Table 50.221
Physical properties of 80°C (176°F) THV[a] jacket from appliance-wiring material

Table 50.221 added May 6, 2003

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	375 percent (3-3/4 inches or 93.8 mm)	3200 lbf/in^2 or 22.1 MPa (MN/m^2) or 2206 N/cm^2 or 2.25 kgf/mm^2
Aged in a full-draft circulatng-air oven for 168 h at 113.0 ±1.0°C (235.0 ±1.8°F)	80 percent of the result with unaged specimens	75 percent of the result with unaged specimens

[a] THV is a thermoplastic material whose characteristic consitituent is a terpolymer of tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride. The material is uncompounded THV to which a small amount of pigment, lubricant, or both is or is not added.

[b] THV is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.223
Physical properties of 105°C (221°F) TPE[a] jacket from CATV cables; insulations and jackets from power-limited circuit cable, from cable for power-limited fire-alarm circuits; and of 105°C (221°F) Class 36 TPE[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength		Maximum deformation (see Section 560 for method, see Table 57.1 of UL 62 for specimen loading)
		Insulation	Jacket	
Unaged	200 percent (2 inches or 50 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0.562 kgf/mm^2	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2	–
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	–
60°C (140°F) oil-resistant jacket or insulation:				–
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	
Heated in an oven at 150.0 ±1.0°C (302.0 ±1.8°F)	–	–	–	50 percent

[a] Class 36 TPE designates an extensible compound whose characteristic constituent is a thermoplastic elastomer.

Table 50.224

Physical properties of 90°C (194°F) TPE[a] jacket form CATV cables; insulations and jackets from power-limited circuit cable, from cable for power-limited fire-alarm circuits; and from other cables; and of 90°C (194°F) Class 36 TPE[a] insulation and jacket

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength		Maximum deformation (see Section 560 for method, see Table 57.1 of UL 62 for specimen loading)
		Insulation	Jacket	
Unaged	200 percent (2 inches or 50 mm)	800 lbf/in^2 or 5.52 MPa (MN/m^2) or 552 N/cm^2 or 0.562 kgf/mm^2	1200 lbf/in^2 or 8.27 MPa (MN/m^2) or 827 N/cm^2 or 0.844 kgf/mm^2	–
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	–
60°C (140°F) oil-resistant jacket or insulation:				–
Aged in oil for 168 h at 60.0 ±1.0°C (140.0 ±1.8°F)	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	75 percent of the result with unaged specimens	
Heated in an oven at 150.0 ±1.0°C (302.0 ±1.8°F)	–	–	–	50 percent

[a] Class 36 TPE designates an extensible compound whose characteristic constituent is a thermoplastic elastomer.

Table 50.226

Physical properties of 60°C (140°F), 75°C (167°F), and 80°C (176°F) TPES[a] insulations and jackets from appliance-wiring material

Table 50.226 added May 6, 2003

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPA (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Specimens of 60°C (140°F) material:	65 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)		

Table 50.226 Continued on Next Page

Table 50.226 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Specimens of 75°C (167°F) material: Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	65 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Specimens of 80°C (176°F) material: Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.0 ±1.0°F)	65 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] TPES designates a compounded thermoplastic material whose characteristic constituent is a polyester such as PBT (polybutylene terepthalate) or PET (polyethylene terepthalate), their individual copolymers, blends of any of these, PBT/polycarbonate blend, or PBT/TEEE (thermoplastic elastomer ether ester) blend.

[b] TPES is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.227
Physical properties of 60°C (140°F), 75°C (167°F), and 80°C (176°F) TPU[a] insulations and jackets from appliance-wiring material

Table 50.227 added May 6, 2003

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
Unaged	100 percent (1 inch or 25 mm)	1500 lbf/in^2 or 10.3 MPA (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Specimens of 60°C (140°F) material: Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Specimens of 75°C (167°F) material: Aged in a full-draft circulating-air oven for 240 h at 100.0 ±1.0°C (212.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	70 percent of the result with unaged specimens
Specimens of 80°C (176°F) material: Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.0 ±1.8°F)	Die-cut specimens: 45 percent of the result with unaged specimens Other specimens: 65 percent of the result with unaged specimens	70 percent of the result with unaged specimens

Table 50.227 Continued on Next Page

Table 50.227 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)[b]	Minimum tensile strength[b]
[a] TPU designates thermoplastic polyurethane, a compounded thermoplastic elastomer material whose main constituent is a polyester- or polyether-based urethane linear polymer resin characterized by soft amorphous segments containing hard crystalline microdomains.		
[b] TPU is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.		

Table 50.228
Physical properties of 90°C (194°F) XL[a] jacket from Type USE-2 and USE cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.229
Physical properties of 75°C (167°F) XL[a] jacket from Type USE cable

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.230
Physical properties of XL[a] jacket from cable for deep-well submersible water pumps

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 100.0 ±1.0°C (212.0 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLPVC (cross-linked polyvinyl chloride), XLEVA (cross-linked ethylene vinyl acetate), or blends thereof. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.231
Physical properties of 90°C (194°F) and 75°C (167°F) XL[a] jackets from CATV cables and insulations and jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables; and XL[a] insulation from Type RFHH-2, RFHH-3, XHHW-2, XHHW, XHH, RHW-2, RHH, RHW, and SIS wires

Table 50.231 revised October 31, 2001

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h:		

Table 50.231 Continued on Next Page

Table 50.231 Continued

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
At 121.0 ±1.0°C (249.8 ±1.8°F) for specimens of 90°C (194°F) insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or of 90°C (194°F) insulation from Type XHHW-2, XHHW, XHH, RHW-2, RHH, and SIS wires	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens
At 113.0 ±1.0°C (235.4 ±1.8°F) for specimens of 75°C (167°F) insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, or of 75°C (167°F) insulation from Type RHW wire	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross-linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof, with the cross-linking achieved either chemically or by irradiation. XL rated 90°C (194°F) is for use as conductor insulation on Type XHHW-2, XHHW, XHH, RHW-2, RHH, and SIS wires without any covering over the insulation. XL rated 75°C (167°F) is for use as conductor insulation on Type RHW wire without any covering over the insulation.

Table 50.232
Physical properties of 125° (257°F) and Class 38 150°C (302°F) XLPO[a] insulations

Table 50.232 revised May 6, 2003

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	300 percent (3 inches or 75 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
125°C (257°F) insulation: Aged in a full-draft circulating-air oven for 168 h at 158.0 ±1.0°C (316.4 ±1.8°F) 150°C (302°F) insulation: Aged in a full-draft circulating-air oven for 168 h at 180.0 ±1.0° (356.0 ±1.8°F)	80 percent of the result with unaged specimens	80 percent of the result with unaged specimens

[a] XL designates a thermoset polyolefin compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLEVA (cross-linked ethylene vinyl acetate), or a blend of the two. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

Table 50.233
Physical properties of 105°C (221°F) XLPO[a] insulation or jacket from power-limited circuit cable, from cable for power-limited fire-alarm circuits, and from other cables

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength[b]
Unaged	150 percent (1-1/2 inches or 37.5 mm)	2000 lbf/in^2 or 13.79 MPa (MN/m^2) or 1379 N/cm^2 or 1.41 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	70 percent of the result with unaged specimens	85 percent of the result with unaged specimens

[a] XLPO designates a thermoset polyolefin compound whose characteristic constituent is XLPE (cross-linked polyethylene), XLEVA (cross-linked ethylene vinyl acetate), or a blend of the two. It is appropriate to accomplish the cross-linking either chemically or by irradiation.

[b] XLPO is to be tested at a speed of 20 ±1 in/min or 500 ±25 mm/min.

Table 50.237
Physical properties of Class 29 90°C (194°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 121.0 ±1.0°C (249.8 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 29 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

Table 50.241
Physical properties of Class 31 75°C (167°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 113.0 ±1.0°C (235.4 ±1.8°F)	70 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 31 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

Table 50.245
Physical properties of Class 33 105°C (221°F) XL[a] insulation

Condition of specimens at time of measurement	Minimum ultimate elongation (1-inch or 25-mm bench marks)	Minimum tensile strength
Unaged	150 percent (1-1/2 inches or 37.5 mm)	1500 lbf/in^2 or 10.3 MPa (MN/m^2) or 1034 N/cm^2 or 1.05 kgf/mm^2
Aged in a full-draft circulating-air oven for 168 h at 136.0 ±1.0°C (276.8 ±1.8°F)	45 percent of the result with unaged specimens	70 percent of the result with unaged specimens

[a] Class 33 XL designates a thermoset compound whose characteristic constituent is cross-linked polyethylene (XLPE), cross linked polyvinyl chloride (XLPVC), cross-linked ethylene vinyl acetate (XLEVA), or blends thereof. It is appropriate to accomplish this cross-linking either chemically or by irradiation.

51 – 199 *Reserved for Future Use*

METHODS

CONDUCTOR DIMENSIONS AND RESISTANCE

200 Conductor Diameter

200.1 Regardless of whether any tin or other metal coating is employed, measurements of the diameter of a solid conductor are to be made over such coating by means of a machinist's micrometer caliper having flat surfaces both on the anvil and on the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, with each division of a width that facilitates estimation of each measurement to 0.0001 inch or 0.001 mm. The maximum and minimum diameters at a given point on the conductor are each to be recorded to the nearest 0.0001 inch or 0.001 mm, added together, and divided by 2 without any rounding of the sum or resulting average.

200.2 Each minimum and maximum diameter in Tables 20.1, 20.2, 20.3, 20.3.1, 20.4, and 20.6 is an absolute minimum or maximum. For the purpose of determining whether the conductor does or does not comply with the diameter requirement(s), the unrounded average of the two micrometer readings is to be compared directly with whichever of the following applies:

a) Both the 0.98 x nominal minimum and the 1.01 x nominal maximum where the wire standard specifies these diameter limits for the solid or stranded conductor.

b) The 0.99 x nominal minimum in Table 20.1 where the wire standard specifies only a minimum diameter for a solid conductor.

201 – 209 *Reserved for Future Use*

210 Conductor Cross-Sectional Area by the Weight Method

210.1 For determining the cross-sectional area of a stranded conductor by the weight method, the test specimen is to consist of a straight length of a single conductor cut from a sample of the finished wire, cable, or cord. The specimen is to be at any convenient room temperature, is to have both of its ends perpendicular to the longitudinal axis of the conductor, and is to have any insulation, separator, and other coverings removed. For an 8 AWG or smaller conductor (8.367 mm^2 or smaller), the specimen is to be at least 48 inches or 1220 mm long. For a conductor larger than 8 AWG (larger than 8.367 mm^2), the specimen is to be at least 24 inches or 610 mm long. The length of the specimen is to be measured to the nearest 1/32 inch or 1 mm. The specimen is to be weighed by means of a precision balance to within 0.1 percent of the weight of the specimen. For example, a 4-ft or 1220-mm specimen of a 12 AWG aluminum conductor having seven round strands (Class B) weighs about 0.02 lb or 11 g. One tenth of 1 percent of these figures is, respectively, 0.00002 lb and 0.009 g, which means that the weight of a 12 AWG aluminum conductor must be determined to the fifth decimal place when in pounds and to the nearest 10 mg when in grams.

210.2 The conductor cross-sectional area in circular mils is to be calculated by whichever of the following formulas applies to the conductor material (as a convenience for the strandings that are common in wiring, it is appropriate to compare the specimen weight directly with the weight in Table 210.1 instead of calculating the cross-sectional area):

For a copper conductor that has each of its strands uncoated or coated with tin or a tin/lead alloy –

$$A_{cmil} = \frac{33.036 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

For a copper-clad aluminum conductor –

$$A_{cmil} = \frac{88.417 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

For an aluminum conductor –

$$A_{cmil} = \frac{108.654 \times 10^{+6} \times W_{lb}}{(100 + k) \times L_{ft}}$$

in which:

A_{cmil} is the cross-sectional area in circular mils,

W_{lb} is the weight of the specimen in pounds (see the last sentence of this paragraph),

L_{ft} is the length of the specimen in feet, and

k is the percentage increase in weight applicable to the type of stranding used from Table 210.2.

For a copper conductor that has each of its strands coated with nickel or silver or another metal other than tin or a tin/lead alloy and for a conductor of a copper-base alloy or a nickel-base alloy –

$$A_{cmil} = \frac{100{,}000 \times W_{lb}}{(100 + k) \times L_{ft} \times f}$$

in which:

A_{cmil}, W_{lb}, k, and L_{ft} are as noted above and

f is the weight factor in lb·cmil/1000 ft applicable to the alloy used or to the thickness and the metal of the coating used.

It is appropriate to weigh a specimen in grams W_g instead of pounds, in which case,

$W_g/453.5924$ is to be substituted for W_{lb} in the formula.

210.3 The conductor cross-sectional area in square millimeters is to be calculated by whichever of the following formulas applies to the conductor material (as a convenience for the strandings that are common in wiring, it is appropriate to compare the specimen weight directly with the weight in Table 210.1 instead of calculating the cross-sectional area):

For a copper conductor that has each of its strands uncoated or coated with tin or a tin/lead alloy –

$$A_{mm^2} = \frac{11248 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

For a copper-clad aluminum conductor –

$$A_{mm^2} = \frac{30105 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

For an aluminum conductor –

$$A_{mm^2} = \frac{36996 \ x \ W_g}{(100 + k) \ x \ L_{mm}}$$

in which:

A_{mm^2} *is the cross-sectional area in square millimeters,*

W_g *is the weight of the specimen in grams,*

L_{mm} *is the length of the specimen in millimeters, and*

k is the percentage increase in weight applicable to the type of stranding used from Table 210.2.

For a copper conductor that has each of its strands coated with nickel or silver or another metal other than tin or a tin/lead alloy and for a conductor of a copper-base alloy or a nickel-base alloy –

$$A_{mm^2} = \frac{45.154222 \times W_g}{(100 + k) \times L_{mm} \times f}$$

in which:

A_{mm^2}, W_g, k, and L_{mm} are as noted above and

f is the weight factor in (kg·mm²)/km applicable to the alloy used or to the thickness and the metal of the coating used.

Table 210.1
Minimum weight of specimens of stranded conductors for which k is 2[a,b]

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g
48 inches or 1220 mm	14 AWG	0.04975	22.57	0.01859	8.43	0.01513	6.86
	13	0.06269	28.44	0.02342	10.62	0.01906	8.64
	12	0.07903	35.85	0.02952	13.39	0.02403[c]	10.90[c]
	11	0.09960	45.18	0.03721	16.88	0.03028[c]	13.74[c]
	10	0.1256	56.97	0.04693	21.29	0.03820[c]	17.33[c]
	9	0.1584	71.85	0.05920	26.85	0.04817[c]	21.85[c]
	8	0.1998	90.63	0.07465	33.86	0.06076[c]	27.56[c]
24 inches or 610 mm	7 AWG	0.1260	57.15	0.04707	21.35	0.03832[c]	17.78[c]
	6	0.1588	72.03	0.05932	26.91	0.04829[c]	21.90[c]
	5	0.2002	90.81	0.07481	33.93	0.06090[c]	27.62[c]
	4	0.2526	114.6	0.09437	42.81	0.07682[c]	34.85[c]
	3	0.3184	144.4	0.1190	53.98	0.09684[c]	43.93[c]
	2	0.4016[d]	182.2[d]	0.1500	68.04	0.1221[c]	55.38[c]
	1	0.5064[d]	229.7[d]	0.1892	85.82	0.1540[c]	69.85[c]
	1/0	0.6390[d]	289.8[d]	0.2387	108.3	0.1944[c]	88.18[c]
	2/0	0.8055[d]	365.4[d]	0.3009	136.5	0.2450[c]	111.1[c]
	3/0	1.015[d]	460.4[d]	0.3794	172.1	0.3088[c]	140.1[c]
	4/0	1.280[d]	580.6[d]	0.4784	217.0	0.3894[c]	176.6[c]

Table 210.1 Continued on Next Page

Table 210.1 Continued

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g
	250 kcmil	1.513	686.3	0.5652	256.4	0.4601[c]	208.7[c]
	300	1.815	823.3	0.6783	307.7	0.5521[c]	250.4[c]
	350	2.118	960.7	0.7913	358.9	0.6442[c]	292.2[c]
	400	2.421	1098	0.9043	410.2	0.7362[c]	333.9[c]
	450	2.723	1235	1.017	461.3	0.8282[c]	375.7[c]
	500	3.026	1373	1.130	512.6	0.9202[c]	417.4[c]
	550	3.328	1510	1.243	563.8	1.012[c]	459.0[c]
24	600	3.631	1647	1.357	615.5	1.104[c]	500.8[c]
	650	3.933	1784	1.470	666.8	1.196[c]	542.5[c]
	700	4.236	1921	1.583	718.0	1.288[c]	584.2[c]
	750	4.539	2059	1.696	769.3	1.380[c]	626.0[c]
inches	800	4.841	2196	1.809	820.5	1.472[c]	667.7[c]
	900	5.446	2470	2.035	923.1	1.656[c]	751.1[c]
	1000	6.052	2745	2.261	1026	1.840[c]	834.6[c]
	1100	6.657	3020	2.487	1128	2.024	918.1
or							
	1200	7.262	3294	2.713	1231	2.209	1002
	1250	7.564	3431	2.826	1282	2.301	1044
	1300	7.867	3568	2.939	1333	2.393	1085
	1400	8.472	3843	3.165	1436	2.577	1169
610 mm	1500	9.077	4120	3.391	1538	2.761	1252
	1600	9.682	4392	3.617	1641	2.945	1336
	1700	0.29	4667	3.843	1743	3.129	1419
	1750	0.59	4804	3.957	1795	3.221	1461
	1800	0.89	4940	4.070	1846	3.313	1503
	1900	1.50	5216	4.296	1949	3.497	1586
	2000	2.10	5488	4.522	2051	3.681	1670

[a] k is 2 for many of the bunch-stranded (single bunch of round strands); concentric-lay (round strands) Classes B, C, and D; 19-wire combination round-lay unilay-stranded copper or aluminum; compact-stranded; and compressed-stranded conductor constructions produced. For these conductor constructions having a k other than 2 and for rope-lay constructions, the minimum cross-sectional area is to be calculated as described in 210.2 – 210.4.

Table 210.1 Continued on Next Page

Table 210.1 Continued

Length of specimen	Size of conductor	Compact-stranded[d] and compressed-stranded copper conductor with each strand uncoated and round-strand copper conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand uncoated or coated with tin or a tin/lead alloy		Round-strand conductor with each strand of copper-clad aluminum		Compact-stranded[c] and compressed-stranded and round-strand aluminum conductor (including 6 – 4/0 AWG 19-wire combination unilay) with each strand of aluminum	
		lb	g	lb	g	lb	g

[b] Weights for copper conductors with each strand coated with nickel or silver are not included because a different value of f (weight factor) applies to each conductor with a different thickness of nickel or silver coating. Where f is known for a particular coated conductor, the minimum cross-sectional area is to be calculated from the specimen weight and the applicable k using the last area formula either in 210.2 (circular mils) or in 210.3 (square millimeters).

[c] For a compact-stranded aluminum conductor, sizes are limited to No. 12 AWG – 1000 kcmil.

[d] For a compact-stranded copper conductor, sizes are limited to Nos. 2 – 4/0 AWG.

Table 210.2
Percentage increase (k) in weight for type of strands

Table 210.2 revised May 6, 2003

Construction of Conductor	k
Bunch-stranded (single bunch of round strands)[a]	2[b]
Concentric-lay Classes B, C, and D (round strands)	2[b]
Compact- or compressed-stranded	2[b]
19-wire combination round-wire unilay-stranded copper or aluminum	2[b]
Rope-lay (constructed of concentric-lay members composed of round strands) Classes G and H:	
49 wires	3
133 wires	4
259 wires	4.5
427 wires	5
more than 427 wires	6
Rope-lay (constructed of bunch-stranded members composed of round strands) Classes I, K, and M:	
7 ropes with each rope consisting of a single bunch	4
19, 37, or 61 ropes with each rope consisting of a single bunch	5
7 ropes with each rope constructed of 7 bunch-stranded members	6
19, 37, or 61 ropes with each rope constructed of 7 bunch-stranded members	7

[a] Includes the following single-bunch constructions included in ICEA requirements (not in ASTM B 172-01) under Classes I, K, and M:

	Number of strands in single bunch		
AWG size	Class I	Class K	Class M
14		41	104
13		52	
12		65	
11	83		

Table 210.2 Continued on Next Page

Table 210.2 Continued

Construction of Conductor				k
	10	26	104	
	9	33		
	8	41		
	7	52		
	6	65		

[b] Values other than 2 percent are used. See 210.4 for the method of calculation.

210.4 It is appropriate, in any case, to calculate the percentage increase k in weight due to stranding by means of the formula

$$k = 100(M - 1)$$

in which:

the ratio increase (conductor lay factor) M is as indicated in one of the following items:

a) For a concentric component or conductor, $M = M_{conc}$

$$M_{conc} = \frac{1 + (p_2)x(m_2) + (p_3)x(m_3) + \ldots + (p_y)x(m_y)}{\text{total number of strands}}$$

in which:

y is the number of layers (including the central wire or central concentric component as the first layer),

p is the number of strands or concentric components in the layer, and

m is the ratio increase (layer lay factor) for the layer as determined from the formula

$$m = \sqrt{1 + \pi^2/n^2}$$

which, for n equal to or greater than 10, is

$$m = 1 + \pi^2/(2n^2) = 1 + \frac{4.9348}{n^2}$$

in which:

n is the lay ratio for the layer determined from

$$n = \frac{\text{length of lay of the strands or components in the layer}}{d}$$

in which:

d is the diameter of the helical path of one strand or component of the layer (pitch diameter) determined from whichever of the following formulas is applicable and convenient (all give the same result).

For round strands or components:

d = diameter under the layer + diameter of one strand or component

or

d = diameter over the layer – diameter of one strand or component

For strands or components of any shape, including round:

$$d = \frac{\text{diameter over the layer} + \text{diameter under the layer}}{2}$$

b) For a bunched component or single-bunch conductor, $M = M_{bunch}$

$$M_{bunch} = \sqrt{1 + \left[\frac{\pi (D - d)}{\sqrt{2}\ LEN}\right]^2}$$

in which:

D is the diameter over the bunched component or single-bunch conductor,

d is the diameter of one strand, and

LEN is the length of lay of the bunched component or of the strands in the single bunch.

c) For a rope-stranded conductor with 1 roping operation,

$$M = M_{single\ rope}$$

$$M_{single\ rope} = M_{unit} \times M_{conc}$$

or

$$M_{single\ rope} = M_{unit} \times M_{bunch}$$

in which:

M_{conc} or M_{bunch} is calculated for one concentric or bunched component as indicated in (a) or (b)

and

M_{unit} is calculated for the single-roped assembly in the same way as M_{conc} or M_{bunch} treating each concentric or bunched component as solid.

d) For a multiple rope-stranded conductor with 2 roping operations, $M = M_{double\ rope}$

$$M_{double\ rope} = M_{mult} \times M_{unit} \times M_{conc}$$

or

$$M_{double\ rope} = M_{mult} \times M_{unit} \times M_{bunch}$$

in which:

$M_{unit} \times M_{conc} \times M_{bunch}$ is calculated as indicated in (a), (b), or (c) for a single rope and

M_{mult} is calculated for the double-roped assembly in the same way as $M_{unit} \times M_{conc}$ or $M_{unit} \times M_{bunch}$ treating each single-rope component as solid.

e) The first formula in (a) expresses the effect of the individual wires based on the weight of each wire. While the wires are identical in (a), six of them are smaller (0.732 x D) in a 19-wire combination round-wire unilay-stranded conductor, which modifies the formula to the following. It is to be understood that this variety of unilay conductor consists of a straight central wire of diameter D, an inner layer of six wires of diameter D with each wire having a length of lay designated as LOL, and an outer layer consisting of six wires of diameter D alternated with six smaller wires having a diameter of 0.732 x D and with all twelve wires of the outer layer having the same length of lay LOL and direction of lay as the six wires of the inner layer.

$$M_{combo.\ unilay} = \frac{1 + 6m_2 + 6m_3 + (6 \times 0.732^2) \times m_4}{1 + 6 + 6 + (6 \times 0.732^2)}$$

in which:

m_2 is the ratio increase (layer lay factor) for the inner layer,

m_3 is the ratio increase for the wires of diameter D in the outer layer, and

m_4 is the ratio increase for the wires of diameter $0.732 \times D$ in the outer layer.

As in (a),

$$m = \sqrt{1 + \pi^2/n^2}$$

in which:

n is the lay ratio determined as follows:

For the central wire of diameter D, n_1 = infinity.

For the 6 wires of diameter D in the inner layer,

$$n_2 = \frac{LOL}{2D}$$

For the 6 wires of diameter D in the outer layer,

$$n_3 = \frac{LOL}{3.464D}$$

For the 6 wires of diameter 0.732 × D in the outer layer,

$$n_4 = \frac{LOL}{3.732D}$$

When n_2 and n_3 and n_4 each equal or exceed 10, an estimate of

$$m = \sqrt{1 + \pi^2/n^2}$$

is

$$m = 1 + \pi^2/(2n^2) = 1 + \frac{4.9348}{n^2}$$

Then,

$$m_2 = 1 + 19.7392 \times \frac{D^2}{(LOL)^2}$$

$$m_3 = 1 + 59.2141 \times \frac{D^2}{(LOL)^2}$$

$$m_4 = 1 + 68.7310 \times \frac{D^2}{(LOL)^2}$$

and

$$M_{combo.\ unilay} = 1 + 42.8423 \times \frac{D^2}{(LOL)^2}$$

and

$$k = 4284 \times \frac{D^2}{(LOL)^2}$$

(applies only where each n equals or exceeds 10).

211 – 219 *Reserved for Future Use*

220 D-C Conductor Resistance

220.1 The direct-current resistance of any length of conductor in ohms per thousand conductor feet or in ohms per conductor kilometer is to be measured to an accuracy of 2 percent or better by means of a Kelvin-bridge ohmmeter or its equivalent – see 220.2 concerning measurement at temperatures other than 25°C (77°F) and 20°C (68°F). Tables 30.1– 30.11 do not cover nickel-coated copper, silver-coated copper, or nickel-base-alloy conductors because the thickness of the nickel or silver and the composition of the nickel-base alloy vary in practice thereby varying the conductor resistance (the maximum conductor resistance is to be determined individually in such cases). Where the results of any measurement do not comply, the results of measurements made under the conditions outlined in 220.3 – 220.9 are to be taken as conclusive.

220.2 The resistance of a conductor measured at a temperature other than 25°C (77°F) or 20°C (68°F) is to be adjusted to the resistance at 25°C (77°F) or 20°C (68°F) by means of the applicable multiplying factor from Table 220.1.

220.3 A referee determination of the direct-current resistance of a conductor is to be made to an accuracy of 0.2 percent or better by means of a general-purpose Kelvin bridge or its equivalent using a straight specimen of the conductor that is 24 – 48 inches or 610 – 1220 mm long.

220.4 Each general-purpose Kelvin-bridge current electrode is to be attached to a stranded specimen in a way – adjacent strands in mutual contact, each strand of the outer layer in full-length contact with the electrode, no strands damaged or bent, uniform pressure by the electrode at all points of strand contact, and so forth – that results in a uniform or nearly uniform distribution of current among the strands.

220.5 The distance between each general-purpose Kelvin-bridge potential electrode and its corresponding current electrode is to equal or exceed 1.5 times the circumference of the conductor specimen. The resistance of the Kelvin-bridge yoke between the reference standard and the specimen is not to be more than 0.1 percent of the resistance of the reference standard or the specimen, whichever is less, unless compensation is made for the potential leads or the coil and lead ratios are balanced.

220.6 Each general-purpose Kelvin-bridge potential electrode shall contact the conductor specimen with a surface that is a sharp knife edge (see 220.9). The length of the conductor specimen between the knife edges is to be measured to the nearest 0.01 inch or 0.2 mm.

220.7 When using the general-purpose Kelvin bridge, the conductor specimen, all equipment, and the surrounding air are to be in thermal equilibrium with one another at one temperature in the range of 15 – 30°C (59 – 86°F). All of the referee resistance measurements are to be made at that one temperature. See 220.2 and note [a] to Table 220.1.

220.8 Because the general-purpose Kelvin-bridge measuring current raises the temperature of the specimen, the magnitude of the current is to be low and the time of its use is to be brief. Too much current, too much time, or both are being used for a measurement where any change in resistance is detected with the galvanometer in two successive readings.

220.9 The contact surfaces of the general-purpose Kelvin-bridge current electrodes, the surface of the conductor specimen, and the knife edges of the general-purpose Kelvin-bridge potential electrodes are to be clean and undamaged. Contact-potential error is to be eliminated by taking four readings in direct succession: the first with the current flowing in one direction, the second with the current flowing in the other direction, then – after the specimen has been turned end for end – the third with the current flowing in one direction, and the fourth with the current flowing in the other direction. Contact-potential imbalance is to be minimized by having the potential electrodes made of the same material.

Table 220.1
Factors for adjusting d-c resistance of conductors[a]

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
0	32.0	1.107	1.110	1.085	1.088
1	33.8	1.102	1.105	1.081	1.083
2	35.6	1.098	1.100	1.076	1.078
3	37.4	1.093	1.095	1.072	1.074
4	39.2	1.089	1.090	1.067	1.069
5	41.0	1.084	1.085	1.063	1.064
6	42.8	1.079	1.081	1.059	1.060
7	44.6	1.075	1.076	1.054	1.055
8	46.4	1.070	1.072	1.050	1.051
9	48.2	1.066	1.067	1.045	1.046
10	50.0	1.061	1.063	1.041	1.042
11	51.8	1.057	1.059	1.037	1.038

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
12	53.6	1.053	1.054	1.033	1.033
13	55.4	1.048	1.050	1.028	1.029
14	57.2	1.044	1.045	1.024	1.024
15	59.0	1.040	1.041	1.020	1.020
16	60.8	1.036	1.037	1.016	1.016
17	62.6	1.032	1.033	1.012	1.012
18	64.4	1.028	1.028	1.008	1.008
19	66.2	1.024	1.024	1.004	1.004
20	68.0	1.020	1.020	1.000	1.000
21	69.8	1.016	1.016	0.996	0.996
22	71.6	1.012	1.012	0.992	0.992
23	73.4	1.008	1.008	0.989	0.988
24	75.2	1.004	1.004	0.985	0.984
25	77.0	1.000	1.000	0.981	0.980
26	78.8	0.996	0.996	0.977	0.976
27	80.6	0.992	0.992	0.973	0.972
28	82.4	0.989	0.989	0.970	0.969
29	84.2	0.985	0.985	0.966	0.965
30	86.0	0.981	0.981	0.962	0.961
31	87.8	0.977	0.977	0.958	0.957
32	89.6	0.974	0.973	0.955	0.954
33	91.4	0.970	0.970	0.951	0.950
34	93.2	0.967	0.966	0.948	0.947
35	95.0	0.963	0.962	0.944	0.943
36	96.8	0.959	0.958	0.941	0.939
37	98.6	0.956	0.955	0.937	0.936
38	100.4	0.952	0.951	0.934	0.932
39	102.2	0.949	0.948	0.930	0.929
40	104.0	0.945	0.944	0.927	0.925
41	105.8	0.942	0.941	0.924	0.922
42	107.6	0.938	0.937	0.921	0.918
43	109.4	0.935	0.934	0.917	0.915
44	111.2	0.931	0.930	0.914	0.911

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
45	113.0	0.928	0.927	0.911	0.908
46	114.8	0.925	0.924	0.908	0.905
47	116.6	0.922	0.920	0.905	0.902
48	118.4	0.918	0.917	0.901	0.898
49	120.2	0.915	0.913	0.898	0.895
50	122.0	0.912	0.910	0.895	0.892
51	123.8	0.909	0.907	0.892	0.889
52	125.6	0.906	0.904	0.889	0.886
53	127.4	0.902	0.900	0.885	0.882
54	129.2	0.889	0.897	0.882	0.879
55	131.0	0.896	0.894	0.879	0.876
56	132.8	0.893	0.891	0.876	0.873
57	134.6	0.890	0.888	0.873	0.870
58	136.4	0.887	0.884	0.870	0.867
59	138.2	0.884	0.881	0.867	0.864
60	140.0	0.881	0.878	0.864	0.861
61	141.8	0.878	0.875	0.861	0.858
62	143.6	0.875	0.872	0.858	0.855
63	145.4	0.872	0.869	0.856	0.852
64	147.2	0.869	0.866	0.853	0.849
65	149.0	0.866	0.863	0.850	0.846
66	150.8	0.863	0.860	0.847	0.843
67	152.6	0.860	0.857	0.844	0.840
68	154.4	0.858	0.855	0.842	0.838
69	156.2	0.855	0.852	0.839	0.835
70	158.0	0.852	0.849	0.836	0.832
71	159.8	0.849	0.846	0.833	0.829
72	161.6	0.846	0.843	0.830	0.826
73	163.4	0.844	0.841	0.828	0.824
74	165.2	0.841	0.838	0.825	0.821
75	167.0	0.838	0.835	0.822	0.818
76	168.8	0.835	0.832	0.819	0.815
77	170.6	0.833	0.829	0.817	0.813

Table 220.1 Continued on Next Page

Table 220.1 Continued

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
78	172.4	0.830	0.827	0.814	0.810
79	174.2	0.828	0.824	0.812	0.808
80	176.0	0.825	0.821	0.809	0.805
81	177.8	0.822	0.818	0.807	0.802
82	179.6	0.820	0.816	0.804	0.800
83	181.4	0.817	0.813	0.802	0.797
84	183.2	0.815	0.811	0.799	0.795
85	185.0	0.812	0.808	0.797	0.792
86	186.8	0.810	0.806	0.794	0.790
87	188.6	0.807	0.803	0.792	0.787
88	190.4	0.805	0.801	0.789	0.785
89	192.2	0.802	0.798	0.787	0.782
90	194.0	0.800	0.796	0.784	0.780

[a] No referee resistance measurement is to be made at a temperature outside the range of 15 – 30°C (59 – 86°F). See 220.7.

221 – 227 *Reserved for Future Use*

WIRE BRAID AND SERVING COVERAGE

228 Measurements and Calculations

228.1 Where a wire covering consists of multiple braids or servings (wraps), separate coverage determinations are to be made for each wire braid and serving. Measurements and calculations are specified for braids and servings of both round and flat wires on round and flat underlying constructions.

228.2 In any one braid or serving, all of the wires are assumed to be of the same metal, the same metal coating (where a metal coating is used), and the same diameter where the wires are round or the same width and thickness where the wires are flat. A wire braid is assumed to be fabricated on a machine using the same number of carriers in each direction and the same number of round or flat wires in each carrier (N in the notes to Table 228.1 provides for weighting of the value for N where not all carriers have the same number of wires).

228.3 The method described here uses measurements made on the finished product. For this method, the coverage of each wire braid and serving in a cord or cable is to be determined from calculations using the measurements, formulas, and number of decimal places specified in Table 228.1 for wire-braid constructions and in Table 228.2 for wire servings.