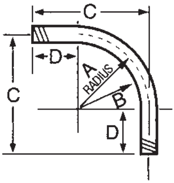
DIMENSIONS AND WEIGHTS
RIGID CONDUIT, PIPE, AND ELECTRICAL METALLIC TUBING
(Garland Manufacturing Company)

		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.	----	----	----

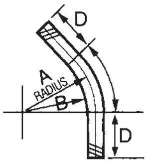
APPROXIMATE DIMENSIONS OF CONDUIT FITTINGS

(General Electric Company)

90 - Degree Elbow



45 - Degree Elbow

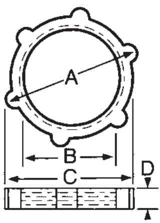


Nominal Size Inches	A Radius	B	C (offset) 90° Elbow	D (Tangent) 90° Elbow	D (Tangent) 45° Elbow
G.E. RIGID STEEL CONDUIT					
1/2"	4	3-21/32	6-11/16	2-11/16	4-5/16
3/4	4-1/2	3-31/32	7-13/32	2-29/32	4-47/64
1	5-3/4	5-3/32	8-27/64	2-43/64	5
1-1/4	7-1/4	6-27/64	9-7/8	2-5/8	3-25/32
1-1/2	8-1/4	7-11/32	11-3/16	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

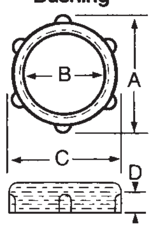
(Steel City Electric Company)

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

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

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

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.

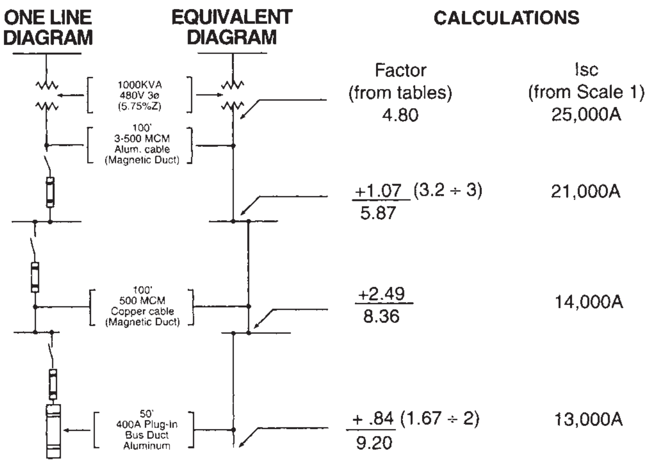
Cable and bus factors are based on 100 foot lengths. Shorter or longer lengths have proportionally smaller or larger factors (i.e. 50’ length = 1/2 factor; 200’ length = 2 x factor).

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

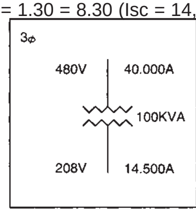
NOTES: 208 VOLT 3∅ transformer factors are calculated for 50% motor load.
240, 480 and 600 volt 3∅ transformer factors are calculated for 100% motor load.
A phase-to-phase fault is .866 times the calculated 3-phase value.

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

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

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

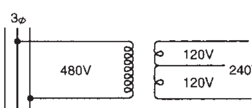


Diagram A

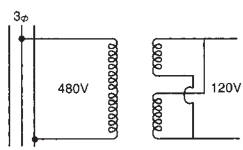


Diagram B

QUICK 3 PHASE SHORT-CIRCUIT CALCULATIONS cont.

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

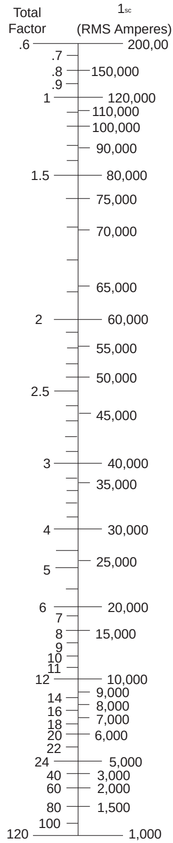
Cable Size	3 ∅ Voltage			
	208	240	480	600
8	79.00	68.00	34.00	27.00
6	50.00	43.00	22.00	17.50
4	32.00	28.00	14.00	11.15
2	21.00	18.00	9.00	7.23
1	17.50	15.00	7.40	5.91
1/0	14.00	12.20	6.10	4.85
2/0	11.80	10.20	5.10	4.05
3/0	9.80	8.50	4.27	3.43
4/0	8.40	7.30	3.67	2.94
250MCM	7.70	6.70	3.37	2.70
300MCM	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.

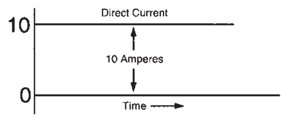


Figure 1

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.

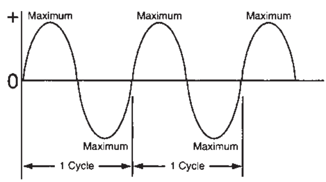


Figure 2

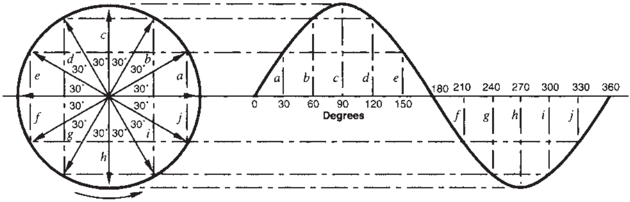


Figure 3

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).

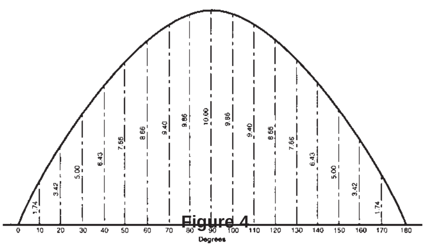


Figure 4

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

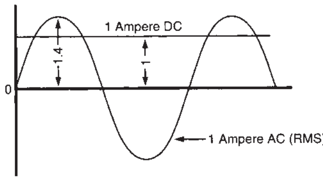


Figure 5

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.

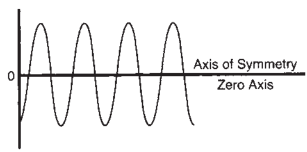


Figure 6

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.

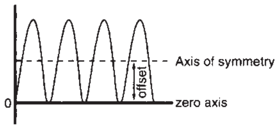


Figure 7

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.

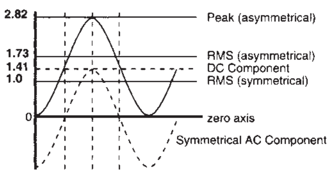


Figure 8

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.

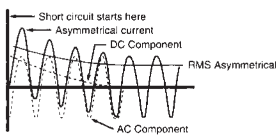


Figure 9

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

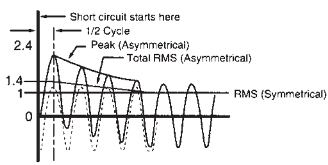


Figure 10

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.

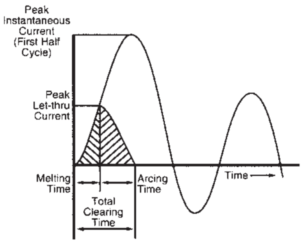


Figure 11

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

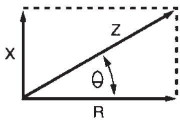


Figure 12

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

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

The resultant θ 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:

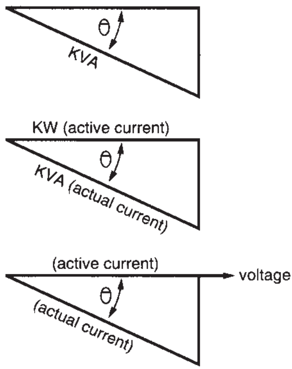


Figure 13

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.

Power Factor = cos θ

X/R = tan θ

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

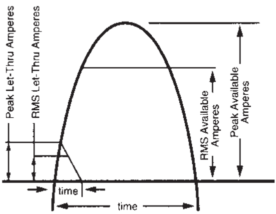


Figure 14

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.

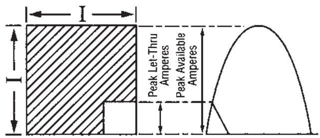


Figure 15

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

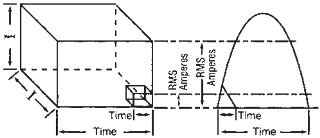


Figure 16

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	France -- NFC 60.269
Canada -- CSA C22.1-98	Germany -- DIN 57636 & VDE 0636
Mexico -- NOM J-9	Spain -- UNE 21.103
United Kingdom -- BS88	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.

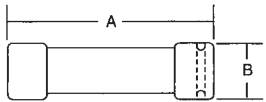
B. As-installed drawings shall be submitted to the engineer after completion of the job.

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.

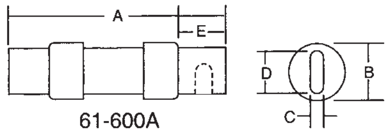
5.0 SUBSTITUTIONS

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



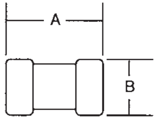
0-60A



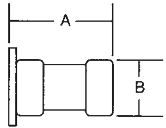
61-600A

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	--	--	--	--	--	--

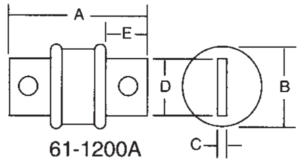
DIMENSIONS OF CLASS T AND CLASS G FUSES



0-60A



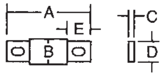
31-60A (600V only)



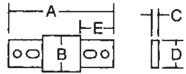
61-1200A

Voltage, Class and Ampere Range	A		B		C		D		E	
	Length Overall		Diameter Overall		Contact Blades					
					Thickness		Width		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	--	--	--	--	--	--

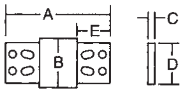
DIMENSIONS OF CLASS L FUSES



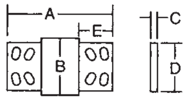
100-800A



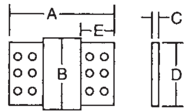
801-2000A



2001-3000A



3001-4000A



4001-6000A

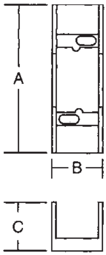
Ampere Rating	A		B		C		D		E	
	Length Overall		Diameter Overall		Contact Blades					
					Thickness		Width		Length	
	Inches	MM	Inches	MM	Inches	MM	Inches	MM	Inches	MM
100 - 600*	8-5/8	219	2	51	5/16	8	1-5/8	41	2-13/32	61
601 - 800	8-5/8	219	2-1/2	63	3/8	9	2	51	2-13/32	61
801 - 1200	10-3/4	273	2-1/2	63	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.

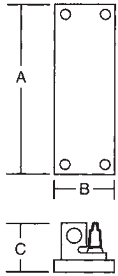
DIMENSIONS OF FUSEHOLDERS

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 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 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 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®

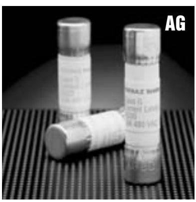
Class T Fast Acting
A3T: 1 to 1200A
300V AC, 200kA I.R.
160V DC, 50kA I.R.
A6T: 1 to 800A
600V AC, 200kA I.R.
300V DC, 100kA I.R.
Current Limiting
UL Listed
CSA Certified

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

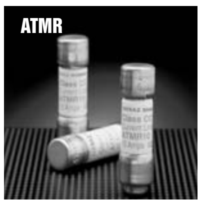
Feeder circuit, panelboard, and circuit breaker back-up protection. Very current limiting.



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

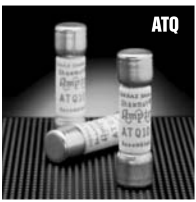
Lowest cost protection for circuits serving heating, lighting, and other non-motor loads.

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.

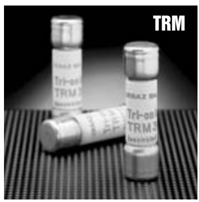
Midget, Miniature & PC Mount Fuses



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

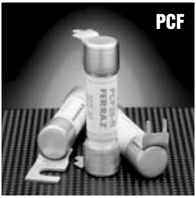
Glass Body FSFE Fuses
Fast Acting
4A to 30A
32V AC/DC

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®

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

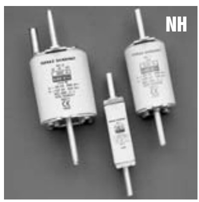
Short circuit protection for medium voltage motors and controllers.

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.

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

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

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 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 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

.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

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.

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

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

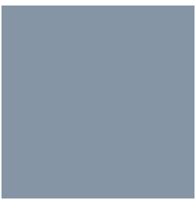
Provides DIN rail mounting capabilities in addition to being completely finger safe to an IP20 level.
Compact modularity
Snap-on DIN rail mounting
Captive termination screw
Ampere ratings 175 to 840A
600V rated
UL Recognized
CSA Certified

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

Disconnect Swtiches

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

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 μs 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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