228.4 For a wire braid, the number of plaits laid in one direction along 1 inch or 20 millimeters of the axial length of the wire braid is to be counted to the nearest tenth of a plait by means of a standard braid counter (see 228.5) at three places that are at least 2 inches or 50 mm apart in any 12-inch or 300-mm section in the center 3 ft or 1 m of a straight 5-ft or 1500-mm specimen of the wire-braid-covered conductor, assembly, or core. The average of the three measurements made in inches is to be expressed to the nearest tenth of a plait and taken as P the number of picks per inch for that wire braid. The average of the three measurements made in millimeters is to be divided by 20. The result expressed to the nearest hundredth of a plait is to be taken as P the number of picks per millimeter for that wire braid.

228.5 Where a braid counter is not available, the count is to be made along 6 inches or 150 mm of the braid at one place in the 12-inch or 300-mm section. This measurement in inches is to be divided by 6. The result expressed to the nearest tenth of a plait is to be taken as P the number of picks per inch for that wire braid. This measurement in millimeters is to be divided by 150. The result expressed to the nearest hundredth of a plait is to be taken as P the number of picks per millimeter for that wire braid.

Table 228.1
Coverage calculations for a wire braid

SHAPE **Makeup of construction under braid**	**Shape of a braid wire**	**Calculations**		
		Name	**Formulas** The notes to this table specify how to determine the value of each parameter to enter in the formulas shown in this column. Use the formulas in the sequence shown reading down this column. Use of other formulas is appropriate where the formulas are applicable, agreed upon, and recorded.	**Number of decimal places**
ROUND 1, 3, 4, or more conductors or other round elements or assemblies or an entire round cable core or 2 or more twisted pairs or 1 parallel or twisted pair of conductors or other round elements. Fillers are included. Pair is round.	Round	Braid Angle (a)	*tan a = 2 x 3.1416 x P(D + 2d)/C*	3
			Determine a (arctan)	Nearest degree
			Determine sin a	3
		1-way coverage (F)	*F = (N x P x d)/sin a*	3
		2-way (total) coverage (G)	*G = 2F - F²*	3
		Percent Total coverage (K)	*K = 100 x G*	Nearest percent
	Flat	Substitute these formulas: *tan a = 2 x 3.1416 x P(D + 2t)/C* *F = (N x P x w)/sin a*		

Table 228.1 Continued on Next Page

Table 228.1 Continued

FLAT Parallel or twisted pair(s) of conductors or other round elements. Fillers are not included. Pair is not round.	Round	Same formulas substituting D_{eq} for D.
	Flat	Same formulas substituting D_{eq} for D.

C = total number of carriers in the wire braid.

d = diameter of one round braid wire to the nearest 0.0001 inch or 0.001 mm.

D = diameter of the round assembly under the wire braid measured to the nearest 0.001 inch or 0.1 mm.

D_{eq} = equivalent diameter over the two parallel or twisted round coaxial elements or insulated conductors under the wire braid determined to the nearest 0.001 inch or 0.1 mm by means of a diameter tape or by dividing the measured circumference of the flat pair by 3.1416 (p).

N = number of round or flat wires in one carrier of the wire braid.

N is to be weighted where several carriers have fewer wires than the rest:

$$N_{weighted} = \frac{\text{(number of carriers having r wires x r) + (number of carriers having s wires x s)}}{\text{number of carriers having r wires + number of carriers having s wires}}$$

$N_{weighted}$ is to be expressed to the third decimal place.

P = picks per inch or picks per millimeter determined as indicated in 228.4 and 228.5.

t = thickness of one flat braid wire to the nearest 0.001 inch or 0.1 mm.

w = width of one flat braid wire to the nearest 0.001 inch or 0.1 mm.

Table 228.2
Coverage calculations for a wire serving (spiral shield or reverse spiral shield)

SHAPE **Makeup of construction under serving (wrap)**	**Shape of a serving wire**	**Calculations**		
		Name	**Formulas** The notes to this table specify how to determine the value of each parameter to enter in the formulas shown in this column. Use the formulas in the sequence shown reading down this column. Use of other formulas is appropriate where the formulas are applicable, agreed upon, and recorded.	**Number of decimal places**
ROUND 1, 3, 4, or more conductors or other round elements or assemblies or an entire round cable core or 2 or more twisted pairs or 1 parallel or twisted pair of conductors or other round elements. Fillers are included. Pair is round.	Round	Serving angle (a)	*tan a = 3.1416 x (D + d)/L*	3
			Determine a (arctan)	Nearest degree
			Determine cos a	3
		Coverage (B)	*B = (H x d)/[3.1416 x (D + d) x cos a]*	3
		Percent coverage (K)	*K = 100 x B*	Nearest percent
	Flat	Substitute these formulas: *tan a = 3.1416 x (D + t)/L* *B = (H x w)/[3.1416 x (D + t) x cos a]*		
FLAT Parallel or twisted pair(s) of conductors or other round elements. Fillers are not included. Pair is not round.	Round	Same formulas substituting D_{eq} for D.		
	Flat	Same formulas substituting D_{eq} for D.		

Table 228.2 Continued on Next Page

Table 228.2 Continued

d = diameter of one round serving wire to the nearest 0.0001 inch or 0.001 mm.
D = diameter of the round assembly under the wire serving measured or calculated to the nearest 0.001 inch or 0.1 mm.
D_{eq} = equivalent diameter over the two parallel or twisted round coaxial elements or insulated conductors under the wire serving determined to the nearest 0.001 inch or 0.1 mm by means of a diameter tape or by dividing the measured circumference of the flat pair by 3.1416 (p).
H = number of round or flat wires in the wire serving.
L = lay length to the nearest 0.01 inch or 0.1 mm along the cord or cable axis for one complete turn of a serving wire around the round or flat construction under the serving.
t = thickness of one flat serving wire to the nearest 0.001 inch or 0.1 mm.
w = width of one flat serving wire to the nearest 0.001 inch or 0.1 mm.

229 – 239 *Reserved for Future Use*

THICKNESSES OF INSULATION AND JACKET

240 Thicknesses of Insulation on Thermoplastic- and Thermoset-Insulated Wires and Cable

Average thickness

240.1 Measurements from which the average thickness of insulation is to be determined are to be made by means of one of the following instruments:

a) Use of a machinist's micrometer caliper is appropriate. The caliper is to have flat surfaces on the anvil and on the end of the spindle and is to be 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 0.002 mm.

b) Use of a dead-weight dial micrometer is appropriate. The micrometer is to exert 10 ±2 gf or 0.10 ±0.02 N on a sample through a flat, rectangular presser foot 0.078 by 0.375 inch or 1.98 by 9.52 mm. The anvil of the instrument is to be of the same dimensions as the presser foot. The instrument is to be calibrated as indicated in (a).

240.2 During the measurements, the sample, the measuring instrument, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F).

240.3 Measurements are to be made on a sample length of finished wire (single conductor or insulated conductor removed from a cable) from which any jacket or other covering has been removed without damaging or stressing the insulation. For the 14 – 9 AWG sizes, the sample is to be at least 60 inches or 1500 mm long and, figuring from one end of the sample, measurement is to be made of the maximum and minimum diameters over the insulation at each of five points 10, 20, 30, 40, and 50 inches from that end or 254, 508, 762, 1016 and 1270 mm from that end. For the 8 AWG – 2000 kcmil sizes, the sample is to be 24 inches or 610 mm long and, figuring from one end of the sample, measurement is to be made of the maximum and minimum diameters over the insulation at each of five points 4, 8, 12, 16, and 20 inches from that end or 102, 203, 305, 406 and 508 mm from that end. Each of the ten measurements (two at each point) is to be estimated to the nearest 0.0001 inch (0.1 mil) or 0.002 mm and recorded. The insulation is to be removed for a short distance at one end of the sample without damage to the conductor or any separator, and the maximum and minimum diameters are then to be measured over the conductor or any separator and recorded as estimates to the nearest 0.0001 inch or 0.002 mm.

240.4 The average of the two recorded measurements over the conductor or any separator is to be subtracted from the average of the ten recorded measurements over the insulation. The result is to be divided by two and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the average thickness of insulation for comparison with the minimum average thickness specified for the construction in the wire standard.

240.5 ROUNDING TO THE NEAREST 0.001 inch – A figure in the third decimal place is to remain unchanged where the figure in the fourth decimal place is 0 – 4 and the figure in the third decimal place is odd or even, or where the figure in the fourth decimal place is 5 and the figure in the third decimal place is even (0, 2, 4, and so forth). A figure in the third decimal place is to be increased by 1 where the figure in the fourth decimal place is 6 – 9 and the figure in the third decimal place is odd or even, or where the figure in the fourth decimal place is 5 and the figure in the third decimal place is odd (1, 3, 5, and so forth).

240.6 ROUNDING TO THE NEAREST 0.01 mm – A figure in the second decimal place is to remain unchanged where the figure in the third decimal place is 0 – 4 and the figure in the second decimal place is odd or even, or where the figure in the third decimal place is 5 and the figure in the second decimal place is even (0, 2, 4, and so forth). A figure in the second decimal place is to be increased by 1 where the figure in the third decimal place is 6 – 9 and the figure in the second decimal place is odd or even, or where the figure in the third decimal place is 5 and the figure in the second decimal place is odd (1, 3, 5, and so forth).

240.7 Where the results obtained via the procedures described in 240.1 – 240.4 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to measure the maximum and minimum thicknesses of insulation directly at each of the five points described in 240.3. To accomplish this, five sections 4 inches or 100 mm long are to be cut from the sample from 240.3 with one of the five points at the center of each section. Without damaging or stressing the insulation, the conductor and any separator are to be removed and the five tubes of insulation are to be cut in two at their centers. Each cut is to be clean and perpendicular to the longitudinal axis of the tube. This yields ten specimens for measurement; however, measurements are to be made on only five specimens – on one specimen from each tube. The clean-cut end of each of the five specimens is to be viewed through the instrument and the maximum and minimum thicknesses of each are to be found and recorded to the nearest 0.0001 inch or 0.001 mm. The average of the ten measurements is to be calculated and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the average thickness specified in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

Minimum thickness at any point

240.8 The point of minimum diameter over the insulation is to be determined with the instrument used for the measurements specified in 240.3. The sample from 240.3 is to be used unless it has been cut as indicated in 240.7, in which case, a second sample of the same length is to be used.

240.9 With the point of minimum diameter at its center, a section 4 inches or 100 mm long is to be cut from the sample. Without damaging or stressing the insulation, the conductor and any separator are to be removed and the tube of insulation is to be cut in two at the point of minimum diameter to yield two specimens for measurement. The cut is to be clean and perpendicular to the longitudinal axis of the tube.

240.10 Measurements of the minimum thickness of insulation are to be made by means of a dead-weight pin-gauge dial micrometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen through a flat, rectangular presser foot 0.043 inch by 0.312 inch or 1.09 mm by 7.92 mm. The pin is to be 0.437 inch or 11.10 mm long and 0.020 inch or 0.51 mm in diameter (a pin 0.043 inch or 1.09 mm in diameter is appropriate for wires and cables having strands larger than 0.043 inch or 1.09 mm in diameter). The instrument is to be 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 0.002 mm. See 240.2.

240.11 While the presser foot of the dial micrometer is raised from the pin, one of the specimens from 240.9 is to be placed on the pin (clean-cut end first) so that the entire length of the pin contacts the interior of the insulation. The presser foot is to be lowered gently onto the specimen and a reading estimated to the nearest 0.0001 inch or 0.002 mm is to be taken immediately and recorded. The presser foot is then to be raised, the specimen is to be rotated on the pin, and a second reading is to be taken and recorded. This procedure is to be repeated until the thinnest point of the insulation is found and recorded. The specimen is not to be rotated while in contact with the presser foot.

240.12 The procedures described in 240.11 are to be repeated with the second specimen.

240.13 The smallest of all of the readings recorded for both specimens is to be rounded off as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the minimum thickness at any point of the insulation for comparison with the minimum thickness at any point specified for the construction in the wire standard.

240.14 Where the results obtained via the procedures described in 240.8 – 240.13 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to view the clean-cut end of one of the two specimens. The point of minimum thickness is to be located and the thickness reading is to be recorded. The recorded value is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the minimum thickness at any point specified for the construction in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

241 – 249 *Reserved for Future Use*

250 Thicknesses of Insulation on Flexible Cord and on Fixture Wire

250.1 Except as noted in 250.11, the difference method is to be employed to determine the average thickness of the insulation on any conductor and to determine the minimum thickness at any point of the insulation on a conductor having a core diameter smaller than the 0.043 inch or 1.09 mm diameter of the gauge pin specified in 250.6 – 250.10 – for example, a 24, 22, or 20 AWG conductor, an 18 AWG solid conductor, or a tinsel-cord conductor.

250.2 The difference method is to consist of determining the average diameter over the insulation and subtracting from it the diameter of the conductor plus any separator, with the difference divided by two and the result taken as the average thickness of the insulation. Measurements are to be made either with a machinist's micrometer caliper having flat surfaces on both the anvil and the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, or by means of a dead-weight dial micrometer having an anvil and presser foot 0.078 inch wide and 0.375 in long (1.98 by 9.52 mm) and resting on a specimen with 10 ±2 gf or 0.10 ±0.02 N.

250.3 Five sets of measurements are to be taken along the specimen and the average of the five sets of measurements determined. Each set of measurements is to consist of the determination of the maximum and the minimum diameters at the place measured.

250.4 Instead of the machinist's micrometer caliper or dead-weight dial micrometer, a simply manipulated optical device accurate to at least 0.001 inch or 0.01 mm is appropriate to use. When using an optical device, specimens are to be cut perpendicular to the axis of the conductor.

250.5 Where the results of measurements by these methods do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. When measured by means of an optical device, it is appropriate for the average thickness of insulation on a stranded conductor to be 3 mils or 0.08 mm less than specified for the construction in the wire standard.

250.6 Except as noted in 250.9, it is appropriate to determine the minimum thickness at any point of the insulation on a conductor having a core diameter of at least 0.043 inch or 1.09 mm – such as an 18 AWG stranded conductor or any larger conductor – and the minimum thickness at any point of the insulation and the web of a parallel cord by means of a pin-gauge dial micrometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen. The pin is to be 0.437 inch or 11.10 mm long and 0.043 inch or 1.09 mm in diameter, and the end of the presser foot that touches the specimen is to be a flat rectangle 0.043 inch wide by 0.312 inch long or 1.09 mm by 7.92 mm.

250.7 The copper conductor(s) and any separator(s) are to be removed. In the case of a parallel cord, each specimen for the measurement of the distance between copper conductors specified in the wire standard is to be cut down on one side to the bottom of the cavity left by one conductor (directly opposite the cavity left by the adjacent conductor) to accommodate the presser foot.

250.8 The specimen is to be placed on the pin, the presser foot brought to rest gently on the specimen, and the reading taken immediately. The specimen is to be located on the pin with the entire length of the presser foot making contact with the specimen. The specimen is to be rotated and several measurements made to determine the actual minimum thickness at any point. The presser foot is not to be in contact with the specimen while the specimen is being rotated.

250.9 Instead of the pin-gauge dial micrometer, it is appropriate to use a simply manipulated optical device accurate to at least 0.001 inch or 0.01 mm. When using an optical device, specimens are to be cut perpendicular to the axis of the conductor.

250.10 Where the results of these measurements do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. When measured by means of an optical device, it is appropriate for the minimum thickness at any point of the insulation on a stranded conductor to be 3 mils or 0.08 mm less than specified for the construction in the wire standard.

250.11 Where the core diameter of a conductor is less than 0.043 inch or 1.09 mm, it is appropriate to determine the average and minimum thicknesses of insulation by means of a pin-gauge dial micrometer where a pin having a diameter less than 0.043 inch or 1.09 mm is used. The wire standards typically specify this pin as 0.020 inch or 0.51 mm in diameter.

251 – 259 *Reserved for Future Use*

260 Thicknesses of Jacket on Thermoplastic- and Thermoset-Insulated Wires and Cables

260.1 Two 6-inch or 150-mm lengths are to be cut from a sample length of the finished, jacketed wire or cable. Each cut is to be clean and in a plane perpendicular to the longitudinal axis of the wire or cable. The two lengths are to be taken from portions of the wire or cable that are at least 10 ft or 3 m apart.

260.2 The conductor or conductors and any separator(s) are to be removed and each hollow section is to be slit longitudinally. In the absence of a tape or braid between the insulation and jacket that facilitates separation of the two in the case of a thermoset-insulated wire or cable, each section is to be split, skived, or buffed on the inside surface to just remove all traces of the insulation. A 3/8-inch or 10-mm slice is to be cut from the center of each of the resulting hollow lengths of PVC or nylon or thermoset jacket. Each cut is to be clean and in a plane perpendicular to the longitudinal axis of the hollow length. The slices are not to be stressed or strained more than the minimum to accomplish the cuts (stretching and squashing alter the dimensions).

260.3 The measurements from which the thicknesses are determined are to made 30 min or more after any splitting, skiving, or buffing. They are to be made by means of a dead-weight pin-gauge dial micromometer that exerts 25 ±2 gf or 0.25 ±0.02 N on a specimen through a flat, rectangular presser foot measuring 0.043 inch by 0.312 inch or 1.09 mm by 7.92 mm. The pin is to be 0.437 inch or 11.10 mm long and 0.020 inch or 0.51 mm in diameter. The instrument is to be 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 0.002 mm. See 240.2 regarding the temperature at which measurements are to be made.

260.4 While the presser foot of the dial micrometer is raised from the pin, one of the slices is to be hung at a location on the pin that enables the entire length of the presser foot to contact the outer surface of the PVC or nylon or thermoset jacket and the entire inner surface of the slice to be contacted by the pin. The presser foot is to be lowered gently onto the slice, and a reading estimated to the nearest 0.0001 inch or 0.002 mm is to be taken immediately and is to be recorded. This procedure is to be repeated until a total of five readings is made, each being at a different part of the slice and one being at the thinnest part of the PVC or nylon or thermoset jacket. The presser foot is not to be in contact with the jacket while the slice is being moved from one position of measurement to the next.

260.5 The procedures described in 260.4 are to be repeated with the second slice of PVC or nylon or thermoset jacket.

260.6 The average of all of the readings recorded for both slices of PVC or thermoset jacket from pump cable is to be calculated and rounded off as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the average thickness of the PVC or thermoset jacket for comparison with the minimum average thickness specified for the construction in the wire standard. See 260.8 concerning referee measurements.

260.7 The smallest of all of the readings recorded for both slices is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm. The rounded result is to be taken as the minimum thickness at any point of the PVC or nylon or thermoset jacket for comparison with the minimum thickness at any point of the jacket specified for the construction in the wire standard. See 260.8 concerning referee measurements.

260.8 Where the results obtained via the procedures described in 260.3 – 260.7 do not comply, a micrometer microscope or other optical instrument calibrated to read directly to at least 0.0001 inch or 0.001 mm is to be used to locate and measure the maximum and minimum thicknesses on each of the slices. The maximum and minimum thicknesses of each slice are to be recorded to the nearest 0.0001 inch or 0.001 mm. The average of the four measurements is to be calculated and then rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the average thickness of the jacket specified for the construction in the wire Standard. The smallest of the four measurements is to be rounded as indicated in 240.5 or 240.6 to the nearest 0.001 inch or 0.01 mm and compared with the minimum thickness of the jacket specified for the construction in the wire standard. The results of this procedure with the optical instrument are to be taken as conclusive.

261 – 279 *Reserved for Future Use*

280 Thicknesses of Jacket on Flexible Cord, Fixture Wire, and Elevator Cable

280.1 The average thickness of a jacket is to be determined by the difference method, which is to consist of determining the average diameter over a specimen of finished cord and subtracting from it the diameter of the core. The difference is then to be divided by two and the result taken as the thickness of the jacket. Five sets of measurements are to be taken along the specimen and the average of the five sets of measurements determined. Each set of measurements is to consist of the determination of the maximum and minimum diameters at the place measured. Measurements are to be made either with a machinist's micrometer caliper having flat surfaces on both the anvil and the end of the spindle and calibrated to read directly to at least 0.001 inch or 0.01 mm, or by means of a similarly calibrated dead-weight dial micrometer having an anvil and presser foot 0.078 inch wide and 0.375 inch long or 1.98 mm by 9.52 mm resting on a specimen with 10 ±2 gf or 0.10 ±0.02 N. The entire surface of the spindle of the machinist's micrometer caliper or the presser foot of the dial micrometer is to be in contact with the specimen during each measurement. Where the results of measurements by this method do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm.

280.2 The minimum thickness at any point of a jacket is to be determined by measuring a specimen that has been removed from the conductor assembly of the cord. The specimen is to be selected, unless its cross section is the complete cross section of the jacket, to include the thinnest portion of the jacket as determined visually. Measurements are to be made with a machinist's micrometer caliper as described in 280.1, with the dead-weight dial micrometer described in 280.3, with the dead-weight pin-gauge dial micrometer described in 260.3, or by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm. The entire surface of the spindle of the machinist's micrometer caliper, the entire surface of the presser foot of the dial micrometer, or the entire length of the pin is to be in contact with the specimen during each measurement. Except where measurement is by means of a pin gauge or optical device, buffing is to be used to just remove all traces left by the core.

280.2 revised May 6, 2003

280.3 The dead-weight dial micrometer referenced in 280.2 is to have a presser foot 0.250 ±0.010 inch or 6.4 ±0.2 mm in diameter and is to exert a total of 3.0 ±0.1 ozf or 0.84 ±0.02 N or 85 ±3 gf on the specimen – the load being applied by means of a weight.

281 – 399 *Reserved for Future Use*

PHYSICAL PROPERTIES TESTS OF INSULATION AND JACKET

400 General

400.1 The descriptions of the test apparatus and methods in Sections 420, 440, 470 and 480 apply to the determination of the physical properties of aged and unaged specimens of compounds that are used as conductor insulation and as jackets.

401 – 419 *Reserved for Future Use*

420 Apparatus

Power-driven testing machine

420.1 Measurement of ultimate elongation and tensile strength are to be made on a power-driven machine provided with a device that indicates the actual maximum load at which a specimen breaks. Where a machine of the spring-balance type is used, the spring is to be kept from recoiling. The machine is to be adjusted to make the speed of the power-actuated grip 20 ±1 in/min or 500 ±25 mm/min (unless specified otherwise in the applicable part of Specific Materials, Section 50, of this standard, or in the applicable wire standard, such as 2.0 ±0.2 in/min or 50 ±5 mm/min for PE as specified in note [c] to Table 50.136). The applied tension as indicated by a dial or scale is to be accurate to 2 percent or less of the value read, and a set of weights is to be on hand for calibrating the machine. A method for calibrating the machine is given in the American Society for Testing and Materials "Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension" (ASTM D 412-98).

Die-cut specimens

420.2 The die used to cut the sample material into specimens is to produce specimens of a dumbbell shape. ASTM die C is to be used to produce dumbbell specimens having a constricted portion 1/4 inch or 6 mm wide, plus the other dimensions shown in Figure 420.1. Where the amount of material is inadequate for die C, it is appropriate to use ASTM die D, which produces dumbbell specimens having a constricted portion 1/8 inch or 3 mm wide and other dimensions smaller than those produced by die C.

Recovery-test apparatus

420.3 Recovery tests are to be made on the power-driven machine described in 420.1 where the machine enables instant stopping of the movable grip. Otherwise, the apparatus shown in Figure 420.2 and Table 420.1 is to be employed. The spools "a" are to be free to slide on the shaft "b" and are to be slotted to engage pins "c", which act as clutches. The movable grips are to be attached to strips of rawhide belt lacing 5/8 inch or 16 mm in width, which are to pass through clamps "d" and then to the spools. The grips illustrated are the ones that are to be used for die-cut specimens. For tubular specimens, roll-type grips are to be used.

420.4 The specimen marker is to consist of a stamp with parallel metal blades capable of marking fine lines with ink on a specimen without damaging the insulation or jacket. The lines (bench marks) are to be 1 inch or 25 mm apart, are to be applied at right angles to the longitudinal axis of the wire, cable, or cord, and are to be centrally located on the constricted portion of the specimen. Because the width of a mark increases while a specimen is being stretched, measurement of elongation is to be made with reference to the center of each mark – that is, with reference to a point halfway between the edges of each mark.

Splitting or skiving machine

420.5 A power-driven splitting or skiving machine is to consist of an adjustable upper pressure roller, a band knife or a rotary bell knife, and a power-driven feed roller that passes a sample across the knife blade thereby separating or slicing the sample into layers, with no resulting heating of the sample material from which die-cut specimens are to be prepared. It is appropriate to use the machine to achieve the following:

a) To produce a strip of insulation from a 6 AWG or larger conductor or a strip of jacketing material, and

b) To remove irregularities from samples of insulation, jacket, or the like that are not thinner than about 30 mils or 0.76 mm.

Figure 420.1
Die-cut specimen

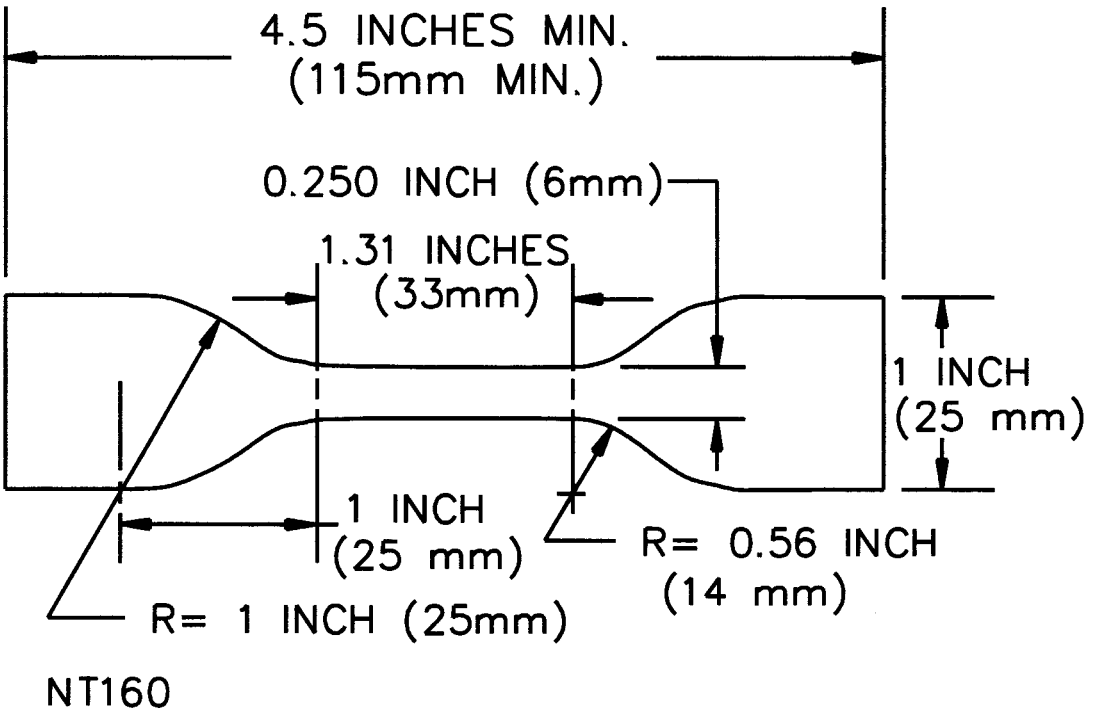


Table 420.1
Decimal-inch and millimeter dimensions of recovery-test machine

Dimension in drawing	Dimension in decimal inches	Dimension in millimeters
1/8 inch	0.125	3.18
3/16	0.188	4.76
1/4	0.250	6.35
5/16	0.312	7.92
3/8	0.375	9.52
1/2	0.500	12.7
19/32	0.594	15.09
5/8	0.625	16
11/16	0.688	17.48
3/4	0.750	19.1
7/8	0.875	22.2
1	1.000	25.4
1-1/16	1.062	27.0
1-1/8	1.125	28.6
1-1/4	1.250	31.8
1-17/64	1.266	32.2
1-1/2	1.5	38
1-3/4	1.75	44.5
2-3/8	2.375	60.3
3-1/4	3.250	82.6
3-7/8	3.875	98.4
6	6	152
1 ft 6 inches	18	457
2 8	32	813

Buffing machine

420.6 A power-driven buffing machine (grinding wheel) is appropriate for buffing irregularities from the samples from which die-cut specimens are to be prepared. The abrasive wheel is to be of about No. 36 grit (particle size of 0.019 inch or 0.486 mm). The wheel is to run true and is not to vibrate. The diameter of the wheel is not specified; however, 4-3/4 – 6-1/4 inch or 0.12 – 0.16 m has been found appropriate. The rotary velocity of the wheel is to be 2500 – 3500 r/min. The diameter and rotary velocity of the wheel are to be selected to give the wheel a peripheral speed (rpm × π × wheel diameter) of 3000 – 5000 ft/min or 15 – 25 m/s. CAUTION – The maximum wheel diameter stated in this paragraph and the maximum wheel rpm stated in this paragraph shall not be used together as this combination will result in a peripheral speed above 5000 ft/min or 25 m/s. This applies even for wheels that are marked as being intended for a peripheral speed above 5000 ft/min or 25 m/s. The machine is to have a slow feed that applies light pressure and removes very little material at one cut, thereby not overheating the specimen or the wheel.

Machine for stretching copper

420.7 A hand- or power-driven machine with steel grips is appropriate for stretching copper for the purpose of removing a copper conductor from the insulation.

Apparatus for aging

Specimen separation

420.8 In each type of apparatus, provision is to be made for suspending each specimen vertically within the chamber without touching the sides of the chamber or any other specimen.

Air-oven aging

420.9 The apparatus for the air-oven aging of specimens is to be as indicated in ASTM D 5423-93(R1999) (Type II ovens) and ASTM D 5374-93(R1999) and is to circulate the air within the aging chamber at high velocity. Fresh air is to be admitted, continuously, to the chamber to maintain normal oxygen content in the air surrounding the specimens. The exhaust ports of the oven are to be adjusted to achieve 100– 200 complete fresh-air changes per hour. The blower, fan, or other means for circulating the air is to be located entirely outside the aging chamber. The oven is to maintain the specified temperature within ±1.0°C (±1.8°F).

421 – 439 *Reserved for Future Use*

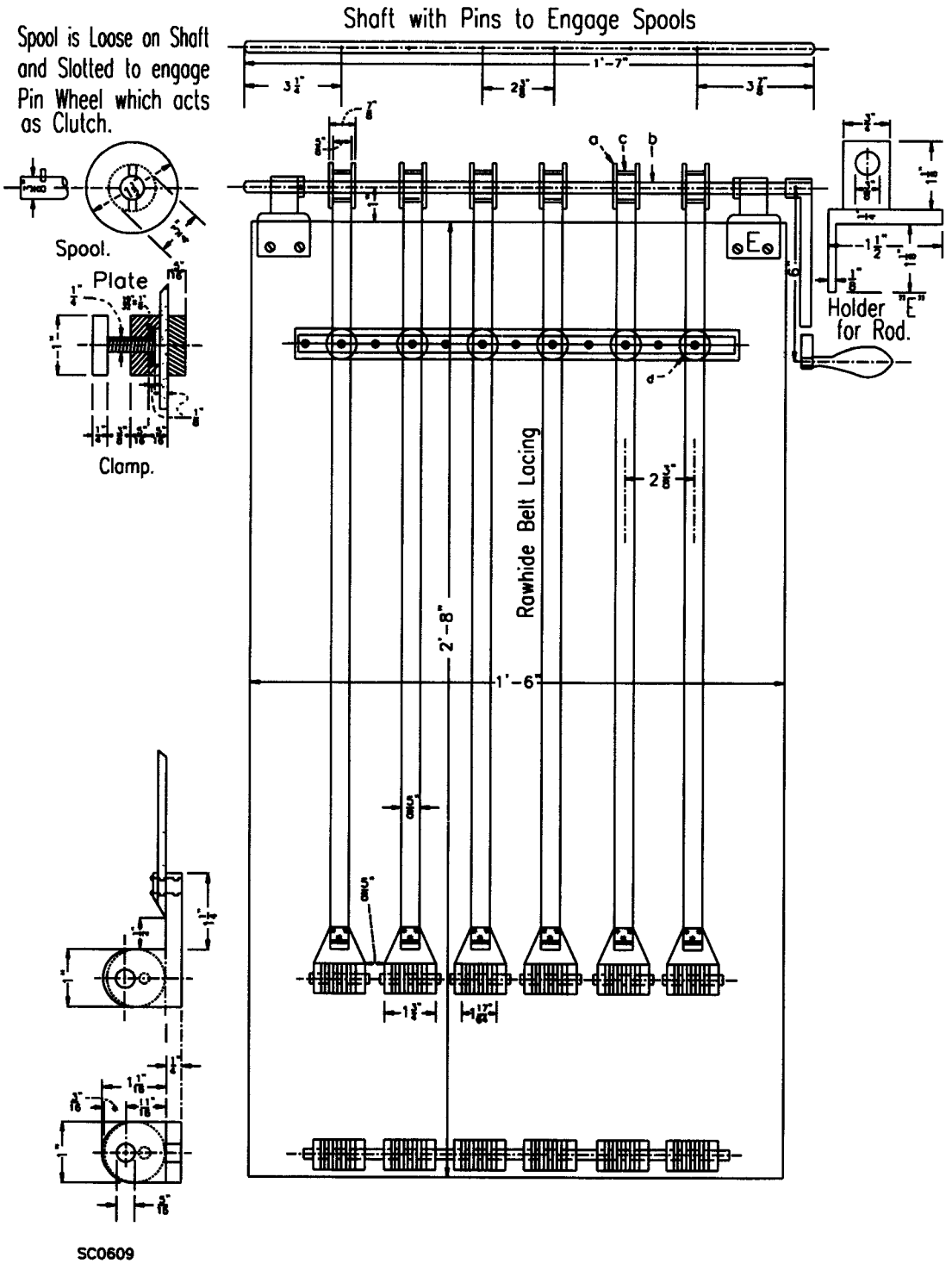
440 Preparation of Specimens

All specimens

440.1 Samples for the physical tests of aged and unaged specimens are to be taken from a coil or reel of finished wire, cable, and/or cord or from the product during manufacture at any point following the cross-linking process in the case of thermosets. The tests are to be conducted at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unless the manufacturer desires to have them made sooner, the measurements of tensile strength and ultimate elongation are not to be made until at least 48 h after the wire, cable, or cord is manufactured.

440.2 For an unjacketed conductor smaller than 6 AWG, except as noted in 440.11, a test specimen is to consist of a length of the complete tube formed by the insulation; however, in the case of a parallel cord, the specimen is to be the unseparated double tube where there is too little material for preparation of a die-cut specimen. For a jacketed conductor, for a 6 AWG or larger conductor, and for a conductor having insulation more than 95 mils or 2.41 mm thick, the tube of insulation is to be cut longitudinally and either any irregularities are to be removed by means of a splitting or skiving machine (see 420.5) or a slow-feed grinding machine (see 420.6), or a strip of the insulation material is to be produced with parallel and smooth surfaces by machine splitting or skiving or, for XL and PE only (see 440.3), by machine planing. The tube, with irregularities removed, or the strip is then to be laid out flat to form a rectangle from which a test specimen is to be cut with a die. A test specimen of a jacket is to be die-cut from a sample that has been cut longitudinally, removed from the conductor assembly, and then prepared as indicated for the insulation. The test specimen is not to have any surface incisions or other imperfections.

Figure 420.2
Recovery-test machine



See Table 420.1 for decimal-inch and millimeter dimensions

440.3 When removing fabric impressions or other unevenness by buffing, the buffing is not to be carried beyond the point at which the unevenness just disappears. When splitting or skiving is used to remove fabric impressions or other unevenness, it is appropriate to remove material past the point at which the unevenness disappears; however, no more additional material is to be removed than required to supply resistance to the blade for an even cut. When removing one layer from a double-layer construction, the buffing, splitting, or skiving is not to be carried beyond the point at which the removed layer just disappears. For reducing the thickness of the sample for the preparation of test specimens, it is appropriate to split or skive the insulation to the required thickness or to slice the insulation nearly to the required thickness and then finish by buffing. In any case, the final split or skived surface(s) or the final buffed surface is (are) to be smooth. Use of specimens of XL or PE material that are die-cut from strips of the material produced by machine planing is appropriate where the planed surfaces are flat, parallel, and smooth. Any splitting, skiving, planing, or buffing is to be completed at least 30 min prior to testing of the specimens.

Specimens from solid conductors

Removal of fibrous insulation or covering

440.4 Where the conductor has a fibrous covering, a sample of the wire about 2 ft or 600 mm in length is to be laid out straight on a table having a smooth, level surface. The fibrous covering is to be cut by means of a plane with a sharp blade adjusted to cut to a depth not greater than the thickness of the fibrous covering. This procedure is also to be followed in the case of the individual fibrous-covered wires of a multiple-conductor wire, cable, or assembly after removal of the outer covering. After the fibrous covering is cut, it is to be taken off by hand and the insulation is to be inspected. Any portion of the insulation showing any physical damage is not to be retained for test purposes. Where a rough edge remains at the seams following the separation of individual wires made by a strip process, such irregularities are to be removed by buffing or filing.

440.5 A braid, wrap, or jacket on a thermoplastic-insulated fixture wire is to be removed from a sample as indicated in 440.4.

Diameters

440.6 The sample is to be cut into specimens of a convenient length. The insulation is then to be cut circumferentially at a distance of 1/2 inch or 13 mm from each end of each specimen, the cut ends of insulation are to be removed, and the exposed ends of the conductor are to be freed from any adhering particles of insulation by means of a wooden blade.

440.7 Measurements to 0.001 inch or 0.01 mm of the diameter of the conductor and the diameter over the insulation are to be made with a machinist's micrometer caliper, dead-weight dial micrometer, or optical device as described in 240.1– 240.7. The diameter of each exposed end section of the copper is to be measured at a point 1/4 inch or 6 mm from the end, and the average of the two measurements is to be taken as the diameter of the conductor.

440.8 Measurements of the maximum and minimum diameters over the insulation are to be made at a point halfway between the ends of the specimen and at points 1 inch or 25 mm to each side to the mid-point. The average of the maximum and minimum diameters at each point is to be determined, and the lowest of the three averages is to be used as the diameter of the specimen in calculating its cross-sectional area.

Conductor removal

440.9 GENERAL – After the measurements of the diameter of the conductor and insulation are obtained, the conductor is to be removed from the insulation by one of the methods described in 440.10, 440.11, and 440.12.

440.10 STRETCHING – The free ends of the conductor are to be clamped in the steel jaws of the machine mentioned in 420.7 and the conductor is to be stretched to its breaking point to facilitate its removal from the insulation. The unbroken end of the conductor is then to be clamped in a vise and the insulation is to be gently and slowly pulled from the copper by hand. During this operation, the tube of insulation is not to be twisted over a quarter of a turn at any point, and is not to be compressed length-wise, which strains it.

440.11 MERCURY – This method applies only in the case of conductors coated with tin or other metal. The specimen is to be prepared and measured as described in 440.4 – 440.8, after which it is to be immersed in pure mercury at a temperature of 24.0 ±8.0°C (75.2 ±14.4°F) until the conductor can be removed from the insulation without damage to the insulation. The specimen is then to be taken out of the mercury, wiped off, and the insulation pulled from the conductor by hand. DANGER – Mercury is poisonous, particularly when its vapors are inhaled. Mercury evaporates at room temperature so, in addition to wearing plastic or rubber gloves to keep mercury from the hands, it is mandatory to use mercury only under an operating fume hood.

440.12 DIE-CUT SPECIMENS – Preparatory to making die-cut specimens, the insulation is to be cut through to the conductor longitudinally and then the conductor is to be removed.

440.13 Where a jacket is applied directly to thermoset insulation, it is usual to prepare die-cut specimens of the insulation and jacket together. An effort is to be made to separate the jacket from the insulation by slitting the covering (insulation plus jacket) through to the conductor and then pulling the jacket and insulation apart by means of pliers. Sometimes this procedure is facilitated by immersing the sample in hot water for a few minutes just prior to pulling the jacket and insulation apart.

440.14 Where the jacket cannot be separated from the insulation, specimens are to be prepared by splitting, skiving, or buffing. Where buffing is used, the apparatus for this operation is to be equipped with a cylindrical table capable of being advanced very gradually.

440.15 To prepare specimens by buffing, two 8-inch or 200-mm lengths of the finished wire are to be taken, and the conductor is to be removed from the covering (insulation plus jacket) after slitting the covering through to the conductor. One length of covering is to be stretched into the clamps of the buffing apparatus to make the covering lie flat, with the jacket toward the wheel. The jacket is then to be buffed away without buffing any farther than is required. This process is to be repeated with the other length of covering, except that the sample is to be reversed in the clamps and the insulation is to be buffed away.

440.16 Die-cut specimens are to be prepared as indicated in 440.22 – 440.24 from the samples from 440.14 and 440.15 after the split, skived, or buffed samples have recovered for at least 30 min. In case of a sample from a small wire, it is appropriate to use a die having a constricted portion 0.125 inch or 3 mm wide.

Bench marks

440.17 Each specimen is then to be examined. Any specimen that shows physical damage is to be discarded and a new specimen is to be prepared. Two marks, 1 inch or 25 mm apart and equidistant from the center of the specimen, are to be placed on the specimen by means of the marker described in 420.4. These bench marks are to be at right angles to the direction of pull in the testing machine. The marks are not to be wide and the specimen is to be completely at rest while being marked.

Specimens from stranded conductors

Diameters

440.18 After the removal of any material applied over the insulation, a sample is to be cut into specimens of a convenient length, the insulation is to be removed from the ends of the conductor, and measurements are to be made of the diameter over the conductor and over the insulation as described for a solid conductor in 440.7 and 440.8.

Conductor removal

440.19 The individual strands of the conductor are to be removed from the insulation by means of a pair of pliers or by the wire-stretching machine described in 420.7, without damaging the specimen. Where difficulty is experienced in removing strands coated with tin or other metal, the sample is to be immersed in mercury as described for solid conductors in 440.11, after which the strands are easily removable.

Die-cut specimens

440.20 Where the conductor has a jacket applied directly to thermoset insulation, die-cut specimens are to be prepared as described in 440.13 – 440.16 and 440.22 – 440.24.

Bench marks

440.21 Each specimen is to be examined. Any specimen that shows physical damage is to be discarded and a new specimen is to be prepared. Two 1-inch or 25-mm bench marks are then to be placed on the specimen as described for a solid conductor in 440.17.

Die-cut specimens

440.22 A sample is to be cut into sections (typically 7 inches or 180 mm) and the insulation on each section is to be cut through to the conductor longitudinally (or, in the case of a jacket or a fibrous covering, the jacket or fibrous covering on each section is to be cut through to the conductor assembly) and the conductor is to be removed. This section of insulation is to be split or skived or buffed to remove any irregularities and a test specimen is then to be cut from it with a die as described in 420.2 and 440.23 and is then to be marked with two lines 1 inch or 25 mm apart. The width of the specimen between the two marks is to be checked.

440.23 The use of a press for operating the die reduces variations between specimens. However, where the die is struck with a mallet, all points or cutting edges of the die are to be in contact with the insulation before the die is struck. The cutting is to be done on a smooth surface that is of a material that does not damage the cutting edges of the die.

440.24 The thickness of the specimen is to be taken as the smallest of four measurements to 0.001 inch or 0.01 mm, two of which are to be made at 1/2-inch or 13-mm intervals between the bench marks on one edge beginning 1/4 inch or 6 mm from either mark, with the other two measurements being made at corresponding points on the opposite edge. These measurements are to be made with a dead-weight dial micrometer having a presser foot 0.250 ±0.010 inch or 6.4 ±0.2 mm in diameter and exerting a total of 3.0 ±0.1 ozf or 85 ±3 gf or 0.84 ±0.02 N on the specimen – the load being applied by means of a weight. The presser foot is to be at least 1/16 inch or 2 mm onto the edge of the specimen for each measurement. Where the results of measurements by this method do not comply, referee measurements are to be made by means of an optical device calibrated to read directly to at least 0.0001 inch or 0.001 mm.

441 – 459 *Reserved for Future Use*

460 Recovery

460.1 The recovery test is to be conducted using specimens that have not been subjected previously to any test. Each specimen is to be clamped in position, with both marks visible between the grips. The grips are to be adjusted symmetrically to distribute the tension uniformly over the cross section of the specimen. The movable grip is to be adjusted to make the test piece taut, not under tension. The temperature of the ambient air is to be recorded.

460.2 The grips are to be separated at a rate of 20 ±1 in/min or 500 ±25 mm/min until the specified elongation is reached. The specimen is to be held in the stretched position for 2 min, released immediately without snapping back, rested for 2 min, and the distance between the marks is then to be measured to the nearest 0.01 inch or 0.1 mm and is to be recorded. Just before releasing the specimen, the distance between the marks is to be observed again. Where it has decreased because of slipping of the specimen in the grips, the test is to be repeated with another specimen.

461 – 469 *Reserved for Future Use*

470 Ultimate Elongation and Tensile Strength

470.1 Ultimate-elongation and tensile-strength tests are to be conducted simultaneously, using specimens that have not been subjected previously to any test. Any paper separator that cannot be removed without damage to the insulation or jacket is to be wet with water or a half-and-half mixture of ethylene or propylene glycol and water just prior to being clamped in the grips. Each specimen (tubular or die-cut) is to be clamped in position with both 1-inch or 25-mm bench marks outside of and between the grips. The marks on a tubular specimen are to be just outside of the grips and centered between the grips (the distance between a mark and the adjacent grip is not to exceed 1/2 inch or 13 mm). The movable grip is to be adjusted to make the specimen (tubular or die-cut) taut, not under tension. The grips are then to be separated at a rate of 20 ±1 in/min or 500 ±25 mm/min (2.0 ±0.2 in/min or 50 ±5 mm/min for high-density PE as specified in note [c] to Table 50.136) until the specimen is ruptured. During separation, the distance between the bench marks is to be measured continuously by an operator using the manual scale method, or the operator is to make the elongation measurement by means of an extensometer. A video or laser extensometer is appropriate. A mechanical extensometer is appropriate where the length of the specimen results in there being room between the grips for the sensor carriages to be connected and where the drag and the contact forces comply with both of the following:

a) Counter weights are to balance the mass of the sensor carriages to the degree that the drag is not greater than 0.05 lbf or 0.22 N or 23 gf.

b) Each carriage contact is to apply the same force to the specimen. The contact force of each sensor carriage on the specimen is to be adjusted to the minimum that keeps the carriage from slipping on the specimen. That minimum force is not to damage the specimen or result in the specimen parting at either carriage contact.

The distance between the bench marks at the instant of rupture is to be recorded with an accuracy of at least 0.1 inch or 2 mm. The ultimate elongation, in percent, is to be taken as 100 times the increase in distance between the bench marks divided by the original distance of 1 inch or 25 mm.

470.2 After rupture of the specimen, the maximum load in pounds force, meganewtons, newtons, or kilograms force is to be noted from the dial or scale and recorded together with the original dimensions of the specimen for use in calculating the tensile strength. Where a specimen breaks within one of the jaws at a value below that specified as the minimum, the test results are to be disregarded and the test is to be repeated with another specimen.

470.3 The cross-sectional area of a tubular specimen is to be computed by means of the formula

$$A = 0.7854\ (D^2 - d^2)$$

in which:

A is the cross-sectional area of the specimen in square inches, square meters, square centimeters, or square millimeters;

D is the diameter over the insulation in inches, meters, centimeters, or millimeters; and

d is the diameter of the conductor in inches, meters, centimeters, or millimeters.

470.4 The cross-sectional area of a tubular specimen with an irregular interior or exterior surface, such as caused by ridges on the outer surface or by coarse stranding, and the cross-sectional area of an integral parallel specimen is to be computed by means of whichever of the following formulas is applicable:

$$A_{in}2 = \frac{W}{163.87\ G}$$

in which:

A is the cross-sectional area of the specimen in square inches,

W is the weight in grams (to the nearest 0.1 g) of a 10-inch length of insulation, and

G is the specific gravity of the compound determined as indicated in 470.5 – 470.9; or

$$A_{m^2} = \frac{4 \times 10^{-6} W}{G}$$

$$A_{cm^2} = \frac{0.04 W}{G}$$

$$A_{mm^2} = \frac{4 W}{G}$$

in which:

A is the cross-sectional area of the specimen in square meters, square centimeters, or square millimeters;

W is the weight in grams of a 250-mm length of insulation; and

G is the specific gravity of the compound determined as indicated in 470.5 – 470.9.

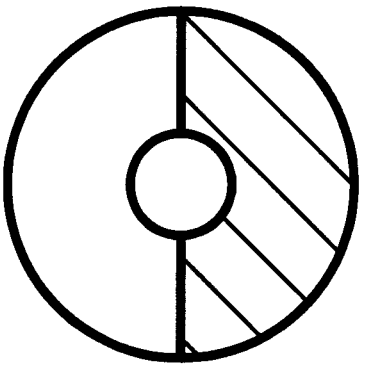
470.5 For use in any of the cross-sectional-area formulas in 470.4, the specific gravity G of a tubular specimen of irregular cross section of an integral parallel specimen is to be determined to two decimal places by the displacement method using a precision balance of a type that either yields the specific gravity G by direct reading (a Young's gravitometer) or requires calculation. All of the equipment, the water, the ethyl alcohol, and the specimen are to be at the same temperature (any convenient room temperature) throughout the procedure.

470.6 A clean 10-inch or 250-mm length adjacent to that used for preparation of the physical-properties specimens is to be cut from the finished integral parallel cord or wire or cable and the conductor(s), any covering(s) over the insulation, and any separator are to be removed. To reduce the likelihood of air being trapped in the hollow left by removal of the conductor(s), the length is to be cut parallel to its longitudinal axis through both walls of the hollow tube to result in samples with cross sections having the shapes shown shaded and unshaded in Figure 470.1. All of the cut surfaces of the sample are to be smooth.

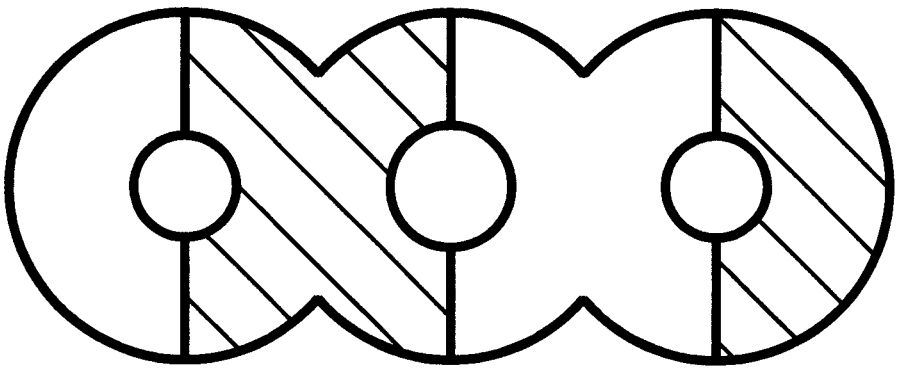
470.7 The samples are to be cut into lengths of 2 inches or 50 mm. A single short length is to be used as the specimen where it weighs 5 g or more. Several short lengths are to be used as the specimen where one short length weighs less than 5 g. The single short length or the bundle of short lengths is to be tied at its center with wire that is not larger in diameter than 0.0050 inch or 0.127 mm (No. 36 AWG) and is to be suspended by the wire from the weighing arm of balance.

470.8 Where a Young's gravitometer is used, the beam weights are to be adjusted to bring the pointer to rest at the infinity mark on the scale. A beaker or other wide-mouth container is to be filled with ethyl alcohol and placed on the platform in the instrument. The specimen is to be lifted by the wire and fully immersed in the alcohol and then removed from the alcohol and rinsed with distilled or demineralized water that is virtually free of air. The container of alcohol is to be removed and replaced with a similar container filled with virtually air-free distilled or demineralized water. The specimen is again to be lifted by the wire and then fully immersed in the water. The ethyl alcohol acts as a wetting agent and thereby helps to keep air bubbles from clinging to the specimen or wire while the specimen and wire are in the water. However, any bubbles that do remain are to be removed by rubbing the bubbles with a fine wire or by agitation of the specimen. Neither the suspending wire nor the specimen is to touch the container. The vibrator in the instrument is to be activated to assist the balance in reaching equilibrium. After equilibrium is reached, the specific gravity G is to be read to two decimal places directly from the scale.

Figure 470.1
Cross sections of samples after longitudinal cutting



single conductor

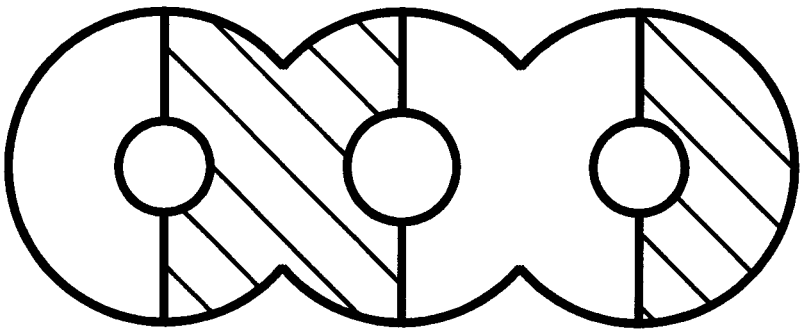


3 circuit conductors no grounding conductor Types SRD and SRDT

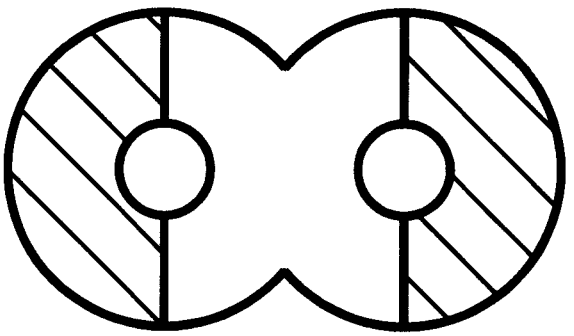
S4216

The vertical lines indicate the cutting that is required

Figure 470.1 (Cont'd)



2 circuit conductors with grounding conductor
Types SPT–1, SPT–2, SPT–3, and HPN



2 circuit conductors no grounding Types TPT, clock, SP–1, SP–2, SP–3, SPT–1, SPT–2, SPT–3, and HPN

S4217

470.9 Where a balance other than a Young's gravitometer is used, the weight W_1 in air of the specimen without its suspending wire is to be determined to the nearest 5 mg. A beaker or other wide-mouth container is to be filled with ethyl alcohol and placed on a stationary support platform below the weighing arm of the balance. The specimen is to be lifted by the wire and fully immersed in the alcohol and then removed from the alcohol and rinsed with distilled or demineralized water that is virtually free of air. The container of alcohol is to be removed and replaced with a similar container filled with virtually air-free distilled or demineralized water. The specimen is again to be lifted by the wire and then fully immersed in the water. The ethyl alcohol acts as a wetting agent and thereby helps to keep air bubbles from clinging to the specimen or wire while the specimen and wire are in the water. However, any bubbles that do remain are to be removed by rubbing the bubbles with a fine wire or by agitation of the specimen. Neither the suspending wire nor the specimen is to touch the container. The weight W_2 in water of the fully immersed specimen and its partially immersed suspending wire is then to be determined to the nearest 5 mg. The point at which the wire meets the surface of the water is to be marked on the wire and the specimen is to be removed from the water and the wire. The wire is then to be reimmersed in the water to the depth of the mark and its weight W_3 is to be accurately determined. The specific gravity G of the specimen is to be calculated to two decimal places by means of the formula

$$G = \frac{W_1}{W_1 - W_2 + W_3}$$

470.10 The tensile strength of the specimen is then to be computed by means of the formula

$$S = \frac{P}{A}$$

or, for a die-cut specimen

$$S = \frac{P}{WT}$$

in which:

S is the tensile strength in pounds force per square inch, meganewtons per square meter, newtons per square centimeter, or kilograms force per square millimeter;

P is the maximum load in pounds force, meganewtons, or kilograms force;

W is the width of the specimen in inches, meters, centimeters, or millimeters; and

T is the thickness of the specimen in inches, meters, centimeters, or millimeters.

471 – 479 *Reserved for Future Use*

480 Accelerated Aging

General

480.1 Where die-cut specimens are not employed, the specimens of conductor insulation are to be lengths of individual conductors from which the conductor and any material applied over the insulation have been removed. Where die-cut specimens are employed, all splitting, skiving, buffing, planing, and die-cutting operations are to be completed at least 30 min before the specimens are placed in the chamber for aging or are immersed in oil. Measurements for determining the cross-sectional area are to be made as described for the physical tests of insulation and are to be made after the 30-min recovery period and before the specimens are aged or are immersed in oil. In the cases of immersion in ASTM Reference Fuel C and of air-oven aging, the bench marks for the determination of elongation are to be placed on the specimens after the specimens are removed from the immersion vessel or from the chamber in which they were aged. For oil immersion, the marks are to be placed on the specimens before they are immersed in oil.

480.2 Physical tests are to be made on both aged and unaged specimens at the same time and at a room temperature of 24.0 ±8.0°C (75.2 ±14.4°F). Unaged specimens are to be maintained at this room temperature for not less than 30 min prior to being subjected to the physical tests. Specimens that have been subjected to air-oven aging are to rest for not less than 16 h and not more than 96 h at this room temperature following their removal from the Fuel C or oven and prior to their being subjected to the physical tests. Specimens that have been subjected to oil immersion are to be blotted lightly to remove any excess oil and are then to be suspended in air at the above-mentioned room temperature for 3.5 – 4.5 h before being subjected to the physical tests. Specimens that are to be aged in an oven are to be suspended vertically and are not to touch one another or the sides of the chamber at any time. Specimens having widely different properties or composition are to be aged in separate ovens. See 420.8 and 420.9.

Air-oven aging

480.3 The specimens are to be heated at the required temperature for the specified time in an oven complying with 420.9, and oven temperatures are to be recorded throughout the time of heating.

480.4 *Reserved for Future Use*

Oil immersion

480.5 The oil referred to in the following paragraphs is IRM902. ASTM D 471-98 specifies this oil as a standard test liquid.

480.6 The immersion vessel is to be a test tube having an overall diameter of at least 1 inch or 25 mm and a length of at least 6 inches or 150 mm. The tube is to be filled with oil and then placed in a bath having an automatic temperature control that maintains the specimens at the specified temperature. Specimens of finished 14 – 7 AWG wires with or without the conductor removed are to be bent at the center to form a narrow U and are then to be suspended vertically in the oil with the ends of each specimen projecting above the oil. Specimens of Types THWN-2, THWN, and THHN wire are to be immersed without removal of the nylon jacket. After immersion for the specified length of time, each specimen is to be cut in half at the center of the U bend to result in two specimens for physical tests from each length immersed. A larger vessel is to be used for die-cut specimens that are to be suspended vertically in the oil.

480.7 Except for specimens of oil-resistant Type TFN and Type TFFN wires (see 480.8), the oil-immersion vessel for flexible cord and elevator cable is to be a stainless-steel beaker or cup with a flat-plate cover and having a capacity of 500 mL. The vessel is to be filled with oil and placed in a liquid bath or a full-draft circulating-air oven. The bath is to be provided with a stirring device and automatic temperature control and is to employ a liquid for maintaining the specimens at the specified temperature. The oil in the immersion vessel is to be heated to the specified temperature before the specimens are immersed. Die-cut specimens are to be suspended vertically in the oil. Specimens of conductor insulation are to be immersed in the form of a vertical U, with the ends of each specimen (conductor or conductors removed or in place) projecting above the oil.

480.8 For specimens of oil-resistant Type TFN and Type TFFN fixture wires, the immersion vessel is to be a test tube having an overall diameter of at least 1 inch or 25 mm and a length that facilitates immersion of a straight specimen at least 6 inches or 150 mm long. The tube is to be filled with oil and placed in a bath or a full-draft circulating-air oven having an automatic temperature control that maintains the specimens at the specified temperature. Specimens of finished wire with or without the conductor removed are to be bent at the center to form a narrow U and are then to be suspended vertically in the oil, with the ends of each specimen projecting above the oil. The specimens are to be immersed without removal of the nylon jacket. After immersion for the specified length of time, each specimen is to be cut in half at the center of the U bend to result in two specimens for physical tests from each length immersed.

Gasoline immersion

480.9 The immersion vessel and specimens for the immersion tests of gasoline-resistant Type TFN and TFFN fixture wires are to be as indicated in 480.8, with 1 inch or 25 mm of tap water at the bottom and the remainder of the vessel filled with ASTM Reference Fuel C, which is described in ASTM D 471-98.

480.10 The immersion vessel and specimens for gasoline immersion of other than Type TFN and TFFN are to be as indicated in 480.6, with 1 inch or 25 mm of tap water at the bottom and the remainder of the vessel filled with ASTM Reference Fuel C (see ASTM D 471-98).