Conversion Factors

To Convert	Into	Multiply by
Acres	square miles	1.562×10^{-3}
Ampere hours	coulombs	3.600.0
Atmospheres	cms of mercury	76.0
BTU's	horsepower-hrs	3.931×10^{-4}
BTU's	kilowatt hours	2.928×10^{-4}
BTU/hr	watts	0.2931
Centimeters	meters	1×10^{-2}
Centimeters	millimeters	10.0
Centimeters	feet	3.281×10^{-2}
Centimeters	inches	0.3937
Coulombs	faradays	1.036×10^{-5}
Cubic centimeters	cubic inches	0.06102
Cubic centimeters	pints (U.S. liq.)	2.113 x 10 -3
Cubic feet	cubic meters	0.02832
Cubic feet/sec.	gallons/min.	448.831
Days	seconds	86,400.0
Degrees (angles)	radians	1.745×10^{-2}
Feet	centimeters	30.48
Feet	meters	0.3048
Feet	miles (statute)	1.894×10^{-4}
Feet/sec.	miles/hour	0.6818
Gallons	liters	3.785
Grams	pounds	2.205×10^{-3}
Horsepower	BTU/min.	42.42
Horsepower	kilowatts	0.7457
Horsepower	Watts	745.7
Hours	Days	4.167×10^{-2}
Hours	Weeks	5.952×10^{-3}
Inches	Centimeters	2.540
Inches	Miles	1.578×10^{-5}
Joules	BTU	9.480×10^{-4}
Kilograms	Pounds	2.205
Kilometers	Feet	3,281.0
Kilometers	Meters	1,000.0

To Convert	Into	Multiply by
Kilometers	miles	0.6214
Kilowatts	horsepower	1.341
Kilowatt - hours	BTU's	3,413.0
Liters	cubic centimeters	1,000.0
Liters	cubic inches	61.02
Liters	gallons (U.S. liq.)	0.2642
Liters	milliliters	1,000.0
Liters	pints (U.S. liq.)	2.113
Meters	centimeters	100.0
Meters	feet	3.281
Meters	kilometers	1×10^{-3}
Meters	miles (statute)	6.214×10^{-4}
Meters	millimeters	1,000.0
Miles (statute)	feet	5,280.0
Miles (statute)	kilometers	1.853
Miles (statute)	miles (nautical)	0.8684
Miles/hour	feet/min.	88.0
Milliliters	liters	1×10^{-3}
Millimeters	inches	3.937×10^{-2}
Ounces	grams	28.349527
Ounces	pounds	6.25×10^{-2}
Pounds	kilograms	0.4536
Pounds	ounces	16.0
Radians	degrees	57.30
Radians	minutes	3,438.0
Revolutions	degrees	360.0
Seconds	minutes	1.667×10^{-2}
Slugs	pounds	32.17
Tons (short)	kilograms	907.1848
Tons (short)	pounds	2,000.0
Watts	BTU/hour	3.4129
Watts	horsepower	1.341×10^{-3}
Yards	meters	0.9144
Yards	miles (statute)	5.682×10^{-4}

FORCES DUE TO SHORT CIRCUIT CURRENTS

Conductors carrying electric currents will exert forces on each other according to well defined rules. These forces are caused by the magnetic field about the conductors and under short circuit when heavy currents flow, these forces can be of great magnitude. The following explains in some detail how the various formulae for calculating these forces are derived. Equations are given for each type of circuit.

All values in these formulae are theoretically applicable only immediately after short circuit and before the decrement sets in. A fully offset wave is assumed for asymmetrical calculations which provides a mathematical ratio of 1.73 between the rms value of the composite current wave and the rms of the corresponding a-c wave. Some decrement will be present, even on the first half cycle peak, so the resulting calculations will be conservative.

From the basic formula for force between two wires,

$$F = \frac{2\, i_1\, i_2}{d} \text{ dynes per centimeter} \qquad (1)$$

where

d = center-to-center spacing of wires in cm
i_1, i_2 = current in each wire in abamperes

we obtain

$$F = \frac{5.4\, I^2}{D\ (10^7)} \text{ pounds per foot} \qquad (2)$$

where

I = current per wire in amperes (going and returning currents assumed alike)
D = center-to-center spacing of wires in inches

Equations (3) to (9), which follow, are derived from equation (1). In all such equations the force F is in pounds per foot.

Conductors will attract each other if carrying like currents and repel if carrying unlike. This formula is applicable to d-c buses exactly as in equation (2), where I is peak current delivered immediately after short circuit by the connected generator capacity and whatever motor feed-back can be delivered by connected machines.

Calculation of forces set up by alternating currents is somewhat complicated by the fact that the force is cyclic in nature and a variety of conditions may arise due to a single or three-phase fault. The use of peak value of the first half-cycle of the current wave makes a sound, sensible basis for developing a set of formulas. Some advocate the use of the average force developed over a half-cycle instead of that delivered by the wave peak. Others introduce the theory of natural frequency of vibration of the bus itself and possibility of resonance with the a-c frequency. If resonance should occur, very great forces might result. This method involves data on buses, bus clamps, insulators, bases and structures which would be practically endless for all possible combinations and introduces a cumbersome calculating procedure. The possibility of resonance is small and values calculated by the peak-of-the-wave method usually exceed those found by the resonant method. Forces calculated by the following formulas are based on peak value of current during the first half-cycle. This gives the maximum force as successive peak currents are smaller due to various decrements. Part of this instantaneous force is absorbed by inertia of the bus system, so a safety factor is present.

In the case of a symmetrical fault, the peak of wave is equal to $\sqrt{2}$ times the rms value. For a single-phase or line-to-line fault (currents in both wires in phase), equation (2) reduces to

$$F = \frac{5.4\ (\sqrt{2}I)^2}{D\ (10^7)} = \frac{10.8\ I^2}{D\ (10^7)} \qquad (3)$$

where I is the rms symmetrical current value

For the asymmetrical fault, if the rms symmetrical value is given, equation (2) becomes

$$F = \frac{5.4[2(\sqrt{2}I)]^2}{D\ (10^7)} = \frac{43.2\ I^2}{D\ (10^7)} \qquad (4)$$

where I is the rms symmetrical current value

If the rms asymmetrical value is given, equation (2) becomes

$$F = \frac{5.4\ (1.63\ I)^2}{D\ (10^7)} = \frac{14.4\ I^2}{D\ (10^7)} \qquad (5)$$

where I is the rms asymmetrical current value and 1.63 is the ratio between the peak value of the composite wave and the rms value of the composite wave.

The usual three-phase bus arrangement is a flat configuration with equally spaced conductors side by side. It can be proved mathematically that the maximum possible force will be impressed on phase B and the short circuit must occur 45° after zero current value in phase B. The maximum force will then occur ½ cycle after the instant of short circuit. Any other combination of circumstances, such as choosing the instant of fault when phase B is at maximum gives a smaller force than the specified conditions.

Call the peak value of the a-c symmetrical wave at maximum force, I_p. At instant of short circuit, B will have the value $+0.7071\ I_p$. A will be $+0.2588\ I_p$ and C will be $-0.9659\ I_p$. The instantaneous values of their transient d-c components will be the negatives of above amounts as shown in the figure. Currents in both A and C tend to force conductor B to the left. As currents are out of phase and their d-c components are of different magnitudes, we cannot use I^2, but must make use of I_1 and I_2. By multiplying current A by B and B by C and adding results (forces on B are both to the left) we can substitute in equation (2) and obtain

$$F = \frac{18.7\ I^2p}{D\ (10^7)} = \frac{37.4\ I^2}{D\ (10^7)} \qquad (6)$$

where I is the rms symmetrical current value

The maximum force obtainable then from a three-phase fault is 86.6% of that from a single-phase fault, where the current per wire of the two types of circuits are the same. However, on the same circuit, the force caused by a three-phase fault will be larger than that resulting from a single-phase fault.

If the rms three-phase asymmetrical value is given, equation (5) becomes

$$F = \frac{14.4\ (0.866)\ I^2}{D\ (10^7)} = \frac{12.5\ I^2}{D\ (10^7)} \qquad (7)$$

where I is the rms asymmetrical current value

It should be noted that equations (6) and (7) are for asymmetrical three-phase faults, the rms symmetrical current value being used in (6) and the rms asymmetrical value in (7). A symmetrical three-phase fault is an impossibility, as the three currents are 120 out of phase and no time can be selected when all three are zero.

By a similar analysis, it can be shown that the maximum force on either outside conductor (when both are equidistant from middle conductor) is

$$F = \frac{34.9\ I^2}{D\ (10^7)} \qquad (8)$$

where I is the rms symmetrical current value

or

$$F = \frac{11.6\ I^2}{D\ (10^7)} \qquad (9)$$

where I is the rms asymmetrical current value

In bus structure calculations, the triangular configuration of conductors is of less interest than the flat arrangement owing to the more general use of the latter construction involving bars, tubes or structural shapes. While the maximum force occurs only on the middle conductor of the flat arrangement, it may occur on any one of the three conductors in the equilateral triangular configuration. The maximum force is the same, and equations (6) and (7) hold for the equilateral arrangement as well as for flat configuration. However, in the triangular configuration, the fault must occur when the current is at a maximum in the conductor under consideration rather than at 45° after maximum current in the middle conductor as is the case in the flat arrangement. The force on any one conductor is the resultant of forces caused by the other two.

The accompanying table summarizes probable forces due to various currents, faults and bus configurations. Equations for single-phase conditions cover faults either on a single-phase circuit or line-to-line short on a three-phase circuit.

All formulas are correct theoretically only for a thin round wire. Actually the error is small regardless of conductor contour if the largest dimension of the conductor is less than the center-to-center distance between phases. With narrow bars and small phase spacing, a correction factor must be applied. A set of curves for determining this factor have been prepared and, are shown on page 19.

In the majority of cases forces on buses can be analyzed by considering long, straight, parallel conductors. When bends, crossovers, etc. must be considered, no simple formula is available to determine resultant forces. Curves have been developed for various bus configurations from which these forces can be read.

When short-circuited current or short-circuited power is computed and the information is to be passed on to others, it should be stated what the value is or how it was obtained. Remember that in computing short-circuit currents in networks, the sub-transient reactance of rotating machinery is used and the amperes obtained are rms symmetrical containing no d-c component. *This component must be added to the calculated value.* On the other hand, if the network is solved for a reactance in percent and current is read from decrement curves, amperes obtained will be rms asymmetrical and *will include* the d-c component.

**Extracted from "Forces Due to Short Circuit Currents," S. C. Killian, Electrical World, December 12, 1942*

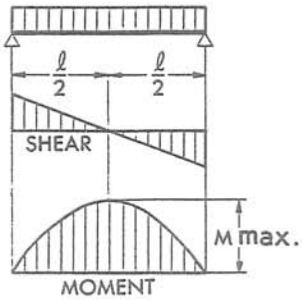
FORCES ON BUSES

SHORT-CIRCUIT CURRENT, *I*, GIVEN AS	TYPE OF FAULT	CONFIGURATION	FORCE ON CONDUCTOR	MAXIMUM *F*, IN POUNDS PER FT. (*D* in INCHES)
D-C		A B o o |←D→|	A or B	$F = \frac{5.4\, I^2}{D\,(10^7)}$
RMS symmetrical	Single-Phase Symmetrical	A B o o |←D→|	A or B	$F = \frac{10.8\, I^2}{D\,(10^7)}$
RMS symmetrical	Single-Phase Asymmetrical	A B o o |←D→|	A or B	$F = \frac{43.2\, I^2}{D\,(10^7)}$
RMS asymmetrical	Single-Phase Asymmetrical	A B o o |←D→|	A or B	$F = \frac{14.4\, I^2}{D\,(10^7)}$
RMS symmetrical	Three-Phase Asymmetrical	A B C o o o |←D→|←D→|	B	$F = \frac{37.4\, I^2}{D\,(10^7)}$
RMS asymmetrical	Three-Phase Asymmetrical	A B C o o o |←D→|←D→|	B	$F = \frac{12.5\, I^2}{D\,(10^7)}$
RMS symmetrical	Three-Phase Asymmetrical	A B C o o o |←D→|←D→|	A or C	$F = \frac{34.9\, I^2}{D\,(10^7)}$
RMS asymmetrical	Three-Phase Asymmetrical	A B C o o o |←D→|←D→|	A or C	$F = \frac{11.6\, I^2}{D\,(10^7)}$
RMS symmetrical	Three-Phase Asymmetrical	B D D A |←D→| C	A, B or C	$F = \frac{37.4\, I^2}{D\,(10^7)}$
RMS asymmetrical	Three-Phase Asymmetrical	B D D A |←D→| C	A, B or C	$F = \frac{12.5\, I^2}{D\,(10^7)}$

NOTE: Single-phase notation indicates either a single-phase system or a line-to-line fault on a three-phase system.

BEAM DIAGRAMS AND FORMULAE

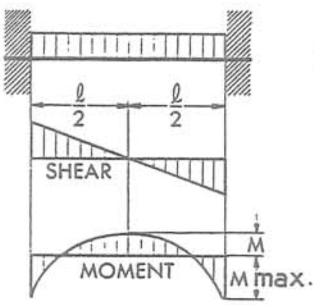
1. Simple Beam — Uniformly Distributed Load



$$M\ max = \frac{w\,l^2}{8}\ \text{(at center)}$$

$$d\ max = \frac{5}{384}\ \frac{w\,l^4}{EI}$$

2. Fixed Beam — Uniformly Distributed Load

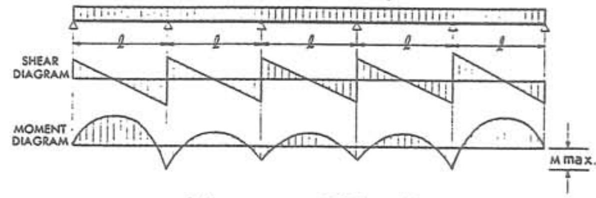


$$M\ max = \frac{w\,l^2}{12}\ \text{(at center)}$$

$$M = \frac{w\,l^2}{24}\ \text{(at ends)}$$

$$d\ max = \frac{w\,l^4}{384\ EI}$$

3. Continuous Beam — Uniformly Distributed Load



$$M\ max = .105\ w\,l^2$$

In the above equations:
M = bending moment in inch-pounds
M max = maximum bending moment in inch-pounds
w = force per unit length in pounds per inch
l = length in inches
d max = maximum deflection in inches
E = modulus of elasticity in pounds per square inch
I = moment of inertia in inches

These equations may be used when calculating stresses in buses resulting from short-circuit conditions. After the force per foot, "F" (see section on short-circuit forces), has been determined, it is substituted into the applicable moment equation above; remembering that

$$w = \frac{F}{12}$$

The stress is then the quotient of the bending moment and the section modulus, i.e.,

$$s = \frac{M}{Z}$$

where s = stress in pounds per square inch and Z = section modulus in inches.

TABLE OF PERMISSIBLE FORCES ON COPPER TUBING

TUBING SIZE IPS		FORCE (POUNDS/FOOT)									
		WEIGHT LB/FT	SPAN (FEET)								
			8	10	12	14	16	18	20	22	24
½	STD	.956	7.8	5.0	3.5	2.5	1.9	1.5	1.2	1.0	0.9
	EXH	1.253	9.3	5.9	4.1	3.0	2.3	1.8	1.5	1.2	1.0
¾	STD	1.30	13.7	8.7	6.1	4.5	3.4	2.7	2.2	1.8	1.5
	EXH	1.706	16.6	10.6	7.4	5.4	4.1	3.3	2.7	2.2	1.8
1	STD	1.83	24.8	16.9	11.0	8.1	6.2	4.9	4.0	3.3	2.8
	EXH	2.509	31.2	20	13.8	10.1	7.8	6.2	5.0	4.1	3.5
1¼	STD	2.68	46.5	30	20.7	15.3	11.6	9.2	7.5	6.2	5.2
	EXH	3.46	56.4	36.1	25	18.4	14.1	11.2	9.0	7.5	6.3
1½	STD	3.19	64.8	41.5	28.8	21.0	16.2	12.8	10.2	8.5	7.2
	EXH	4.191	80	51.2	35.6	26.2	20	15.8	12.8	10.6	8.9
2	STD	4.21	110	70	48.5	35.5	27.3	21.5	17.6	13.2	12.2
	EXH	5.791	142	91	63	46.5	35.5	28	22.7	18.8	15.8
2½	STD	6.12	192	123	86	63	48.2	38	31	25.5	21.5
	EXH	8.839	260	166	116	85	65	51	41	34.5	29
3	STD	8.72	337	216	151	110	85	67	54	45	38
	EXH	11.82	430	275	190	140	107	85	68	57	47
3½	STD	11.38	500	320	220	162	124	98	80	66	55
	EXH	14.37	610	390	270	198	152	120	97	80	67
4	STD	12.90	650	415	285	210	162	128	102	85	72
	EXH	17.25	830	530	370	270	207	164	132	110	92
5	STD	16.12	1020	655	454	334	255	200	164	135	112
	EXH	23.67	1420	925	630	465	355	282	228	188	158
6	STD	19.35	1480	950	660	485	370	292	236	196	165
	EXH	32.93	2350	1500	1040	765	585	460	375	310	260

SKIN EFFECT and PROXIMITY EFFECT

Any conductor carrying an alternating current is exposed to the alternating magnetic flux linkages generated within the conductor. Each filament of current in the conductor is circled with its own flux linkage and it can readily be seen that those filaments closest to the center of the conductor will be linked by the greatest number of loops. Conversely, the closer the current filament is to the surface of the conductor, the lesser will be the number of flux linkages encircling it. Those filaments closest to the center with the greatest number of linkages will therefore be in a higher reactance area than those at the outside of the conductor and will consequently carry much less current than those at the outside. This causes concentration of current close to the surface of the conductor and this is the familiar "skin effect." It is an important factor at sixty cycles and becomes more and more a factor as the frequency is raised, until the video and radar frequencies are reached when *all* the current is carried on the skin of the conductor. At the other end of the scale, direct current, no alternating flux linkage is present. Consequently there is no increase in reactance and no decrease in current carrying capacity. For this reason the d-c capacity of any conductor is larger than the a-c capacity.

All sixty cycle capacities given here or in any other publication have made proper allowance for skin effect. Because of skin effect, tubes which eliminate the inefficient core are able to handle more "amperes per square inch of cross section" than other sections such as rods and bars. In a general manner it can be stated that for copper tubes large enough to carry several thousand amperes, a 3⁄8″ wall thickness is the heaviest section that can be economically used. Another 1⁄8″ on the wall will increase the carrying capacity but by so little that the additional 33% increase in weight is hardly justified under ordinary circumstances. A further increase of wall thickness adds substantially nothing to the conductor capacity.

Aluminum conductors have higher resistances than the same copper conductors and consequently a lesser skin effect. Aluminum tubes can therefore be used with good economy in the higher capacities with wall thickness of about ½″.

Beside the circular tube, many other shapes strive to keep the skin effect as small as possible. These are square tubes, hollow squares made of four bars, two bars widely spaced, two channels, toe to toe and others.

Now again imagine a-c current filaments with their corresponding flux linkage in two parallel conductors, going and return, close to each other. The flux fields of each conductor will *oppose* one another because the currents flow in opposite directions. Those filaments in each conductor closest to the adjacent conductor will have the *least* flux linkages because of this opposition flux. Those filaments furthest from the adjacent conductor will have the most flux linkages. Therefore, the reactance of those sections of the conductor nearest each other will be smaller than other sections and this causes a concentration of current at these nearest sections. This is "proximity effect."

At the usual phase spacings employed in bus and station design, proximity effect is not an important factor, as the conductors are comparatively well separated. However in an approximate manner for high capacity buses if phase spacings are small and approach two times the conductor diameter, proximity effect should be considered.

CONDUCTOR EMISSIVITY

Emissivity in bus engineering defines the ability of a conductor to radiate heat. A bright, polished conductor is a poor radiator and on a comparative basis a poor current carrier. Conductors as received from the mill are also poor radiators. Well weathered conductors are good radiators. Conductors coated with some covering such as dull, black paint are very fine radiators and consequently have higher ampere capacities than any other equal cross section. A conductor with a dull, black coating may show a current carrying capacity 20 percent in excess of the same conductor as received from the mill.

LINEAR EXPANSION

Linear expansion is an important factor; copper expands 1.11" per 100 ft. per 100 F rise, aluminum 1.54." Bus-runs should be checked to make sure that excessive stresses due to temperature changes are not transmitted to bus supports and other apparatus.

With bus supports mounted on concrete or brick, the wall expansion is small, helping but little to compensate for bus expansion.

Steel structures, however, expand 0.80" per 100 ft. per 100 F, compensating to some extent for bus expansion, provided the structure is subjected to as large a temperature differential as the bus.

TEMPERATURE DIFFERENCE IN DEGREES CENTIGRADE	LINEAR EXPANSION IN INCHES PER 100 FEET		
	ALUMINUM	COPPER	STEEL
10	.28	.20	.14
20	.55	.40	.29
30	.83	.60	.43
40	1.1	.80	.58
50	1.4	1.0	.72
60	1.7	1.2	.87
70	1.9	1.4	1.0
80	2.2	1.6	1.2
90	2.5	1.8	1.3
100	2.8	2.0	1.5

Where expansion is a factor, bus supports with roller type clamps should be used to prevent porcelain breakage.

For complete protection, expansion joints should be installed. These fittings also protect against misalignment and uneven foundation settings.

TEMPERATURE DIFFERENCE IN DEGREES FAHRENHEIT	LINEAR EXPANSION IN INCHES PER 100 FEET		
	ALUMINUM	COPPER	STEEL
10	.15	.11	.08
20	.31	.22	.16
30	.46	.33	.24
40	.62	.44	.32
50	.77	.56	.40
60	.92	.67	.48
70	1.1	.78	.56
80	1.2	.89	.64
90	1.4	1.0	.72
100	1.5	1.1	.80
110	1.7	1.2	.88
120	1.8	1.3	.97
130	2.0	1.4	1.0
140	2.2	1.6	1.1
150	2.3	1.7	1.2
160	2.5	1.8	1.3
170	2.6	1.9	1.4
180	2.8	2.0	1.5

ENCLOSED BUSES

When conductors are put in any kind of an enclosure, the current carrying capacity is materially reduced, the amount depending upon size, design and ventilation. For enclosed buses where no ventilation is permitted, use 60% of the current carrying capacity shown in the various tables in this publication. As louvers and vents are added, this 60% value will increase until some open enclosure such as an expanded mesh is reached when the value will approach 100%.

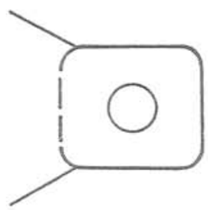
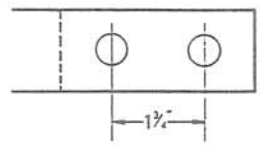
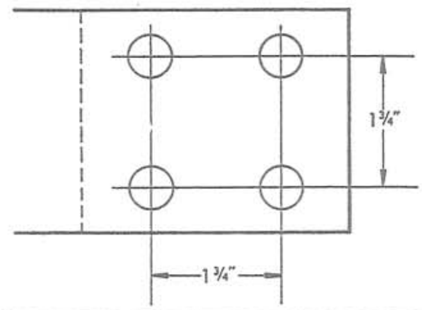
When the conductor is mounted in a metal enclosure, induced currents in the enclosure must be considered when the current in the mains is approximately 2000 amperes or more. Enclosures may heat to objectionable temperatures unless given proper consideration. Those enclosures where the three phases are covered by a common sheet will heat to the greatest degree because voltages induced in this sheet above each phase will have different instantaneous time values, allowing these voltages to close on one another. This permits much larger currents to flow and increases heating. On the other hand, enclosures of this type will protect building steel from induced heating while those with separate covers over individual phases will not protect building steel from induced heating.

In general, segregated or nonsegregated metal enclosed buses will follow these rules.

1. Induced currents in enclosures are proportional to main currents.
2. Decreasing phase spacing of the mains decreases induced currents.
3. Voltages induced are proportional to enclosure length and to the current in the mains.
4. Circulating currents flowing in enclosures reduces the reactance between the main conductors.
5. Circulating, currents in enclosures do not increase with the lengthening of the bus after a length of, say, 10 to 20 feet is exceeded.
6. Large end effect currents will flow at the end of each enclosure section and to avoid heating from these currents at every enclosure joint, all sections should be electrically bonded together.
7. Proximity effect in enclosures insulated from each other must be considered since this produces additional heating.
8. On basis of power loss, an enclosure material can be selected which will provide minimum loss consistent with necessary structural strength and economic requirements.
9. Induced currents in average enclosures reduce the field strength outside the enclosure to about 10 percent of that without enclosures.

ARRANGEMENT and SIZES of BOLTS for TERMINAL CONNECTORS

The arrangement of bolts in the tangs of electric power connectors intended for use with electrical equipment rated 3000 amperes or less shall be as follows:

CURRENT RATING OF EQUIPMENT AMPERES	1 HOLE 	2 HOLES 	4 HOLES 
200	½"	½"	....
400	¾"	½"	....
600	1"	½"	....
1200	1½"	½"	½"
2000	....	....	½"
3000	....	....	½"

RECOMMENDED MINIMUM ELECTRICAL CLEARANCES for STANDARD BASIC INSULATION LEVELS (OUTDOOR A-C)

KV CLASS	BIL LEVEL (KV WITH-STAND)	MINIMUM CLEARANCE TO GROUND FOR RIGID PARTS, IN INCHES	MINIMUM CLEARANCE BETWEEN PHASES (OR LIVE PARTS) FOR RIGID PARTS, IN INCHES, METAL TO METAL	MINIMUM CLEARANCE BETWEEN OVERHEAD CONDUCTORS & GRADE FOR PERSONNEL SAFETY, INSIDE SUBSTATION — IN FEET	MINIMUM CLEARANCE BETWEEN WIRES AND ROADWAYS — INSIDE SUBSTATION ENCLOSURE — IN FEET
7.5	95	6	7	8	20
15	110	7	12	9	20
23	150	10	15	10	22
34.5	200	13	18	10	22
46	250	17	21	10	22
69	350	25	31	11	23
115	550	42	53	12	25
138	650	50	62	13	25
161	750	58	72	14	26
230	825	65	80	15	27
230	900	71	89	15	27
	1050	83	105	16	28
	1175	94	113	17	29

NOTES:

"A" Co-ordinate KV class and BIL when choosing minimum clearances.

"B" The values above are recommended minimums but may be decreased in line with good practice depending on local conditions, procedures, etc.

"C" The values above apply to 3300 feet above sea level. Above this elevation increase above values according to paragraph 22-4 of A.I.E.E. Standard No. 22-A.

"D" These recommended minimum clearances are for rigid conductors. Any structural tolerances, or allowances for conductor movement, or possible reduction in spacing by foreign objects should be added to these minimum values.

"E" These minimum clearances are intended as a guide for the installation of equipment in the field only and not for the design of electrical devices or apparatus such as circuit breakers, transformers, etc.

TABLE 1. Ampacities of Copper No. 110 Bus Bars

Dimensions, In.	Area		Weight Per Foot, Lb	DC Resistance at 20 C, Microhms Per Ft	30 C Rise		50 C Rise		65 C Rise	
	Sq In.	Circular Mils, Thousands			Skin Effect Ratio at 70 C	60-Hz Ampacity,* Amp	Skin Effect Ratio at 90 C	60-Hz Ampacity,* Amp	Skin Effect Ratio at 105 C	60-Hz Ampacity,* Amp
1/16 x 1/2	0.0312	39.7	0.121	264.0	1.00	103	1.00	136	1.00	157
1/16 x 3/4	0.0469	59.7	0.181	175.0	1.00	145	1.00	193	1.00	225
1/16 x 1	0.0625	79.6	0.241	132.0	1.00	187	1.00	250	1.00	285
1/16 x 1 1/2	0.0938	119	0.362	87.7	1.00	270	1.00	355	1.00	410
1/16 x 2	0.125	159	0.483	65.8	1.01	345	1.01	460	1.01	530
1/8 x 1/2	0.0625	79.6	0.241	132.	1.00	153	1.00	205	1.00	235
1/8 x 3/4	0.0938	119	0.362	87.7	1.00	215	1.00	285	1.00	325
1/8 x 1	0.125	159	0.483	65.8	1.01	270	1.01	360	1.01	415
1/8 x 1 1/2	0.188	239	0.726	43.8	1.01	385	1.01	510	1.01	590
1/8 x 2	0.250	318	0.966	32.9	1.02	495	1.02	660	1.02	760
1/8 x 2 1/2	0.312	397	1.21	26.4	1.02	600	1.02	800	1.02	920
1/8 x 3	0.375	477	1.45	21.9	1.03	710	1.03	940	1.03	1,100
1/8 x 3 1/2	0.438	558	1.69	18.8	1.04	810	1.03	1,100	1.03	1,250
1/8 x 4	0.500	636	1.93	16.5	1.04	910	1.04	1,200	1.04	1,400
3/16 x 1/2	0.0938	119	0.362	87.7	1.00	195	1.00	260	1.00	300
3/16 x 3/4	0.141	179	0.545	58.4	1.01	270	1.01	360	1.01	415
3/16 x 1	0.188	239	0.726	43.8	1.01	340	1.01	455	1.01	520
3/16 x 1 1/2	0.281	358	1.09	29.3	1.02	480	1.02	630	1.02	730
3/16 x 2	0.375	477	1.45	21.9	1.03	610	1.03	810	1.03	940
3/16 x 2 1/2	0.469	597	1.81	17.5	1.04	740	1.04	980	1.03	1,150
3/16 x 3	0.562	715	2.17	14.6	1.05	870	1.05	1,150	1.04	1,350
3/16 x 3 1/2	0.656	835	2.53	12.5	1.07	990	1.06	1,300	1.06	1,500
3/16 x 4	0.750	955	2.90	11.0	1.09	1,100	1.08	1,450	1.07	1,700
1/4 x 1/2	0.125	159	0.483	65.8	1.01	240	1.01	315	1.01	360
1/4 x 3/4	0.188	239	0.726	43.8	1.01	320	1.01	425	1.01	490
1/4 x 1	0.250	318	0.966	32.9	1.02	400	1.02	530	1.02	620
1/4 x 1 1/2	0.375	477	1.45	21.9	1.03	560	1.03	740	1.03	860
1/4 x 2	0.500	637	1.93	16.5	1.04	710	1.04	940	1.04	1,100
1/4 x 2 1/2	0.625	796	2.41	13.2	1.06	850	1.06	1,150	1.06	1,300
1/4 x 3	0.750	955	2.90	11.0	1.08	990	1.08	1,300	1.07	1,550
1/4 x 3 1/2	0.875	1,110	3.38	9.40	1.10	1,150	1.09	1,500	1.09	1,750
1/4 x 4	1.00	1,270	3.86	8.23	1.12	1,250	1.11	1,700	1.10	1,950
1/4 x 5	1.25	1,590	4.83	6.58	1.16	1,500	1.15	2,000	1.14	2,350
1/4 x 6	1.50	1,910	5.80	5.49	1.18	1,750	1.17	2,350	1.17	2,700
1/4 x 8	2.00	2,550	7.73	4.11	1.23	2,250	1.22	3,000	1.21	3,450
1/4 x 10	2.50	3,180	9.66	3.29	1.27	2,700	1.26	3,600	1.25	4,200
1/4 x 12	3.00	3,820	11.6	2.74	1.31	3,150	1.30	4,200	1.28	4,900
3/8 x 3/4	0.281	358	1.09	29.3	1.02	415	1.02	550	1.02	630
3/8 x 1	0.375	477	1.45	21.9	1.03	510	1.03	680	1.03	790
3/8 x 1 1/2	0.562	715	2.17	14.6	1.05	710	1.04	940	1.04	1,100
3/8 x 2	0.750	955	2.90	11.0	1.08	880	1.08	1,150	1.07	1,350
3/8 x 2 1/2	0.938	1,190	3.62	8.77	1.12	1,050	1.10	1,400	1.09	1,600
3/8 x 3	1.12	1,430	4.35	7.35	1.15	1,200	1.14	1,600	1.13	1,850
3/8 x 3 1/2	1.31	1,670	5.06	6.28	1.18	1,350	1.16	1,800	1.15	2,100
3/8 x 4	1.50	1,910	5.80	5.49	1.20	1,500	1.19	2,000	1.18	2,350
3/8 x 5	1.88	2,390	7.26	4.38	1.24	1,800	1.23	2,400	1.22	2,800
3/8 x 6	2.25	2,860	8.69	3.66	1.27	2,100	1.26	2,800	1.24	3,250
3/8 x 8	3.00	3,820	11.6	2.74	1.33	2,650	1.31	3,550	1.30	4,100
3/8 x 10	3.75	4,770	14.5	2.19	1.38	3,200	1.36	4,300	1.35	4,900
3/8 x 12	4.50	5,730	17.4	1.83	1.42	3,700	1.40	5,000	1.38	5,800
1/2 x 1	0.500	637	1.93	16.5	1.04	620	1.04	820	1.04	940
1/2 x 1 1/2	0.750	955	2.90	11.0	1.08	830	1.08	1,100	1.07	1,250
1/2 x 2	1.00	1,270	3.86	8.23	1.12	1,000	1.11	1,350	1.10	1,550
1/2 x 2 1/2	1.25	1,590	4.83	6.58	1.16	1,200	1.15	1,600	1.14	1,850
1/2 x 3	1.50	1,910	5.80	5.49	1.20	1,400	1.19	1,850	1.18	2,150
1/2 x 3 1/2	1.75	2,230	6.76	4.70	1.24	1,550	1.22	2,100	1.21	2,400
1/2 x 4	2.00	2,550	7.73	4.11	1.26	1,700	1.25	2,300	1.24	2,650
1/2 x 5	2.50	3,180	9.66	3.29	1.32	2,050	1.30	2,750	1.29	3,150
1/2 x 6	3.00	3,820	11.6	2.74	1.36	2,400	1.34	3,150	1.33	3,650
1/2 x 8	4.00	5,090	15.5	2.06	1.42	3,000	1.40	4,000	1.39	4,600
1/2 x 10	5.00	6,360	19.3	1.65	1.47	3,600	1.45	4,800	1.44	5,500
1/2 x 12	6.00	7,640	23.2	1.37	1.52	4,200	1.51	5,600	1.50	6,400
3/4 x 4	3.00	3,820	11.6	2.74	1.42	2,050	1.40	2,750	1.38	3,150
3/4 x 5	3.75	4,770	14.5	2.19	1.48	2,400	1.46	3,250	1.44	3,750
3/4 x 6	4.50	5,730	17.4	1.83	1.52	2,800	1.50	3,750	1.48	4,300
3/4 x 8	6.00	7,640	23.2	1.37	1.60	3,500	1.58	4,700	1.56	5,400
3/4 x 10	7.50	9,550	29.0	1.10	1.67	4,200	1.64	5,600	1.62	6,500
3/4 x 12	9.00	11,500	34.8	0.914	1.72	4,900	1.69	6,500	1.67	7,500

* Applicable to typical in-service conditions (indoors, 40C ambient temperature), horizontal run on edge, and free from external magnetic influences.

TABLE 2. Mechanical Properties of Copper No. 110 Bus Bars

Dimensions, In.	Area		Weight Per Foot, Lb	Horizontal Axis			Vertical Axis			Yield Load,* Lb
	Sq In.	Circular Mils, Thousands		Moment of Inertia, In.^{4}	Section Modulus, In.^{3}	Radius of Gyration, In.	Moment of Inertia, In.^{4}	Section Modulus, In.^{3}	Radius of Gyration, In.	
1/16 x 1/2	0.0312	39.7	0.121	0.000651	0.00260	0.144	0.0000102	0.000326	0.0180	780
1/16 x 3/4	0.0469	59.7	0.181	0.00220	0.00586	0.217	0.0000153	0.000488	0.0180	1,170
1/16 x 1	0.0625	79.6	0.241	0.00521	0.0104	0.289	0.0000203	0.000651	0.0180	1,560
1/16 x 1 1/2	0.0938	119	0.362	0.0176	0.0234	0.433	0.0000305	0.000977	0.0180	2,340
1/16 x 2	0.125	159	0.483	0.0417	0.0417	0.577	0.0000407	0.00130	0.0180	3,120
1/8 x 1/2	0.0625	79.6	0.241	0.00130	0.00521	0.144	0.0000814	0.00130	0.0361	1,560
1/8 x 3/4	0.0938	119	0.362	0.00440	0.0117	0.217	0.000122	0.00195	0.0361	2,340
1/8 x 1	0.125	159	0.483	0.0104	0.0208	0.289	0.000163	0.00260	0.0361	3,120
1/8 x 1 1/2	0.188	239	0.726	0.0352	0.0469	0.433	0.000244	0.00391	0.0361	4,690
1/8 x 2	0.250	318	0.966	0.0833	0.0833	0.577	0.000326	0.00521	0.0361	6,250
1/8 x 2 1/2	0.312	397	1.21	0.163	0.130	0.722	0.000407	0.00651	0.0361	7,810
1/8 x 3	0.375	477	1.45	0.281	0.188	0.866	0.000488	0.00781	0.0361	9,380
1/8 x 3 1/2	0.438	558	1.69	0.447	0.255	1.01	0.000570	0.00912	0.0361	10,940
1/8 x 4	0.500	636	1.93	0.667	0.333	1.16	0.000651	0.0104	0.0361	12,500
3/16 x 1/2	0.0938	119	0.362	0.00195	0.00781	0.144	0.000275	0.00293	0.0541	2,340
3/16 x 3/4	0.141	179	0.545	0.00659	0.0176	0.217	0.000412	0.00440	0.0541	3,520
3/16 x 1	0.188	239	0.726	0.0156	0.0312	0.289	0.000549	0.00586	0.0541	4,690
3/16 x 1 1/2	0.281	358	1.09	0.0527	0.0703	0.433	0.000824	0.00879	0.0541	7,031
3/16 x 2	0.375	477	1.45	0.125	0.125	0.577	0.00110	0.0117	0.0541	9,380
3/16 x 2 1/2	0.469	597	1.81	0.244	0.195	0.722	0.00137	0.0146	0.0541	11,700
3/16 x 3	0.562	715	2.17	0.422	0.281	0.866	0.00165	0.0176	0.0541	14,100
3/16 x 3 1/2	0.656	835	2.53	0.670	0.383	1.01	0.00192	0.0205	0.0541	16,400
3/16 x 4	0.750	955	2.90	1.00	0.500	1.16	0.00220	0.0234	0.0541	18,800
1/4 x 1/2	0.125	159	0.483	0.00260	0.0104	0.144	0.000651	0.00521	0.0722	3,120
1/4 x 3/4	0.188	239	0.726	0.00879	0.0234	0.217	0.000977	0.00781	0.0722	4,690
1/4 x 1	0.250	318	0.966	0.0208	0.0417	0.289	0.00130	0.0104	0.0722	6,250
1/4 x 1 1/2	0.375	477	1.45	0.0703	0.0938	0.433	0.00195	0.0156	0.0722	9,380
1/4 x 2	0.500	637	1.93	0.167	0.167	0.577	0.00260	0.0208	0.0722	12,500
1/4 x 2 1/2	0.625	796	2.41	0.326	0.260	0.722	0.00326	0.0260	0.0722	15,600
1/4 x 3	0.750	955	2.90	0.562	0.375	0.866	0.00391	0.0312	0.0722	18,800
1/4 x 3 1/2	0.875	1,110	3.38	0.893	0.510	1.01	0.00456	0.0365	0.0722	21,900
1/4 x 4	1.00	1,270	3.86	1.33	0.667	1.16	0.00521	0.0417	0.0722	25,000
1/4 x 5	1.25	1,590	4.83	2.60	1.04	1.44	0.00651	0.0521	0.0722	31,200
1/4 x 6	1.50	1,910	5.80	4.50	1.50	1.73	0.00781	0.0625	0.0722	37,500
1/4 x 8	2.00	2,550	7.73	10.7	2.67	2.31	0.0104	0.0833	0.0722	50,000
1/4 x 10	2.50	3,180	9.66	20.8	4.17	2.89	0.0130	0.104	0.0722	62,500
1/4 x 12	3.00	3,820	11.6	36.0	6.00	3.46	0.0156	0.125	0.0722	75,000
3/8 x 3/4	0.281	358	1.09	0.0132	0.0352	0.217	0.00330	0.0176	0.108	7,030
3/8 x 1	0.375	477	1.45	0.0312	0.0625	0.289	0.00439	0.0234	0.108	9,380
3/8 x 1 1/2	0.562	715	2.17	0.105	0.141	0.433	0.00659	0.0352	0.108	14,100
3/8 x 2	0.750	955	2.90	0.250	0.250	0.577	0.00879	0.0469	0.108	18,800
3/8 x 2 1/2	0.938	1,190	3.62	0.488	0.391	0.722	0.0110	0.0586	0.108	23,400
3/8 x 3	1.12	1,430	4.35	0.844	0.562	0.866	0.0132	0.0703	0.108	28,100
3/8 x 3 1/2	1.31	1,670	5.06	1.34	0.766	1.01	0.0154	0.0820	0.108	32,800
3/8 x 4	1.50	1,910	5.80	2.00	1.00	1.16	0.0176	0.0938	0.108	37,500
3/8 x 5	1.88	2,390	7.26	3.91	1.56	1.44	0.0220	0.117	0.108	46,900
3/8 x 6	2.25	2,860	8.69	6.75	2.25	1.73	0.0264	0.141	0.108	56,200
3/8 x 8	3.00	3,820	11.6	16.0	4.00	2.31	0.0352	0.188	0.108	75,000
3/8 x 10	3.75	4,770	14.5	31.2	6.25	2.89	0.0439	0.234	0.108	93,800
3/8 x 12	4.50	5,730	17.4	54.0	9.00	3.46	0.0527	0.281	0.108	112,000
1/2 x 1	0.500	637	1.93	0.0417	0.0833	0.289	0.0104	0.0417	0.144	9,000
1/2 x 1 1/2	0.750	955	2.90	0.141	0.188	0.433	0.0156	0.0625	0.144	13,500
1/2 x 2	1.00	1,270	3.86	0.333	0.333	0.577	0.0208	0.0833	0.144	18,000
1/2 x 2 1/2	1.25	1,590	4.83	0.651	0.521	0.722	0.0260	0.104	0.144	22,500
1/2 x 3	1.50	1,910	5.80	1.12	0.750	0.866	0.0312	0.125	0.144	27,000
1/2 x 3 1/2	1.75	2,230	6.76	1.79	1.02	1.01	0.0365	0.146	0.144	31,500
1/2 x 4	2.00	2,550	7.73	2.67	1.33	1.16	0.0417	0.167	0.144	36,000
1/2 x 5	2.50	3,180	9.66	5.21	2.08	1.44	0.0521	0.208	0.144	45,000
1/2 x 6	3.00	3,820	11.6	9.00	3.00	1.73	0.0625	0.250	0.144	54,000
1/2 x 8	4.00	5,090	15.5	21.3	5.33	2.31	0.0833	0.333	0.144	72,000
1/2 x 10	5.00	6,360	19.3	41.7	8.33	2.89	0.104	0.417	0.144	90,000
1/2 x 12	6.00	7,640	23.2	72.0	12.0	3.46	0.125	0.500	0.144	108,000
3/4 x 4	3.00	3,820	11.6	4.00	2.00	1.16	0.141	0.375	0.216	54,000
3/4 x 5	3.75	4,770	14.5	7.81	3.12	1.44	0.176	0.469	0.216	67,500
3/4 x 6	4.50	5,730	17.4	13.5	4.50	1.73	0.211	0.562	0.216	81,000
3/4 x 8	6.00	7,640	23.2	32.0	8.00	2.31	0.281	0.750	0.216	108,000
3/4 x 10	7.50	9,550	29.0	62.5	12.5	2.89	0.352	0.938	0.216	135,000
3/4 x 12	9.00	11,500	34.8	108.	18.0	3.46	0.422	1.12	0.216	162,000

*In this instance, yield load equals yield strength times cross-sectional area of the bus bar. A yield strength of 25,000 psi has been assumed for bus bar less than ½ in. thick and 18,000 psi for bus bar ½ in. thick or more.

TABLE 3. Quick Bus Bar Size Selector

Required Ampacity,* (Range) Amp	Bus Bar Dimensions, In.** 30 C Rise	Bus Bar Dimensions, In.** 50 C Rise	Bus Bar Dimensions, In.** 65 C Rise
100 (100-149)	1/16x1/2, 1/16x3/4	1/16 x 1/2	
150 (150-199)	1/16 x 1 1/8 x 1/2 3/16 x 1/2	1/16 x 3/4	1/16 x 1/2
200 (200-249)	1/8 x 3/4 1/4 x 1/2	1/8 x 1/2	1/16 x 3/4 1/8 x 1/2
250 (250-299)	1/16 x 1 1/2 1/8 x 1 3/16 x 3/4	1/16 x 1 1/8 x 3/4 3/16 x 1/2	1/16 x 1
300 (300-349)	1/16 x 2 3/16 x 1 1/4 x 3/4	1/4 x 1/2	1/8 x 3/4 3/16 x 1/2
350 (350-399)	1/8 x 1-1/2	1/16 x 1 1/2 1/8 x 1 3/16 x 3/4	1/4 x 1/2
400 (400-449)	1/4 x 1 3/8 x 3/4	1/4 x 3/4	1/16 x 1 1/2 1/8 x 1 3/16 x 3/4
450 (450-499)	1/8 x 2 3/16 x 1 1/2	1/16 x 2 3/16 x 1	1/4 x 3/4
500 (500-599)	1/4 x 1 1/2 3/8 x 1	1/8 x 1 1/2 1/4 x 1 3/8 x 3/4	1/16 x 2 1/8 x 1 1/2 3/16 x 1
600 (600-699)	1/8 x 2 1/2 3/16 x 2 1/2 x 1	1/8 x 2 3/16 x 1 1/2 3/8 x 1	1/4 x 1 3/8 x 3/4
700 (700-799)	1/8 x 3 3/16 x 2 1/2 1/4 x 2 3/8 x 1 1/2	1/4 x 1 1/2	1/8 x 2 3/16 x 1 1/2 3/8 x 1
800 (800-899)	1/8 x 3 1/2 3/16 x 3 1/4 x 2 1/2 3/8 x 2	1/8 x 2 1/2 3/16 x 2 1/2 x 1	1/4 x 1 1/2
900 (900-999)	1/8 x 4	1/8 x 3	1/8 x 2 1/2
900 (900-999)	3/16 x 3 1/2 1/4 x 3	3/16 x 2 1/2 1/4 x 2 3/8 x 1 1/2	3/16 x 2 1/2 x 1
1000 (1000-1249)	3/16 x 4 1/4 x 3 1/2 3/8x2 1/2, 3/8 x 3 1/2x2, 1/2 x 2 1/2	1/8 x 4 3/16 x 3 1/4 x 2 1/2 3/8 x 2	1/8 x 3 3/16 x 2-1/2 1/4 x 2 3/8 x 1 1/2
1250 (1250-1499)	1/4 x 4 3/8 x 3 1/2 1/2 x 3	3/16x3 1/2, 3/16 x 4 1/4 x 3 3/8 x 2 1/2 1/2 x 2	1/8 x 4 3/16 x 3 1/4 x 2 1/2 3/8 x 2
1500 (1500-1749)	1/4 x 5 3/8 x 4 1/2x3 1/2, 1/2x4	1/4x3 1/2, 1/4 x 4 3/8 x 3 1/2 x 2 1/2	3/16x3 1/2, 3/16x4 1/4 x 3 3/8 x 2 1/2 1/2 x 2
1750 (1750-1999)	1/4 x 6 3/8 x 5	3/8 x 3 1/2 1/2 x 3	1/4x3-1/2, 1/4x4 3/8 x 3 1/2 x 2-1/2
2000 (2000-2499)	1/4 x 8 3/8 x 6 1/2 x 5, 1/2 x 6 3/4 x 4, 3/4 x 5	1/4 x 6 3/8 x 5 1/2 x 4	1/4 x 5 3/8 x 4 1/2 x 3 1/2
2500 (2500-2999)	1/4 x 10 3/8 x 8 3/4 x 6	3/8 x 6 1/2 x 5 3/4 x 4	1/4 x 6 3/8 x 5 1/2 x 4
3000 (3000-3499)	1/4 x 12 3/8 x 10 1/2 x 8	1/4 x 8 1/2 x 6 3/4 x 5	1/4 x 8 3/8 x 6 1/2 x 5 3/4 x 4
3500 (3500-3999)	3/8 x 12 1/2 x 10 3/4 x 8	1/4 x 10 3/8 x 8 3/4 x 6	1/2 x 6 3/4 x 5
4000 (4000-4499)	1/2 x 12 3/4 x 10	1/4 x 12 3/8 x 10 1/2 x 8	1/4 x 10 3/8 x 8 3/4 x 6
4500 (4500-4999)	3/4 x 12	1/2 x 10 3/4 x 8	1/4 x 12 3/8 x 10 1/2 x 8
5000 (5000-5999)		3/8 x 12 1/2 x 12 3/4 x 10	3/8 x 12 1/2 x 10 3/4 x 8

* For 60 Hz current

** Table gives bus bar cross sections which will probably be large enough for ampacities within each range. Knowing required ampacity, determine possible bus bar dimensions from the table. Then check Table 1 to verify that size selected has the necessary ampacity. Example: Assume that required ampacity is 185 amp at 30 C rise. Table 3 indicates that 1/16 x 1 in. size would probably be adequate. This is confirmed by Table 1 which lists the ampacity of 1/16 x 1 in. bus bar as 187 amp.

TABLE 4. Effect of Emissivity and Number of Busses on Ampacity

Number of 1/4 x 4 In. Busses*	Ampacity, Amp — 30 C Rise, Emissivity 0.15	0.4	0.7	0.9	50 C Rise, Emissivity 0.15	0.4	0.7	0.9	65 C Rise, Emissivity 0.15	0.4	0.7	0.9
1	1100	1250	1400	1600	1500	1700	1900	2000	1700	1950	2200	2300
2	1900	2050	2200	2300	2550	2750	2950	3100	2950	3200	3400	3600
3	2500	2700	2850	3000	3400	3600	3850	4000	3950	4200	4500	4600
4	3100	3300	3450	3600	4200	4400	4700	4800	4900	5100	5400	5600

* 1/4 in. spacing. Ampacities of bus bar systems of other configurations must be calculated, taking into account size, spacing, number of bus bars and overall skin-effect ratio.

PROPERTIES OF COPPER AND ALUMINUM

	COPPER	ALUMINUM
Weight, pounds per cu. in.	0.322	0.098
Density, grams per cu. cm.	3.91	2.70
Specific Heat, calories per gram per ° C.	0.092	0.230
Melting Point, ° F.	1981	1220
Annealing Point, ° F.	482	650
Modulus of Elasticity	16,000,000	10,300,000
Ultimate Strength, pounds per sq. in.		
Cast	23-26,000	11-14,000
Annealed	28-32,000	12-15,000
Hard Drown Sections	38-42,000	22-31,000
Hard Drawn Wire	50-60,000	22-31,000
Length-Temperature Coefficient		
Per ° C.	0.00001665	0.0000231
Per ° F.	0.00000922	0.0000128
Thermal Conductivity, calories per sq. cm. per sec. per ° C.	0.92	0.52
Electrical Conductivity, hard drawn, percent I.A.C.S. at 20° C.	98	61
Resistance-Temperature Coefficient at 20° C for 98% copper and 61% aluminum	0.00385	0.00403
*Change in Resistivity with Change in Temperature		
Microhms per cubic cm per degree C for 98% copper and 61 % aluminum	0.0068	0.0115
Resistance at 20° C for 98% copper and 61% aluminum		
One sq. cm. one cm. long (microhms)	1.7593	2.828
One sq. in. one ft. long (microhms)	8.3117	13.3606
One cir. mil one ft. long (ohms)	10.583	17.007

(The International Copper Standard for the resistance of annealed copper of 100% conductivity at 20° C is 0.1 5328 ohms for a uniform round wire one meter long weighing one gram. This corresponds to 8.1455 microhms for a bar of 100% conductivity copper one square inch in section by one foot long. The value 8.3117 stated above for the same size bar has been corrected for 98% conductivity.)

*This value is the sum of the length-temperature coefficient and the resistance-temperature coefficient, multiplied by the resistance per cubic cm , at 20° C.

PROPERTIES OF BARE COPPER WIRE (SOLID)

SIZE AWG	DIA. IN INCHES	AREA AT 20° C (68° F.) CIRCULAR MILS	SQUARE INCHES	WEIGHT POUNDS PER 1000 FT.	RESISTANCE OHMS PER 1000 FT. AT 20° C. (68° F.)	ULTIMATE STRENGTH IN POUNDS NOMINAL (HARD DRAWN)	*CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE INDOOR	OUTDOOR
6	.162	26,250	.0206	79	.395	1280	65	90
5	.182	33,102	.0260	100	.313	1590	75	105
4	.204	41,742	.0328	126	.248	1970	90	125
3	.229	52,634	.0413	159	.197	2440	105	145
2	.258	66,373	.0521	200	.156	3000	125	175
1	.289	83,694	.0657	253	.124	3680	145	205
0	.325	105,538	.0829	319	.098	4520	170	240
00	.365	133,079	.1045	402	.078	5520	200	280
000	.410	167,805	.1318	507	.062	6720	235	330
0000	.460	211,600	.1662	640	.049	8140	275	380

PROPERTIES OF BARE COPPER CABLE (STRANDED)

A.W. GAUGE NO.	DIAMETER INCHES	AREA CIRCULAR MILS	SQUARE INCHES	NUMBER OF WIRES	RESISTANCE AT 68° F AND 20° C OHMS PER 1000 FEET	ULTIMATE STRENGTH IN POUNDS NOMINAL (HARD DRAWN)	WEIGHT POUNDS PER 1000 FEET	*CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE INDOOR	OUTDOOR
0	0.368	105500	0.0829	7	0.1043	4750	326	175	245
00	0.414	133100	0.1045	7	0.0827	5930	411	205	285
000	0.464	167800	0.1318	7	0.0656	7370	518	240	335
0000	0.522	211600	0.1662	7	0.0520	9150	653	280	385
	0.600	250000	0.1964	12	0.0440	11130	772	320	435
	0.657	300000	0.2356	12	0.0367	13170	926	360	485
	0.710	350000	0.2749	12	0.0314	15140	1080	400	535
	0.726	400000	0.3142	19	0.0275	17560	1235	435	580
	0.770	450000	0.3534	19	0.0245	19750	1390	475	625
	0.811	500000	0.3927	19	0.0220	21950	1540	510	670
		550000	0.4320	37	0.0200	24720	1700	540	710
		600000	0.4712	37	0.0183	27190	1850	590	755
		650000	0.5105	37	0.0169	29180	2010	605	785
		700000	0.5498	37	0.0157	31200	2160	640	825
		750000	0.5890	37	0.0147	33380	2320	675	865
		800000	0.6283	37	0.0137	35380	2470	700	895
		900000	0.7069	37	0.0122	40090	2780	760	965
		1000000	0.7854	37	0.0110	43780	3090	815	1035
		1250000	0.9817	61	0.0088	55720	3860	920	1160
		1500000	1.178	61	0.0073	66350	4630	1025	1280
		1750000	1.374	91	0.0063	78180	5400	1125	1390
		2000000	1.571	91	0.0055	88980	6180	1225	1500

PROPERTIES OF STANDARD PIPE SIZE COPPER TUBING

SIZE OF TUBE I.P.S.	DIAMETER OF TUBE — INCHES		WALL THICKNESS INCHES	AREA OF SECTION SQUARE INCHES	WEIGHT IN POUNDS PER FOOT	MOMENT OF INERTIA INCHES⁴	SECTION MODULUS INCHES³	RESISTANCE MICROHMS PER FOOT	*CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE	
	OUTSIDE	INSIDE							INDOOR	OUTDOOR
¼	0.540	0.375	0.0825	0.118	0.45	0.0032	0.0019	70.44	240	320
⅜	0.675	0.494	0.0905	0.166	0.63	0.0073	0.021	50.07	310	415
½	0.840	0.625	0.1075	0.247	0.95	0.017	0.040	33.65	410	550
¾	1.050	0.822	0.1140	0.335	1.29	0.037	0.071	24.81	515	680
1	1.315	1.062	0.1265	0.472	1.81	0.084	0.128	17.61	675	860
1¼	1.660	1.368	0.1460	0.694	2.67	0.200	0.242	11.98	875	1130
1½	1.900	1.600	0.1500	0.824	3.17	0.318	0.334	10.01	1025	1285
2	2.375	2.062	0.1565	1.09	4.20	0.674	0.567	7.618	1300	1585
2½	2.875	2.500	0.1875	1.58	6.09	1.43	0.999	5.25	1700	2010
3	3.500	3.062	0.2190	2.25	8.69	3.05	1.74	3.68	2175	2560
3½	4.000	3.500	0.2500	2.94	11.34	5.200	2.60	2.82	2525	3040
4	4.500	4.000	0.2500	3.33	12.85	7.56	3.36	2.49	2850	3400
5	5.563	5.063	0.2500	4.17	16.07	14.7	5.30	1.992	3425	4100
6	6.625	6.125	0.2500	5.00	19.28	25.4	7.69	1.66	4150	4750

PROPERTIES OF EXTRA HEAVY PIPE SIZE COPPER TUBING

SIZE OF TUBE I.P.S.	DIAMETER OF TUBE — INCHES		WALL THICKNESS INCHES	AREA OF SECTION SQUARE INCHES	WEIGHT IN POUNDS PER FOOT	MOMENT OF INERTIA INCHES⁴	SECTION MODULUS INCHES³	RESISTANCE MICROHMS PER FOOT	*CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE	
	OUTSIDE	INSIDE							INDOOR	OUTDOOR
¼	0.540	0.294	0.123	0.161	.624	.0038	.014	51.63	280	375
⅜	0.675	0.421	0.127	0.218	.847	.0086	.025	38.13	355	475
½	0.840	0.542	0.149	0.323	1.25	.0202	.048	25.73	460	620
¾	1.050	0.736	0.157	0.440	1.71	.0452	.085	18.89	575	770
1	1.315	0.951	0.182	0.647	2.51	.1067	.161	12.85	750	1010
1¼	1.660	1.272	0.194	0.893	3.46	.244	.294	9.31	1000	1270
1½	1.900	1.494	0.203	1.08	4.19	.395	.416	7.70	1150	1460
2	2.375	1.933	0.221	1.49	5.79	.876	.737	5.58	1500	1850
2½	2.875	2.315	0.280	2.28	8.84	1.94	1.35	3.65	1975	2390
3	3.500	2.892	0.304	3.05	11.8	3.93	2.24	2.73	2475	3000
3½	4.000	3.358	0.321	3.71	14.3	6.32	3.16	2.24	2875	3410
4	4.500	3.818	0.341	4.46	17.2	9.70	4.31	1.86	3225	3880
5	5.563	4.813	0.375	6.11	23.6	20.6	7.43	1.36	4000	4700
6	6.625	5.751	0.437	8.50	32.9	40.8	12.3	0.978	4800	5400

ACSR – PHYSICAL CHARACTERISTICS

CODE WORD	ACSR CROSS SECTION ALUMINUM CIR MILS OR AWG	ALUMINUM SQUARE INCHES	TOTAL SQUARE INCHES	COPPER EQUIVALENT CIR MILS OR AWG	STRANDING, NUMBER AND DIAMETER OF STRANDS, INCHES ALUMINUM	STEEL	DIAMETER, INCHES COMPLETE CONDUCTOR	STEEL CORE
Turkey	6	0.0206	0.0240	8	6 x 0.0661	1 x 0.0661	0.198	0.0661
Swan	4	0.0328	0.0383	6	6 x 0.0834	1 x 0.0834	0.250	0.0834
Swanate	4	0.0328	0.0411	6	7 x 0.0772	1 x 0.1029	0.257	0.1029
Sparrow	2	0.0521	0.0608	4	6 x 0.1052	1 x 0.1052	0.316	0.1052
Sparate	2	0.0521	0.0653	4	7 x 0.0974	1 x 0.1299	0.325	0.1299
Robin	1	0.0657	0.0767	3	6 x 0.1181	1 x 0.1181	0.355	0.1182
Raven	1/0	0.0829	0.0967	2	6 x 0.1327	1 x 0.1327	0.398	0.1327
Quail	2/0	0.1045	0.1219	1	6 x 0.1490	1 x 0.1490	0.447	0.1490
Pigeon	3/0	0.1318	0.1538	1/0	6 x 0.1672	1 x 0.1672	0.502	0.1672
Penguin	4/0	0.1662	0.1939	2/0	6 x 0.1878	1 x 0.1878	0.563	0.1878
Waxwing	266800	0.2095	0.2211	3/0	18 x 0.1217	1 x 0.1217	0.609	0.1217
Owl	266800	0.2095	0.2367	3/0	6 x 0.2109	7 x 0.0703	0.633	0.2109
Partridge	266800	0.2095	0.2436	3/0	26 x 0.1013	7 x 0.0788	0.642	0.2364
Ostrich	300000	0.2356	0.2740	188700	26 x 0.1074	7 x 0.0835	0.680	0.2505
Merlin	336400	0.2642	0.2789	4/0	18 x 0.1367	1 x 0.1367	0.684	0.1367
Linnet	336400	0.2642	0.3072	4/0	26 x 0.1137	7 x 0.0884	0.720	0.2652
Oriole	336400	0.2642	0.3259	4/0	30 x 0.1059	7 x 0.1059	0.741	0.3177
Chickadee	397500	0.3122	0.3295	250000	18 x 0.1486	1 x 0.1486	0.743	0.1486
Brant	397500	0.3122	0.3525	250000	24 x 0.1287	7 x 0.0858	0.772	0.2574
Ibis	397500	0.3122	0.3630	250000	26 x 0.1236	7 x 0.0961	0.783	0.2883
Lark	397500	0.3122	0.3850	250000	30 x 0.1151	7 x 0.1151	0.806	0.3453
Pelican	477000	0.3746	0.3954	300000	18 x 0.1628	1 x 0.1628	0.814	0.1628
Flicker	477000	0.3746	0.4231	300000	24 x 0.1410	7 x 0.0940	0.846	0.2820
Hawk	477000	0.3746	0.4356	300000	26 x 0.1354	7 x 0.1053	0.858	0.3159
Hen	477000	0.3746	0.4620	300000	30 x 0.1261	7 x 0.1261	0.883	0.3783
Osprey	556500	0.4371	0.4614	350000	18 x 0.1758	1 x 0.1758	0.879	0.1758
Parakeet	556500	0.4371	0.4938	350000	24 x 0.1523	7 x 0.1015	0.914	0.3045
Dove	556500	0.4371	0.5083	350000	26 x 0.1463	7 x 0.1138	0.927	0.3414
Eagle	556500	0.4371	0.5391	350000	30 x 0.1362	7 x 0.1362	0.953	0.4086
Peacock	605000	0.4752	0.5368	380500	24 x 0.1588	7 x 0.1059	0.953	0.318
Squab	605000	0.4752	0.5526	380500	26 x 0.1525	7 x 0.1186	0.966	0.356
Teal	605000	0.4752	0.5835	380500	30 x 0.1420	19 x 0.0852	0.994	0.426
Swift	636000	0.4995	0.5134	400000	36 x 0.1329	1 x 0.1329	0.930	0.1329
Kingbird	636000	0.4995	0.5272	400000	18 x 0.1880	1 x 0.1880	0.940	0.1880
Rook	636000	0.4995	0.5643	400000	24 x 0.1628	7 x 0.1085	0.977	0.326
Grosbeak	636000	0.4995	0.5809	400000	26 x 0.1564	7 x 0.1216	0.990	0.365
Egret	636000	0.4995	0.6134	400000	30 x 0.1456	19 x 0.0874	1.019	0.437
....	653900	0.5136	0.5321	411300	18 x 0.1906	3 x 0.0885	0.953	0.1906
Flamingo	666600	0.5235	0.5914	419000	24 x 0.1667	7 x 0.1111	1.000	0.333
Gannet	666600	0.5235	0.6087	419000	26 x 0.1601	7 x 0.1245	1.014	0.373
Stilt	715500	0.5620	0.6348	450000	24 x 0.1727	7 x 0.1151	1.036	0.345
Starling	715500	0.5620	0.6535	450000	26 x 0.1659	7 x 0.1290	1.051	0.387
Redwing	715500	0.5620	0.6901	450000	30 x 0.1544	19 x 0.0926	1.081	0.463
Coot	795000	0.6244	0.6417	500000	36 x 0.1486	1 x 0.1486	1.040	0.1486
Tern	795000	0.6244	0.6676	500000	45 x 0.1329	7 x 0.0886	1.063	0.266
Cuckoo	795000	0.6244	0.7053	500000	24 x 0.1820	7 x 0.1213	1.092	0.364
Condor	795000	0.6244	0.7053	500000	54 x 0.1213	7 x 0.1213	1.093	0.364
Drake	795000	0.6244	0.7261	500000	26 x 0.1749	7 x 0.1360	1.108	0.408
Mallard	795000	0.6244	0.7668	500000	30 x 0.1628	19 x 0.0977	1.140	0.489
Ruddy	900000	0.7069	0.7555	566000	45 x 0.1414	7 x 0.0943	1.131	0.283
Canary	900000	0.7069	0.7985	566000	54 x 0.1291	7 x 0.1291	1.162	0.387
Catbird	954000	0.7493	0.7701	600000	36 x 0.1628	1 x 0.1628	1.140	0.1628
Rail	954000	0.7493	0.8011	600000	45 x 0.1456	7 x 0.0971	1.165	0.291
Cardinal	954000	0.7493	0.8464	600000	54 x 0.1329	7 x 0.1329	1.196	0.399
Tanager	1033500	0.8117	0.8342	650000	36 x 0.1694	1 x 0.1694	1.186	0.1694
Ortolan	1033500	0.8117	0.8678	650000	45 x 0.1515	7 x 0.1010	1.212	0.303
Curlew	1033500	0.8117	0.9169	650000	54 x 0.1383	7 x 0.1383	1.244	0.415
Bluejay	1113000	0.8741	0.9346	700000	45 x 0.1573	7 x 0.1049	1.259	0.315
Finch	1113000	0.8741	0.9849	700000	54 x 0.1436	19 x 0.0862	1.293	0.431
Bunting	1192500	0.9366	1.001	750000	45 x 0.1628	7 x 0.1085	1.302	0.326
Grackle	1192500	0.9366	1.0552	750000	54 x 0.1486	19 x 0.0892	1.333	0.446
Bittern	1272000	0.9990	1.068	800000	45 x 0.1681	7 x 0.1121	1.345	0.336
Pheasant	1272000	0.9990	1.1256	800000	54 x 0.1535	19 x 0.0921	1.382	0.461
Dipper	1351500	1.062	1.135	850000	45 x 0.1733	7 x 0.1155	1.385	0.345
Martin	1351500	1.062	1.1959	850000	54 x 0.1582	19 x 0.0949	1.424	0.475
Bobolink	1431000	1.124	1.202	900000	45 x 0.1783	7 x 0.1189	1.427	0.357
Plover	1431000	1.124	1.2663	900000	54 x 0.1628	19 x 0.0977	1.465	0.489
Nuthatch	1510500	1.186	1.268	950000	45 x 0.1832	7 x 0.1221	1.466	0.366
Parrot	1510500	1.186	1.3366	950000	54 x 0.1672	19 x 0.1003	1.506	0.502
Lapwing	1590000	1.249	1.335	1000000	45 x 0.1880	7 x 0.1253	1.504	0.376
Falcon	1590000	1.249	1.4076	1000000	54 x 0.1716	19 x 0.1030	1.545	0.515
Chukar	1780000	1.398	1.512	1119000	84 x 0.1456	19 x 0.0874	1.602	0.437
Bluebird	2156000	1.693	1.828	1352000	84 x 0.1602	19 x 0.0961	1.762	0.481
Kiwi	2167000	1.702	1.776	1361000	72 x 0.1735	7 x 0.1157	1.737	0.347

Note · The size in **Bold Face Type** indicates those "Preferred" sizes most commonly used.

PROPERTIES OF ALUMINUM CABLE (BARE)

CONDUCTOR SIZE			COPPER EQUIVALENT BASED ON EQUAL D.C. RESISTANCE C.M. OR A.W.G.	STRANDING		ULTIMATE STRENGTH POUNDS	CABLE DIAMETER INCHES	D.C. RESISTANCE AT 20° C OHMS PER 1000 FEET	WEIGHT POUNDS PER 1000 FEET	*CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE	
A.W.G.	CIRCULAR MILS	SQUARE INCHES		CLASS	NUMBER OF STRANDS					INDOOR	OUTDOOR
6	26250	0.0206	8	A	7	528	0.184	0.6606	24.6	....	....
4	41470	0.0328	6	A	7	826	0.232	0.4155	39.2	....	....
3	52640	0.0413	5	A	7	1022	0.260	0.3295	49.4	....	....
2	66370	0.0521	4	AA, A	7	1266	0.292	0.2613	62.3	....	....
1	83690	0.0657	3	AA, A	7	1537	0.328	0.2072	78.5	....	....
1/0	105500	0.0829	2	AA, A	7	1865	0.368	0.1643	99.1	135	180
2/0	133100	0.1045	1	AA, A	7	2350	0.414	0.1303	124.9	165	220
3/0	167800	0.1318	1/0	AA, A	7	2845	0.464	0.1033	157.5	....	....
4/0	211600	0.1662	2/0	AA, A	7	3590	0.522	0.08195	198.6	215	280
....	266800	0.2095	3/0	....	7	4525	0.586	0.06500	250.4	250	330
....	266800	0.2095	3/0	A	19	4800	0.593	0.06500	250.4	250	330
....	336400	0.2642	4/0	AA, A	19	5940	0.666	0.05155	315.8	....	....
....	397500	0.3122	250000	AA, A	19	6880	0.724	0.04363	372.5	340	440
....	477000	0.3746	300000	AA	19	8090	0.793	0.03636	447.8	390	490
....	477000	0.3746	300000	A	37	8600	0.795	0.03636	447.8	390	490
....	556500	0.4371	350000	....	19	9440	0.856	0.03116	522.4	....	....
....	556500	0.4371	350000	AA, A	37	9830	0.858	0.03116	522.4	....	....
....	636000	0.4995	400000	AA, A	37	11240	0.918	0.02727	597.0	450	570
....	715500	0.5620	450000	AA	37	12640	0.974	0.02424	671.6	520	660
....	715500	0.5620	450000	A	61	13150	0.975	0.02424	671.6	520	660
....	795000	0.6244	500000	AA	37	13770	1.026	0.02181	746.3	....	....
....	795000	0.6244	500000	A	61	14330	1.028	0.02181	746.3	....	....
....	874500	0.6868	550000	AA	37	14830	1.077	0.01983	820.9	....	....
....	874500	0.6868	550000	A	61	15760	1.078	0.01983	820.9	....	....
....	954000	0.7493	600000	AA	37	16180	1.124	0.01818	895.5	....	....
....	954000	0.7493	600000	A	61	16860	1.126	0.01818	895.5	....	....
....	1033500	0.8117	650000	AA	37	17530	1.170	0.01678	970.1	630	790
....	1033500	0.8117	650000	A	61	18260	1.172	0.01678	970.1	630	790
....	1113000	0.8741	700000	AA, A	61	19660	1.216	0.01558	1045	....	....
....	1272000	0.9990	800000	AA, A	61	22000	1.300	0.01363	1193	....	....
....	1431000	1.1240	900000	AA, A	61	24300	1.379	0.01212	1343	800	1000
....	1590000	1.2490	1000000	AA	61	27000	1.454	0.01091	1493	....	....
....	1590000	1.2490	1000000	A	91	28100	1.454	0.01091	1493	....	....

PROPERTIES OF STANDARD PIPE SIZE REGULAR ALUMINUM TUBING (ASA SCHEDULE 40 PIPE)

Reference: Alcoa Aluminum Bus Conductor Handbook.

STANDARD PIPE SIZE REGULAR	DIAMETER INCHES		WALL THICKNESS INCHES	AREA SQUARE INCHES	WEIGHT POUNDS PER FOOT	D. C. RESISTANCE MICROHMS PER FOOT AT 20°C	MOMENT OF INERTIA INCHES	SECTION MODULUS INCHES	CURRENT CAPACITY AMPERES 60 CYCLE—AC 30° C RISE*	
	OUTSIDE	INSIDE							INDOOR	OUTDOOR
1/2	0.840	0.622	0.109	0.250	0.294	61.41	0.0171	0.0407	300	400
3/4	1.050	0.824	0.113	0.333	0.390	46.21	0.0370	0.0705	400	520
1	1.315	1.049	0.133	0.494	0.580	31.12	0.0873	0.1328	520	675
1-1/4	1.660	1.380	0.140	0.668	0.785	22.99	0.1947	0.2346	620	815
1-1/2	1.900	1.610	0.145	0.800	0.939	19.22	0.3099	0.3262	735	930
2	2.375	2.067	0.154	1.075	1.262	14.30	0.6657	0.5606	980	1225
2-1/2	2.875	2.469	0.203	1.704	2.002	9.02	1.5300	1.0649	1215	1470
3	3.500	3.068	0.216	2.228	2.617	6.896	3.0177	1.7244	1470	1790
3-1/2	4.000	3.548	0.226	2.680	3.147	5.735	4.7877	2.3938	1725	2107
4	4.500	4.026	0.237	3.174	3.729	4.842	7.2325	3.2144	1960	2400
4-1/2	5.000	4.506	0.247	3.688	4.333	4.167	10.4433	4.1773	2255	2745
5	5.563	5.047	0.258	4.300	5.051	3.574	15.1600	5.4510	2645	3185
6	6.625	6.065	0.280	5.582	6.564	2.756	28.1400	8.4960	3500	3750

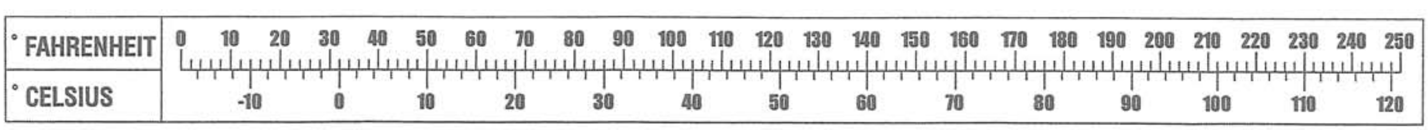
PROPERTIES OF EXTRA-HEAVY PIPE SIZE ALUMINUM TUBING

EXTRA-HEAVY IRON PIPE SIZE INCHES	DIAMETER INCHES		WALL THICKNESS INCHES	AREA SQUARE INCHES	WEIGHT POUNDS PER FOOT	D. C. RESISTANCE MICROHMS PER FOOT AT 20°C	MOMENT OF INERTIA INCHES4	SECTION MODULUS INCHES3	CURRENT CAPACITY AMPERES 60 CYCLE — AC 30° C RISE	
	OUTSIDE	INSIDE							INDOORS	OUTDOORS
¼	0.540	0.302	0.119	0.157	0.185	91.02	0.0038	0.0139	215	280
⅜	0.675	0.423	0.126	0.217	0.255	65.85	0.0086	0.0255	275	355
½	0.840	0.546	0.147	0.320	0.376	44.66	0.0201	0.0478	360	475
¾	1.050	0.742	0.154	0.434	0.509	32.93	0.0448	0.0853	475	620
1	1.315	0.957	0.179	0.639	0.750	22.36	0.1056	0.1606	625	800
1¼	1.660	1.278	0.191	0.881	1.035	16.22	0.2418	0.2913	750	950
1½	1.900	1.500	0.200	1.068	1.254	13.38	0.3912	0.4118	860	1100
2	2.375	1.939	0.218	1.477	1.735	9.68	0.8679	0.7309	1150	1500
2½	2.875	2.323	0.276	2.254	2.647	6.34	1.9264	1.3397	1425	1800
3	3.500	2.900	0.300	3.016	3.543	4.74	3.8943	2.2253	1750	2150
3½	4.000	3.364	0.318	3.678	4.321	3.89	6.2800	3.1400	2050	2550
4	4.500	3.826	0.337	4.407	5.178	3.24	9.6100	4.2710	2300	2900
4½	5.000	4.290	0.355	5.180	6.086	2.76	14.0532	5.6212	2700	3300
5	5.563	4.813	0.375	6.112	7.180	2.34	20.6700	7.4310	3150	3800

ASCR RANGE	CORRESPONDING SOLID RANGE (CU OR AL)	ASCR RANGE
#7 to 1/0	#5 to 3/0	#6 to 2/0
1/0 to 3/0	1/o to ½"	#1 to 4/0
1/0 to 266,800 C.M.	3/8" to 5/8"	1/0 to 300,000 C.M.
266,800 to 397,500 C.M.	5/8" to 3/4"	300,000 to 500,000 C.M.
397,500 to 715,500 C.M.	3/4" to 7/8"	500,000 to 800,000 C.M.
636,000 to 874,500 C.M.	1" to 1 1/8"	750,000 to 1,000,000 C.M.
874,500 to 1,272,000 C.M.	1 1/8" to 1 3/8"	1,000,000 to 1,500,000 C.M.
1,272,000 to 1,590,000 C.M.	1 3/8" to 1 1/2"	1,500,000 to 2,000,000 C.M.

HARDWARE DATA
TORQUE CHART

SIZE OF BOLTS	RECOMMENDED TORQUE (ft-lbs)		
	STEEL	BRONZE	ALUMINUM (LUBRICATED)
3/8 - 16	20	20	15
1/2 - 13	40	40	25
5/8 - 11	55	55	40



ALUMINUM CONDUCTOR, EC-H19, EC-H26 OR H16, EC-H24 OR H14 – PHYSICAL CHARACTERISTICS CLASSES B AND C

CONDUCTOR SIZE		COPPER EQUIVALENT	STRANDING		CON-DUCTOR DIA., INCHES	ULTIMATE STRENGTH, POUNDS EC-H19	MINIMUM ULTIMATE STRENGTH, POUNDS EC-H26 EC-H16	MINIMUM ULTIMATE STRENGTH, POUNDS EC-H24 EC-H14	WEIGHT PER 1,000 FT., LB.
CIRCULAR MILS OR AWG	SQUARE INCHES	CIR MILS OR AWG	CLASS	NUMBER AND DIA. OF WIRES, INCHES					
6	0.0206	8	B	7 x 0.0612	0.184	555	335	295	24.6
4	0.0328	6	B	7 x 0.0772	0.232	870	530	465	39.2
2	0.0521	4	B	7 x 0.0974	0.292	1,335	840	740	62.3
2	0.0521	4	C	19 x 0.0591	0.296	1,360	800	705	62.3
1	0.0657	3	B	19 x 0.0664	0.332	1,685	1,000	890	78.5
1/0	0.0829	2	B	19 x 0.0745	0.373	2,090	1,270	1,120	99.1
2/0	0.1045	1	B	19 x 0.0837	0.419	2,586	1,600	1,410	124.9
2/0	0.1045	1	C	37 x 0.0600	0.420	2,725	1,600	1,410	124.9
3/0	0.1318	1/0	B	19 x 0.0940	0.470	3,200	2,015	1,780	157.5
3/0	0.1318	1/0	C	37 x 0.0673	0.471	3,380	2,015	1,780	157.5
4/0	0.1662	2/0	B	19 x 0.1055	0.528	3,890	2,540	2,240	198.6
4/0	0.1662	2/0	C	37 x 0.0756	0.529	4,190	2,540	2,240	198.6
250000	0.1964	157300	B	37 x 0.0822	0.575	4,860	3,000	2,650	234.7
250000	0.1964	157300	C	61 x 0.0640	0.576	5,040	3,000	2,650	234.7
300000	0.2356	188800	B	37 x 0.0900	0.629	5,830	3,600	3,180	281.6
300000	0.2356	188800	C	61 x 0.0701	0.631	5,940	3,600	3,180	281.6
350000	0.2749	220200	B	37 x 0.0973	0.681	6,680	4,200	3,710	328.6
350000	0.2749	220200	C	61 x 0.0757	0.681	6,930	4,200	3,710	328.6
400000	0.3142	251500	B	37 x 0.1040	0.728	7,350	4,800	4,240	375.5
400000	0.3142	251500	C	61 x 0.0810	0.729	7,780	4,800	4,240	375.5
450000	0.3534	283000	B	37 x 0.1103	0.772	8,110	5,400	4,770	422.4
450000	0.3534	283000	C	61 x 0.0859	0.773	8,750	5,400	4,770	422.4
500000	0.3927	314500	B	37 x 0.1162	0.813	9,010	6,000	5,300	469.4
500000	0.3927	314500	C	61 x 0.0905	0.815	9,540	6,000	5,300	469.4
550000	0.4320	346000	B	61 x 0.0950	0.855	10,490	6,610	5,830	516.3
550000	0.4320	346000	C	91 x 0.0777	0.855	10,880	6,600	5,830	516.3
600000	0.4712	377000	B	61 x 0.0992	0.893	11,450	7,210	6,360	563.2
600000	0.4712	377000	C	91 x 0.0812	0.893	11,660	7,200	6,360	563.2
650000	0.5105	409000	B	61 x 0.1032	0.929	11,940	7,810	6,890	610.2
650000	0.5105	409000	C	91 x 0.0845	0.930	12,630	7,800	6,890	610.2
700000	0.5498	440000	B	61 x 0.1071	0.964	12,860	8,410	7,420	657.1
700000	0.5498	440000	C	91 x 0.0877	0.964	13,600	8,400	7,420	657.1
750000	0.5890	472000	B	61 x 0.1109	0.998	13,510	9,010	7,950	704.0
750000	0.5890	472000	C	91 x 0.0908	0.999	14,310	9,000	7,950	704.0
800000	0.6283	503000	B	61 x 0.1145	1.031	14,410	9,610	8,480	751.0
800000	0.6283	503000	C	91 x 0.0938	1.032	15,270	9,600	8,480	751.0
900000	0.7069	566000	B	61 x 0.1215	1.094	15,900	10,810	9,540	844.8
900000	0.7069	566000	C	91 x 0.0994	1.093	17,180	10,800	9,540	844.8
1000000	0.7854	629000	B	61 x 0.1280	1.152	17,670	12,020	10,600	938.7
1000000	0.7854	629000	C	91 x 0.1048	1.153	18,380	12,000	10,600	938.7
1100000	0.8639	692000	B	91 x 0.1099	1.209	20,210	13,220	11,660	1,033.
1100000	0.8639	692000	C	127 x 0.0931	1.210	21,000	13,200	11,660	1,033.
1200000	0.9425	755000	B	91 x 0.1148	1.263	21,630	14,420	12,720	1,126.
1200000	0.9425	755000	C	127 x 0.0972	1.264	22,900	14,400	12,720	1,126.
1250000	0.9818	786000	B	91 x 0.1172	1.289	22,530	15,020	13,250	1,173.
1250000	0.9818	786000	C	127 x 0.0992	1.290	23,900	15,000	13,250	1,173.
1300000	1.021	818000	B	91 x 0.1195	1.315	23,430	15,620	13,780	1,220.
1300000	1.021	818000	C	127 x 0.1012	1.316	23,900	15,600	13,780	1,220.
1400000	1.100	880000	B	91 x 0.1240	1.364	24,750	16,830	14,850	1,314.
1400000	1.100	880000	C	127 x 0.1050	1.365	25,700	16,800	14,850	1,314.
1500000	1.178	943000	B	91 x 0.1284	1.412	26,500	18,020	15,900	1,408.
1500000	1.178	943000	C	127 x 0.1087	1.413	27,600	18,000	15,900	1,408.
1600000	1.257	1006000	B	127 x 0.1122	1.459	28,840	19,230	16,970	1,502.
1600000	1.257	1006000	C	169 x 0.0973	1.460	30,500	19,200	16,970	1,502.
1700000	1.335	1069000	B	127 x 0.1157	1.504	30,630	20,400	18,020	1,596.
1700000	1.335	1069000	C	169 x 0.1003	1.505	31,200	20,400	18,020	1,596.
1750000	1.374	1101000	B	127 x 0.1174	1.526	31,530	21,000	18,550	1,643.
1750000	1.374	1101000	C	169 x 0.1018	1.527	32,100	21,000	18,550	1,643.
1800000	1.414	1132000	B	127 x 0.1191	1.548	32,450	21,600	19,090	1,690.
1800000	1.414	1132000	C	169 x 0.1032	1.548	33,100	21,600	19,090	1,690.
1900000	1.492	1195000	B	127 x 0.1223	1.590	33,570	22,800	20,100	1,784.
1900000	1.492	1195000	C	169 x 0.1060	1.590	34,900	22,800	20,100	1,784.
2000000	1.571	1258000	B	127 x 0.1255	1.632	35,340	24,000	21,200	1,877.
2000000	1.571	1258000	C	169 x 0.1088	1.632	36,800	24,000	21,200	1,877.
2500000	1.964	1570000	B	127 x 0.1403	1.824	43,300	30,000	26,500	2,370.
2500000	1.964	1570000	C	169 x 0.1216	1.824	44,200	30,000	26,500	2,370.
3000000	2.356	1890000	B	169 x 0.1332	1.998	53,010	36,000	31,800	2,844.
3500000	2.749	2200000	B	169 x 0.1439	2.158	60,610	40,500	37,100	3,350.

ALUMINUM CONDUCTOR, EC-H19 – PHYSICAL CHARACTERISTICS CLASSES AA AND A

CABLE CODE WORD	CONDUCTOR SIZE		COPPER EQUIVALENT	STRANDING		CON-DUCTOR DIA., INCHES	ULTI-MATE STRENGTH, POUNDS	WEIGHT, POUNDS	
	CIRCULAR MILS OR AWG	SQUARE INCHES	CIR MILS OR AWG	CLASS	NUMBER AND DIA. OF WIRES, INCHES			PER 1,000 FEET	PER MILE
Peachbell	6	0.0206	8	A	7 x 0.0612	0.184	555	24.6	130
Rose	4	0.0328	6	A	7 x 0.0772	0.232	875	39.2	207
Iris	2	0.0521	4	AA, A	7 x 0.0974	0.292	1,335	62.3	329
Pansy	1	0.0657	3	AA, A	7 x 0.1093	0.328	1,625	78.5	414
Poppy	1/0	0.0829	2	AA, A	7 x 0.1228	0.368	1,970	99.1	523
Aster	2/0	0.1045	1	AA, A	7 x 0.1379	0.414	2,480	124.9	659
Phlox	3/0	0.1318	1/0	AA, A	7 x 0.1548	0.464	3,005	157.5	832
Oxlip	4/0	0.1662	2/0	AA, A	7 x 0.1739	0.522	3,590	198.6	1,049
Sneezewort	250000	0.1964	157200	....	7 x 0.1890	0.567	4,480	234.7	1,239
Valerian	250000	0.1964	157200	A	19 x 0.1147	0.574	4,510	234.7	1,239
Daisy	266800	0.2095	3/0	....	7 x 0.1953	0.586	4,775	250.5	1,323
Laurel	266800	0.2095	3/0	A	19 x 0.1185	0.593	4,800	250.5	1,323
Peony	300000	0.2356	188700	A	19 x 0.1257	0.629	5,300	281.6	1,487
Tulip	336400	0.2642	4/0	A	19 x 0.1331	0.666	5,940	315.8	1,667
Daffodil	350000	0.2749	220000	A	19 x 0.1357	0.679	6,180	328.6	1,735
Canna	397500	0.3122	250000	AA, A	19 x 0.1447	0.724	6,880	373.2	1,970
Goldentuft	450000	0.3534	283000	AA	19 x 0.1539	0.770	7,630	422.4	2,230
Cosmos	477000	0.3746	300000	AA	19 x 0.1584	0.793	8,090	447.8	2,364
Syringa	477000	0.3746	300000	A	37 x 0.1135	0.795	8,600	447.8	2,364
Zinnia	500000	0.3927	314000	AA	19 x 0.1622	0.811	8,480	469.4	2,478
Hyacinth	500000	0.3927	314000	A, A	37 x 0.1162	0.813	9,010	469.4	2,478
Dahlia	556500	0.4371	350000	....	19 x 0.1711	0.856	9,440	522.4	2,758
Mistletoe	556500	0.4371	350000	AA, A	37 x 0.1226	0.858	9,830	522.4	2,758
Meadowsweet	600000	0.4712	377000	AA, A	37 x 0.1273	0.891	10,600	563.2	2,974
Orchid	636000	0.4995	400000	AA, A	37 x 0.1311	0.918	11,240	597.0	3,152
Heuchera	650000	0.5105	409000	AA	37 x 0.1325	0.928	11,490	610.2	3,222
Verbena	700000	0.5498	440000	AA	37 x 0.1375	0.963	12,370	657.1	3,469
Flag	700000	0.5498	440000	A	61 x 0.1071	0.964	12,860	657.1	3,469
Violet	715500	0.5620	450000	AA	37 x 0.1391	0.974	12,640	671.7	3,547
Nasturtium	715500	0.5620	450000	A	61 x 0.1083	0.975	13,150	671.7	3,547
Petunia	750000	0.5890	472000	AA	37 x 0.1424	0.997	12,990	704.0	3,717
Cattail	750000	0.5890	472000	A	61 x 0.1109	0.998	13,510	704.0	3,717
Arbutus	795000	0.6244	500000	AA	37 x 0.1466	1.026	13,770	746.3	3,940
Lilac	795000	0.6244	500000	A	61 x 0.1142	1.028	14,330	746.3	3,940
Cockscomb	900000	0.7069	566000	AA	37 x 0.1560	1.092	15,270	844.9	4,461
Snapdragon	900000	0.7069	566000	A	61 x 0.1215	1.094	15,900	844.9	4,461
Magnolia	954000	0.7493	600000	AA	37 x 0.1606	1.124	16,180	895.6	4,729
Goldenrod	954000	0.7493	600000	A	61 x 0.1251	1.126	16,860	895.6	4,729
Hawkweed	1000000	0.7854	629000	AA	37 x 0.1644	1.151	16,960	938.7	4,956
Camellia	1000000	0.7854	629000	A	61 x 0.1280	1.152	17,670	938.7	4,956
Bluebell	1033500	0.8117	650000	AA	37 x 0.1672	1.170	17,530	970.2	5,123
Larkspur	1033500	0.8117	650000	A	61 x 0.1302	1.172	18,260	970.2	5,123
Marigold	1113000	0.8741	700000	AA, A	61 x 0.1351	1.216	19,660	1,045.	5,518
Hawthorn	1192500	0.9366	750000	AA, A	61 x 0.1398	1.258	21,000	1,119.	5,908
Narcissus	1272000	0.999	800000	AA, A	61 x 0.1444	1.300	22,000	1,194.	6,304
Columbine	1351500	1.062	850000	AA, A	61 x 0.1489	1.340	23,400	1,269.	6,700
Carnation	1431000	1.124	900000	AA, A	61 x 0.1532	1.379	24,300	1,343.	7,091
Gladiolus	1510500	1.186	950000	AA, A	61 x 0.1574	1.417	25,600	1,418.	7,487
Coreopsis	1590000	1.249	1000000	AA	61 x 0.1615	1.454	27,000	1,493.	7,883
Jessamine	1750000	1.374	1101000	AA	61 x 0.1694	1.525	29,700	1,643.	8,675
Cowslip	2000000	1.570	1260000	A	91 x 0.1482	1.630	34,600	1,877.	9,911
Sagebrush	2250000	1.766	1415000	A	91 x 0.1572	1.729	38,100	2,133.	11,262
Lupine	2500000	1.962	1570000	A	91 x 0.1657	1.823	42,400	2,368.	12,503
Bitterroot	2750000	2.158	1730000	A	91 x 0.1738	1.912	46,600	2,607.	13,765
Trillium	3000000	2.350	1890000	A	127 x 0.1537	1.996	50,800	2,844.	15,016
Bluebonnet	3500000	2.749	2200000	A	127 x 0.1660	2.158	59,400	3,350.	17,688

NOTES:

1. CLASS OF STRANDING: The stranding must be specified on all orders. Class B stranding is usually specified for conductors to be insulated with various materials such as rubber, paper, varnished cloth, etc. Class C stranding is specified for conductors where greater flexibility than provided by Class B is required.
2. LAY: The direction of lay of the outside layer of wires will be left hand unless otherwise specified.
3. TEMPER: The temper designation must be specified on all orders. i.e., EC-H19, EC-H26 or H16, EC-H24 or H14.