

480.11 ASTM Reference Fuel C can be made by mixing equal volumes of iso-octane and toluene. The following precautionary statements apply

Iso-octane:

**DANGER – Extremely Flammable. Harmful where inhaled. Vapor may cause flash fire.**

Do not smoke.

Eliminate all sources of ignition, especially electrical equipment that is not explosion-proof.

Use and store in closed containers.

Use forced ventilation.

Avoid build-up of vapor.

Do not breathe vapor.

Protect eyes and skin from contact.

Toluene:

**DANGER – Flammable. Vapor harmful where inhaled. Central nervous system depressant. Vapor and liquid irritate eyes, mucous membranes, and skin.**

Do not smoke.

Eliminate all sources of ignition.

Use and store in closed containers.

Use forced ventilation.

Do not breathe vapor.

Protect eyes and skin from contact.

## 481 Long-Term Aging

481.1 The temperature rating of a material is to be determined using the method of testing and evaluation described in 481.2 – 481.8.

481.2 Specimens of insulation or jacket material are to be prepared as described in Preparation of Specimens, Section 440. The prepared specimens are to be placed in a full-draft circulating-air oven that complies with 420.9. The oven is to be operating at the temperature specified in 481.3 at the time that the specimens are placed. The total number of specimens in the oven is to enable removal of specimens in sets of at least six at a time at intervals of 90, 120, and 150 days and, at the manufacturer's request, at additional intervals of 180 and 210 days.

481.3 The oven operating temperature  $T_{\text{test}}$  is to be 102 percent of the desired temperature rating expressed on the absolute (Kelvin) scale. This temperature is to be calculated using the following formula.  $T_{\text{test}}$  is to be rounded to the nearest whole number.

$$T_{\text{test}} (\text{°C}) = 1.02 \times [273.15 + T_{\text{rating}} (\text{°C})] - 273.15$$

481.4 After each of the aging intervals indicated in 481.2, a set of specimens is to be removed from the oven and the specimens in that set are to be tested individually for ultimate elongation as described in Ultimate Elongation and Tensile Strength, Section 470. The elongation value resulting for each specimen is to be expressed and recorded in percent. The elongation values for six specimens are to be averaged for each aging time interval. Each of the averages is to be recorded to the nearest whole percent.

481.5 The formula for elongation (mathematical model) is:

$$E(t) = E_{90} \times e^{-R(t - 90)}$$

The variables in the formula are the elongation in percent  $E(t)$ , the time in days  $t$ , the regression constant  $E_{90}$  (the elongation computed at 90 days), and the decay constant  $R$ .

481.6 The variables in the formula transformed as  $Y = \ln[E(t)]$ ,  $B = \ln[E_{90}]$ , and  $T = (t - 90)$  put the formula into a linear form:

$$Y = B - RT$$

481.7 Using the 90-day and longer-term data, the constants  $B$  and  $R$  are to be determined by least squares linear regression. The projected elongation at 300 days is then to be calculated.

481.8 The elongation calculated for 300 days shall not be less than 50 percent.

481.9 SHORT-TERM TEST LIMITS – For determining the values of ultimate elongation and tensile strength to establish as the minimums for unaged insulation or jacket material and for determining the retention values of ultimate elongation and tensile strength to establish as the minimums for short-term-aged insulation or jacket material, specimens are to be prepared from the same sample material from which specimens were prepared for use in the procedure described in 481.1 – 481.8 for determining the temperature rating of the material. Preparation of the specimens is to be as described in Preparation of Specimens, Section 440. Tensile strength and ultimate elongation values are to be

obtained as described in 470.1 – 480.3 using unaged specimens and specimens aged in a preheated full-draft circulating-air oven that complies with 420.9 and is operated at the temperature and for the length of time specified in Table 481.1.

481.9 added May 6, 2003

**Table 481.1**  
**Oven temperature and time for short-term aging**

Table 481.1 added May 6, 2003

°C temperature rating determined for the material as described in 481.1 – 481.8	60	75	80	90	105	125	150	180	200	250
Oven aging temperature, °C ±1°C	100	100	113	121	136	158	180	213	232	287
Oven aging time, days	7	10	7	7	7	7	7	7	7	7

481.10 The **percent ultimate elongation that is to be established as the minimum value for unaged specimens** is to be calculated as 0.85 times the percent elongation obtained in 481.9 for unaged specimens, with the result rounded (typically down) to the nearest 25 percent. For example, 300% unaged x 0.85 = 255%, which rounds to 250%.

481.10 added May 6, 2003

481.11 The **lbf/in<sup>2</sup> tensile strength that is to be established as the minimum value for unaged specimens** is to be calculated as 0.85 times the lbf/in<sup>2</sup> tensile strength obtained in 481.9 for unaged specimens, with the result rounded (typically down) to the nearest 25 lbf/in<sup>2</sup>. For example, 2000 lbf/in<sup>2</sup> unaged x 0.85 = 1700 lbf/in<sup>2</sup>.

481.11 added May 6, 2003

481.12 The **percent retention of ultimate elongation that is to be established as the minimum value for aged specimens** is not to be above 85 percent and is to be calculated as 0.85 times (percent elongation obtained in 481.9 for aged specimens) / (percent elongation obtained in 481.9 for unaged specimens), with the result rounded (typically down) to the nearest 5 percent. For example, (aged / unaged = 65% of original) x 0.85 = 55.25%, which rounds to 55%. See 481.14.

481.12 added May 6, 2003

481.13 The **percent retention of tensile strength that is to be established as the minimum value for aged specimens** is not to be above 85 percent and is to be calculated as 0.85 x (lbf/in<sup>2</sup> tensile strength obtained in 481.9 for aged specimens) / (lbf/in<sup>2</sup> tensile strength obtained in 481.9 for unaged specimens), with the result rounded (typically down) to the nearest 5 percent. For example, (aged / unaged = 70% of original) x 0.85 = 59.5%, which rounds to 60%. See 481.14.

481.13 added May 6, 2003

481.14 Where the elongation or tensile strength obtained in 481.9 for aged specimens is 55 percent or less of the elongation or tensile strength obtained for unaged specimens (aged / unaged ≤ 55%), the elongation or tensile strength to establish as the minimum value after aging is to be the manufacturer's choice of either of (a) or (b) below or, alternatively, the manufacturer has the choice of assignment of the next lower Table 481.1 temperature rating to the material, with the four minimum values established under that rating as described in 481.9 – 481.13 without the (a) and (b) options:

- a) The absolute value calculated as 0.85 times the elongation or tensile strength obtained in 481.9 after aging.

b) The minimum percent retention determined using the  $\times 0.85$  calculation as described in 481.12 or 481.13 using the elongation or tensile strength obtained from a test for 30 or 60 days at the temperature obtained by calculation as described in 481.3 instead of from a test for the time indicated in Table 481.1. In this case, the duration of the short-time aging test is to be established as 30 or 60 days rather than the shorter time indicated in Table 481.1.

481.14 added May 6, 2003

482 – 489 Reserved for Future Use

## COMPOUND ANALYSIS

Polyvinyl Chloride (PVC) Compounds

### 490 Infrared Spectroscopy

490.1 GENERAL – Infrared Analysis is to be used to provide a method for the identification of PVC wire and cable compounds. Interpretation of infrared spectral transmittance is to be used to identify the composition of a compound by comparing the compound's infrared spectra to the spectra of materials having known compositions.

490.2 The analysis is to be performed with a Fourier Transform Infrared (FTIR) Spectrometer and/or a Dispersive Infrared Spectrophotometer. The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the sample versus the number of wavelengths in one centimeter [the reciprocal wavelength ( $\text{cm}^{-1}$ ) or "wavenumber"] of the radiation. Percent transmittance is to be expressed on the ordinate and wavenumber on the abscissa. The infrared spectra obtained by the methods described is to consist of a wavenumber range of at least 4000– 400 reciprocal centimeters.

490.3 SAMPLE PREPARATION / TEST PROCEDURE– The PVC compound is to be separated into solvent-soluble and solvent-insoluble fractions by use of a centrifuge and/or by filtration. Stabilized (peroxide-inhibited) tetrahydrofuran (THF) **See 490.4**, or other solvents with demonstrated comparable solubilities, are to be used. Stabilized (peroxide-inhibited) THF is the solvent of choice and centrifugation is the preferred fraction-separation method of choice. The solvents are to be readily evaporable by gentle heating and are not to react with the PVC material. The THF stabilizer/peroxide inhibitor component shall not be present in quantities detectable in the infrared spectra. Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

490.4 PARTICULAR CAUTIONS WITH THF, AN ETHER– Tetrahydrofuran (THF) is indicated as a solvent in Infrared Spectroscopy, Section 490, Elemental Analysis, Section 492, and Gel Permeation Chromatography, Section 493 of this standard, and use of **stabilized** THF is specified. **Unstabilized THF shall not be used.** Stabilization of an ether inhibits the formation of peroxides, which are explosive when concentrated. Peroxides often concentrate as an ether is stored or exposed to air for a prolonged period; as an ether is distilled, heated to dryness, or otherwise evaporates; as heat/shock/friction are applied; and upon disposal in a manner in which incompatible materials are mixed.

490.5 The solvent-soluble compound fraction is to be cast on an optically transparent potassium bromide (KBr) crystal. The crystal is to be placed in an explosion-proof oven to evaporate the solvent, leaving a thin film of the soluble compound fraction on the KBr crystal. The crystal is then to be placed directly into the sample holder of the instrument for recording the infrared spectrum.

490.6 The insoluble portion is to be washed with additional solvent, centrifuged, and then decanted to remove the soluble compound components (resin, plasticizer, and the like). The insoluble portion is to be placed in an explosion-proof oven to evaporate the solvent. After drying, the insolubles are to be mixed with powdered spectroscopic-grade potassium bromide (KBr) and ground in a vibrating ball mill. A quantity of this mixture that produces a disk typically 1 mm thick and 1/2 inch or 12.7 mm in diameter is then to be placed in an evacuable die. The die is to be put under a vacuum and mechanical pressure of 10,000 – 15,000 lbf/in<sup>2</sup> or 69 – 103 MPa or 7 – 11 kgf/mm<sup>2</sup> is to be applied. The pressed disk is to be removed from the die, put into a disk holder, and then placed directly into the sample holder of the instrument for recording the infrared spectrum.

490.7 In the event that the PVC compound is not soluble in stabilized THF or hot ortho-dichlorobenzene, the IR spectrum is to be created from the preparation techniques described in Infrared Spectroscopy, Section 494 of this standard.

490.8 Pyrolytic Gas Chromatography (Section 495) is appropriate in place of Infrared Analysis of the PVC compound where the compound is not soluble in stabilized THF or in ortho-dichlorobenzene and the IR sample preparation techniques described in Infrared Spectroscopy, Section 494, are not effective.

490.9 REPORT – The individual spectra are to include all of the following:

- a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The sample preparation procedure or preparation code.
- d) The instrument parameters (number of scans, resolution, slit program, and the like).
- e) The test date and operator identification.

#### **491 Determination of the Ash Content**

491.1 GENERAL – This method is to be used to determine the amount of noncombustible components in a PVC wire and cable material. This is similar to the direct-calcination procedure (Method A) described in ISO 3451-89, Part 5, covering methods for the ash-content analysis of polyvinyl chloride (PVC) materials.

491.2 MATERIALS AND EQUIPMENT – The following equipment is to be used in conducting the test:

- a) An analytical balance capable of weighing to the nearest 0.1 mg.
- b) Silica or platinum crucibles of a size fillable to no more than half way by the test portion.
- c) A fume hood over the burner specified in (d) and a fume hood over the furnace specified in (e).
- d) Burner apparatus consisting of a Bunsen burner with a tripod and a clay triangle for supporting the crucible above the burner flame.
- e) A muffle furnace controlled thermostatically to a temperature of  $850 \pm 50^{\circ}\text{C}$  ( $1562 \pm 90^{\circ}\text{F}$ ).
- f) A desiccator containing an effective drying agent that does not react with the ash components.

490.7 In the event that the PVC compound is not soluble in stabilized THF or hot ortho-dichlorobenzene, the IR spectrum is to be created from the preparation techniques described in Infrared Spectroscopy, Section 494 of this standard.

490.8 Pyrolytic Gas Chromatography (Section 495) is appropriate in place of Infrared Analysis of the PVC compound where the compound is not soluble in stabilized THF or in ortho-dichlorobenzene and the IR sample preparation techniques described in Infrared Spectroscopy, Section 494, are not effective.

490.9 REPORT – The individual spectra are to include all of the following:

- a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The sample preparation procedure or preparation code.
- d) The instrument parameters (number of scans, resolution, slit program, and the like).
- e) The test date and operator identification.

#### **491 Determination of the Ash Content**

491.1 GENERAL – This method is to be used to determine the amount of noncombustible components in a PVC wire and cable material. This is similar to the direct-calcination procedure (Method A) described in ISO 3451-89, Part 5, covering methods for the ash-content analysis of polyvinyl chloride (PVC) materials.

491.2 MATERIALS AND EQUIPMENT – The following equipment is to be used in conducting the test:

- a) An analytical balance capable of weighing to the nearest 0.1 mg.
- b) Silica or platinum crucibles of a size fillable to no more than half way by the test portion.
- c) A fume hood over the burner specified in (d) and a fume hood over the furnace specified in (e).
- d) Burner apparatus consisting of a Bunsen burner with a tripod and a clay triangle for supporting the crucible above the burner flame.
- e) A muffle furnace controlled thermostatically to a temperature of  $850 \pm 50^{\circ}\text{C}$  ( $1562 \pm 90^{\circ}\text{F}$ ).
- f) A desiccator containing an effective drying agent that does not react with the ash components.

491.3 TEST PROCEDURE – A sample of the PVC compound (typically 4 – 5 grams) is to be placed in a weighed crucible that has been dried to a constant weight. The weight of the dried crucible plus the sample is to be recorded. Under the fume hood, the crucible is to be heated using the burner apparatus in a manner that burns the sample slowly and does not result in any loss of the ash. When the smoking ceases, the crucible is to be placed in a muffle furnace under an operating fume hood and heated at  $850 \pm 50^{\circ}\text{C}$  ( $1562 \pm 90^{\circ}\text{F}$ ) for 30 min. The crucible is to be removed from the furnace, cooled in a desiccator, and weighed. The crucible is to be returned to the furnace for an additional 30 min and then is to be cooled and reweighed. This calcination procedure is to be repeated until constant mass is reached – that is, until the results of two consecutive weighings do not differ by more than 0.5 mg. However, the duration of heating in the furnace is not to exceed a total of 3 h. Where a constant mass is not attained in 3 h, the mass (weight) after 3 hours is to be used for calculating the results.

491.4 At least two determinations are to be performed and the mean of the results calculated. Where the individual test results differ from one another by more than 10 percent of the mean, the procedure is to be repeated until two successive results do not differ by more than 10 percent of the mean.

491.5 CALCULATIONS – The ash content is to be calculated in percent by dividing the weight of the residue after ignition at  $850 \pm 50^{\circ}\text{C}$  ( $1562 \pm 90^{\circ}\text{F}$ ) by the original weight of the sample and multiplying by 100. The average of the results of the two or more determinations is to be recorded as the ash content.

491.6 REPORT – The report is to include each of the following:

- a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or trade name of the material manufacturer and the assigned code (file number).
- c) The weights recorded to the nearest 0.1 mg.
- d) The average ash content calculated to the nearest 0.1 percent.
- e) The test date(s) and operator identification.

## 492 Elemental Analysis

492.1 GENERAL – Elemental Analysis is to be used to provide quantitative data on the lead, cadmium, barium, or zinc content of a PVC wire and cable compound. The heat stabilizer system typically consists of compounds of one or more of these metals.

492.2 The analysis is to be performed on an atomic absorption (AA) spectrophotometer by the flame technique. The instrument is to be calibrated using standards of known metallic content. The sample solutions are then to be analyzed and the values derived by plotting the readings on the calibration curve.

492.3 One of two sample preparation methods is to be used as described in this section. Where the Perchloric / Nitric Acid Digestion method (Method 1) cannot be used, Method 2 is to be employed. In either case, quantitative metal content comparisons are to be made between data derived only from the same sample preparation method.



492.4 Precautions are to be taken for the safe handling, storage, and disposal of each solvent and acid employed.

492.5 SAMPLE PREPARATION METHOD 1 (PERCHLORIC / NITRIC ACID DIGESTION FOR LEAD, CADMIUM, ZINC, AND BARIUM) – Under an operating fume hood, the PVC sample (250 – 325 mg) is to be digested on a hot plate in an equal mixture of concentrated perchloric acid (69 – 72 percent) **See 492.6** and concentrated nitric acid (69 – 71 percent). This digestion is to proceed over moderate heat in an oxidizing state until all of the polymeric and other carbon-based materials are decomposed. The solution is to be cooled. The solution is then to be filtered. The digestion beaker and filter paper are to be washed with several portions of hot, dilute nitric acid. The filtrate and washings are to be diluted to a known volume and analyzed.

492.6 PARTICULAR CAUTIONS WITH PERCHLORIC ACID, AN OXIDIZING MATERIAL – Perchloric acid is indicated as half of the digestive mixture in 492.5 of this Standard, and use in a **concentrated** (69 – 72 percent) form is specified. Perchloric acid can ignite upon contact with combustible material or a dehydrating agent or upon disposal in a manner in which incompatible materials are mixed. Perchloric acid in any concentration destroys living tissue upon contact.

492.7 SAMPLE PREPARATION METHOD 2 (NITRIC ACID DIGESTION OF THE THF-INSOLUBLE PORTION FOR LEAD, CADMIUM, AND ZINC) – The PVC sample (250 – 325 mg) is to be dissolved in a test tube using stabilized tetrahydrofuran (THF) **See 490.4** or another solvent with demonstrated comparable compound component solubilities and Pb, Cd, Zn, and Ba recoveries. The solution is to be centrifuged to separate the insolubles. The THF/PVC resin solution is to be decanted, and the insoluble portion washed with additional solvent, centrifuged, and decanted to remove the soluble compound components. The insoluble pellet is then to be dried in an explosion-proof oven. After drying, the pellet is to be dissolved in dilute nitric acid and the solution is to be filtered. The tube and filter are to be washed several times with hot, dilute nitric acid. The sample is to be diluted to a known volume and analyzed.

492.8 SAMPLE PREPARATION METHOD 2 (HYDROCHLORIC ACID DIGESTION OF THE SAMPLE ASH FOR BARIUM) – The PVC sample (1.0 – 1.2 g) is to be ashed slowly using a ceramic crucible in a muffle furnace by raising the temperature from 250 to 650°C in steps. The final temperature is to be held for 30 min. The ash is to be digested with a hot, 50-percent solution of hydrochloric acid. The solution is then to be filtered. The crucible and filter are to be washed several times with hot, 10-percent hydrochloric acid. The sample solution is to be diluted to a known volume and analyzed.

492.9 REPORT – The report is to include each of the following:

- a) The sample preparation method used (Method 1 or Method 2) and complete identification of the PVC material tested– including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The sample weight, initial volume including any dilutions, and the AA spectrophotometer response.
- d) The type of metal and its content in the material expressed in parts per thousand of the compound.
- e) The test date(s) and operator identification.

### 493 Gel Permeation Chromatography

493.1 GENERAL – Gel Permeation Chromatography (GPC) is a type of liquid chromatography that employs a porous gel as a separation medium. GPC typically is used to analyze large compounds such as polymers that are not appropriate for traditional chromatographic separation media. The method described here is designed to analyze the organic-soluble non-resin PVC wire and cable compound components (for example, plasticizers) that appear within the working range of the column bank.

493.2 This analysis is to be performed with small-particle-and-pore-size cross-linked spherical polystyrene/divinylbenzene matrix-column packing material. Compound components that appear within the working range of the column bank are to be evaluated. Refractive Index and Ultraviolet detection are to be used for qualitative evaluations. Quantitative evaluations are to be performed by the internal standard method (relative to a plasticizer standard) employing refractive-index detection. Relative quantitative calculation is to be derived from detector responses of the sample and from the plasticizer/internal standard calibration curve. For the chromatograph mobile phase and as the solvent for sample and standards preparation, stabilized tetrahydrofuran (THF) **See 490.4** or another solvent with demonstrated comparable PVC resin and compound component solubilities, chromatographic resolutions, and detector responses is to be used. Comparisons are to be made between data derived only from use of the same solvents.

493.3 Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

493.4 STANDARDS PREPARATION – The standards are to consist of three stabilized tetrahydrofuran (THF) solutions containing different concentrations of a typical vinyl-compound plasticizer and identical concentrations (approximately 0.2 percent by volume) of the internal standard. The plasticizer concentrations are to represent typically 5, 25, and 50 percent of the sample mass diluted to the same volume.

493.5 SAMPLE PREPARATION – A sample of the PVC compound (typically 250 mg) is to be combined with stabilized THF and the internal standard. The compound/internal standard/THF solution is to be agitated to dissolve the resin and then is to be transferred to a volumetric flask. Additional portions of stabilized THF are to be added to the initial compound/internal standard/THF container and agitated to extract any residual compound components or internal standard. The washes are to be added to the volumetric flask and brought to a final concentration near 5 mg/ml (compound/stabilized THF). The volumetric solution is then to be filtered to remove particulates before entering the sample loop of the chromatograph.

493.6 REPORT – The report is to contain each of the following:

- a) Complete identification of the PVC material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The sample weights, dilution volumes, detector responses, and calibration curve slopes.
- d) A refractive index chromatogram including all of the evaluated components.
- e) The average relative percent of compound results of the quantified components to the nearest 0.01 percent.
- f) The test date(s) and operator identification.

## Nylon and TPE compounds

### 494 Infrared Spectroscopy

494.1 GENERAL – Infrared Analysis is to be used as the method for the identification of nylon or TPE wire and cable compounds. Interpretation of infrared spectral transmittance is to be used to identify the composition of a compound by comparing the compound's infrared spectra to the spectra of materials having known compositions.

494.2 The analysis is to be performed with a Fourier Transform Infrared (FTIR) Spectrometer and/or a Dispersive Infrared Spectrophotometer. The results are to be recorded as a plot of the percent transmittance of the infrared radiation through the sample versus the number of wavelengths in one centimeter [the reciprocal wavelength ( $\text{cm}^{-1}$ ) or "wavenumber"] of the radiation. Percent transmittance is to be expressed on the ordinate and wavenumber on the abscissa. The infrared spectra obtained by the methods described is to consist of a wavenumber range of at least 4000– 400 reciprocal centimeters.

494.3 SAMPLE PREPARATION – The general polymer-specimen preparation techniques for infrared analysis include solvent casts, potassium bromide (KBr) pellets, solvent-slurry KBr pellets, glass-plate cast films, and reflectance accessories. Solvents typically include chloroform, o-dichlorobenzene, formic acid, and m-cresol. Precautions are to be taken for the safe handling, storage, and disposal of each solvent employed.

494.4 Thermoplastic/solvent solutions are to be placed or "cast" on an optically transparent salt crystal [on potassium bromide (KBr), for example] from which the solvent is to be evaporated by gentle heating, thereby leaving a uniform thin film of polymer. The salt plate is then to be mounted directly in the instrument and the infrared spectrum of the material recorded. For nylon materials that are soluble in formic acid, the polymer solution is to be cast on a glass plate. After evaporation of the solvent, the thin polymer film is to be removed from the glass, placed in a film holder, and mounted in the instrument for recording the infrared spectrum.

494.5 The solvents used are to be those that dissolve the nylon or TPE material without reacting with it and are readily evaporated by gentle heating. Examples of solvents for certain polymer types are:

- a) Chloroform – For many thermoplastic polymers (for example, styrenic TPE compounds).
- b) o-Dichlorobenzene – For many TPE compounds.
- c) Formic Acid – For many nylons (polyamides).
- d) m-Cresol – For certain nylons (polyamides).

494.6 High-molecular-weight, high-crystalline, heavily filled, or cross-linked nylon or TPE materials that are insoluble in all volatile solvents are to be prepared by the pressed halide disk-or-pellet technique. A few milligrams of the material are to be removed from the surface of a sample by a razor blade or fine file. These scrapings or filings are to be ground in a vibrating ball mill for 3 – 5 min. To minimize scattering effects, the particles are to be reduced to a size (typically 2  $\mu\text{m}$ ) that is smaller than the shortest wavelength to be scanned. The ground specimen is to be intimately mixed with powdered spectroscopic-grade potassium bromide (KBr), and a quantity of this mixture that produces a disk typically 1 mm thick and 1/2 inch or 12.7 mm in diameter is to be placed in an evacuable die. The die is to be put under a vacuum and mechanical pressure of 10,000– 15,000 lbf/in<sup>2</sup> or 69 – 103 MPa or 7 – 11 kgf/mm<sup>2</sup> is to be applied. The pressed disk is to be removed from the die, put into a disk holder, and then placed directly into the sample holder of the instrument for recording the infrared spectrum of the material.

494.7 REPORT – The individual spectra are to be marked with each of the following:

- a) Complete identification of the nylon or TPE material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The sample preparation procedure or the preparation code.
- d) The instrument parameters (number of scans, resolution, slit program, and the like).
- e) The test date(s) and operator identification.

#### **495 Pyrolytic Gas Chromatography**

495.1 GENERAL – Pyrolytic Gas Chromatography is to be used to identify nylon or TPE wire and cable compounds. A gas chromatograph equipped with a pyrolysis accessory is to be used for volatilizing the solid specimens for analysis. The pyrolysis products are to be swept through the column of the gas chromatograph by means of a carrier gas. The results are to be recorded as a plot of time (measured from the start of the analysis) versus the detector response to the individual fractions produced by the pyrolysis. This plot is to be used as the “pyrogram” of the material.

495.2 This identification technique is to be used where infrared analysis is not effective, as when the nature of certain resins or additives makes it difficult to prepare specimens for the infrared method. Typically, this applies to materials with a high carbon black or metallic content.

495.3 INSTRUMENTATION – The gas chromatograph, pyrolysis devices, and columns are not specified as long as the parameters and the system hardware are identical for all test data that are being compared. Typically, thermal-conductivity or flame-ionization detection is to be used for pyrolysis gas chromatography, with helium or nitrogen as the carrier gas.

495.4 REPORT – The individual pyrogram is to include each of the following:

- a) Complete identification of the nylon or TPE material tested – including the designation for the material and the form and color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The operating conditions or instrument method reference for the analysis.
- d) The test date(s) and operator identification.

## 496 Thermogravimetry

496.1 The test method for determination of the rapid thermal decomposition of a solid nylon or TPE wire and cable material by Thermogravimetry is to be as described in the Standard Test Method for Rapid Thermal Degradation of Solid Electrical Insulating Materials by Thermogravimetric Method (TGA), ASTM D 3850-94(R2000), except that the specimen is to be heated at the rate of 20°C (36°F) per minute in a nitrogen atmosphere. Additional testing using different test parameters is to be conducted where agreeable to those concerned.

496.2 ASTM D 3850 describes a method in which small pieces cut from a test specimen are heated at a controlled rate until degradation is complete. The resulting thermogram, which plots percent specimen mass versus increasing temperature, is to be used to identify the tested material.

496.3 The individual curve is to include each of the following:

- a) Complete identification of the nylon or TPE material tested – including the designation for the material, the generic type of material, and the color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The operating conditions used for the Thermogravimetry.
- d) The test date(s) and operator identification.

## 497 Differential Scanning Calorimetry

497.1 The test method for determining the transition temperatures of solid nylon or TPE wire and cable compounds by Differential Scanning Calorimetry (DSC) is to be as described in the Standard Test Method for Transition Temperatures of Polymers by Thermal Analysis, ASTM D 3418-99, except that the specimen is to be heated at the rate of 20°C (36°F) per minute in a nitrogen atmosphere without a preliminary thermal cycle. Additional testing using different test parameters is to be conducted where agreeable to those concerned.

497.2 ASTM D 3418 describes a method in which thin sections of the material are heated at a controlled rate through the thermal transitions of interest. The resulting thermogram, which plots these transitions as heat flow versus increasing temperature, is to be used to characterize the tested material.

497.3 The individual curve is to be marked with each of the following:

- a) Complete identification of the nylon or TPE material tested – including the designation for the material, the generic type of material, and the color of the sample.
- b) The name and/or tradename of the material manufacturer and the assigned code (file number).
- c) The operating conditions used for the Differential Scanning Calorimetry.
- d) The test date(s) and operator identification.

**498 and 499** *Reserved for Future Use*

## **CONDUCTOR CORROSION**

### **500 General**

500.1 A copper or copper-clad aluminum conductor not having any metal coating over the copper, when removed from unaged specimens of the finished wire, cable, or cord and from specimens aged at elevated temperature as described in the physical-properties requirements in Specific Materials, Section 50, for the particular insulation being employed, shall not show any evidence of corrosion of the copper (normal oxidation or discoloration of the copper not caused by the insulation or any separator is to be disregarded) in a visual examination. The examination is to be made with normal or corrected vision without magnification.

500.1 revised May 6, 2003

**501 – 519** *Reserved for Future Use*

## **INSULATION FALL-IN**

### **520 Test**

520.1 A 3-inch or 75-mm length of the insulation is to be stripped from a sample length of the finished stranded conductor, and the outer surface of the conductor is to be cleaned with a wire brush to remove the visible insulation. The outermost strands are to be peeled back where any insulation is found on the portions of these strands that were not accessible to the wire brush or on the remainder of the conductor beneath these strands, the wire or cable does not comply.

**521 – 539** *Reserved for Future Use*

## **HEAT SHOCK**

### **540 Test**

540.1 The test of flexible-cord and fixture-wire conductor insulation, parallel-cord insulation, and other insulation is to be made using specimens of finished individual conductors (unseparated in the case of a parallel cord). The test of jacket material is to be made using specimens of the complete wire, cable, or cord or Type TFN and TFFN fixture wires (nylon in place). Each specimen is to be tightly wound for six complete turns (except as specified for the larger sizes of jacketed constructions) around a mandrel having the specified diameter. Successive turns are to be made in contact with one another, and both ends of the specimen are to be securely held in place. The specimens are to be examined on their inside and outside surfaces after heating for 1 h to a temperature of  $121.0 \pm 1.0^\circ\text{C}$  ( $249.8 \pm 1.8^\circ\text{F}$ ) in a full-draft circulating-air oven that complies with 420.9. Circumferential depressions in the outer surface indicate cracks on the inside surface of the insulation or jacket of most materials. Circumferential depressions in a fluoropolymer outer surface are indications of cracking or yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

540.2 In the case of a Type TW, THW-2, THHW, THW, THWN-2, THWN, THHN, TBS, or other wire having a 1 AWG or smaller conductor, four adjacent turns are to be tightly wound around the mandrel and both ends of the specimen are to be securely held in place by means of friction tape. In the case of a Type TW, THW-2, THHW, THW, THWN-2, THWN, THHN, TBS, or other cable having a 1/0 AWG or larger conductor, a U bend is to be made with the specimen in contact with the mandrel for not less than 180°, and the specimen is to be securely held in place. The specimens are to be examined on their inside and outside surfaces after heating for 1 h to a temperature of 121.0 ±1.0°C (249.8 ±1.8°F) in a full-draft circulating-air oven that complies with 420.9. Circumferential depressions in the outer surface indicate cracks on the inside surface of most materials. Circumferential depressions in a fluoropolymer outer surface are indications of cracking or yield marks (locally stronger points), so the inside fluoropolymer surface is to be examined visually. The examinations are to be made with normal or corrected vision without magnification.

**541 – 559** *Reserved for Future Use*

## DEFORMATION

### 560 Test

560.1 For the No. 14 – 4/0 AWG sizes of thermoplastic-insulated, thermoset-insulated, or other wire, the insulation thickness  $T_1$  is to be determined from measurements made at a marked position on a 1-inch or 25-mm length of the finished, insulated conductor. The diameter  $D_1$  over the insulation is to be measured to the nearest 0.001 inch or 0.01 mm by means of a dead-weight dial micrometer whose presser foot puts a load of 85 ±3 gf or 0.84±0.02 N or 3.0 ±0.1 ozf on the specimen. The presser foot is to have a flat, round face whose diameter is 0.250 ±0.010 inch or 6.4±0.2 mm. The anvil of the instrument is to be round, is to be at least 1.5 inches or 38 mm in diameter, and is to be parallel to the face of the presser foot. The diameter  $d$  over the conductor, or over any separator, is to be measured by means of the same dial micrometer. The thickness  $T_1$  is then to be calculated to the nearest 0.001 inch or 0.01 mm from the formula

$$T_1 = \frac{D_1 - d}{2}$$

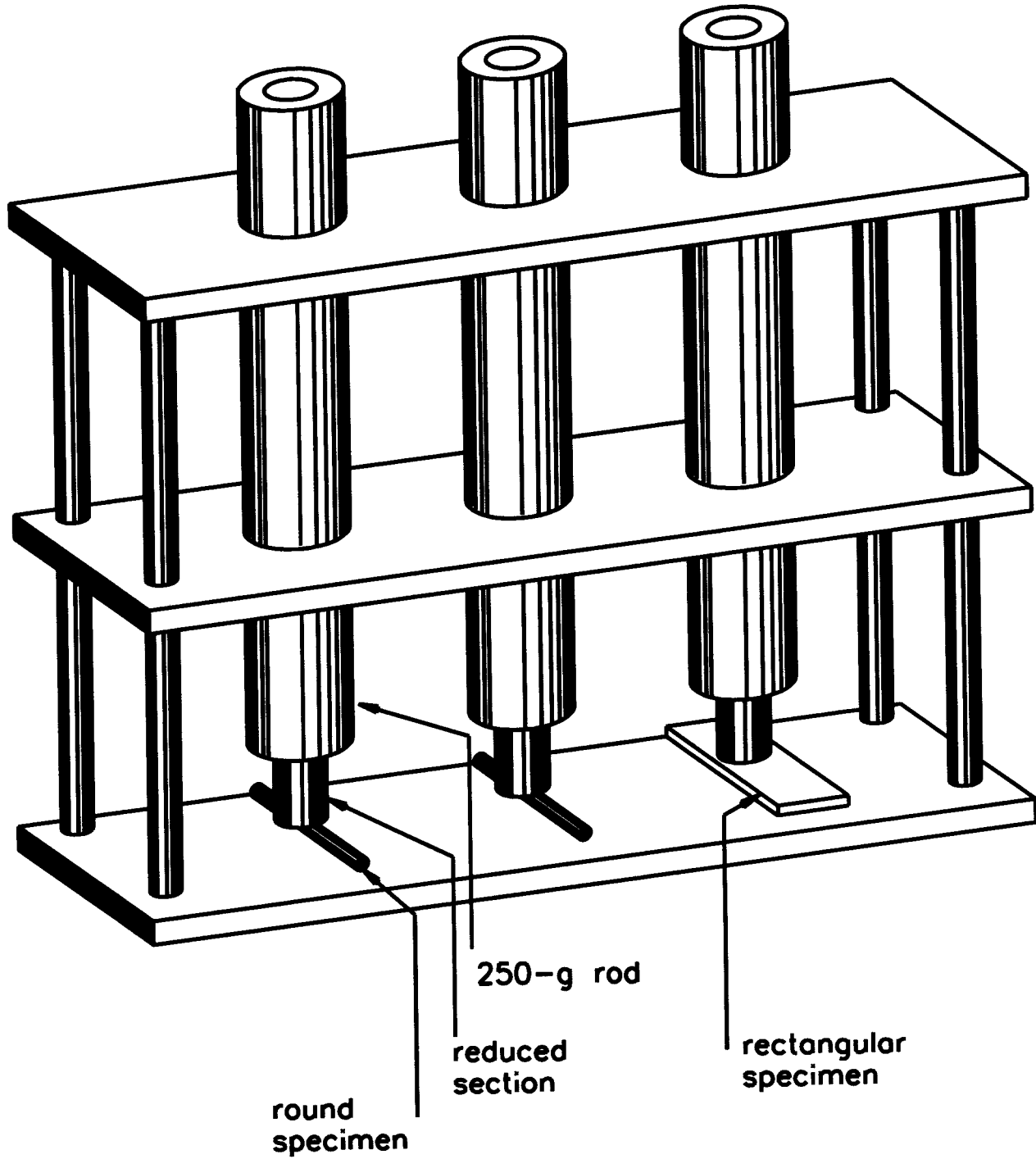
560.2 For the 250 – 2000 kcmil sizes of thermoplastic-insulated, thermoset-insulated, or other wire, and for the jacket removed from finished jacketed cable or flexible cord, a sample of insulation or jacket 8 inches or 200 mm long is to be removed from the finished insulated cable, conductor, or cord. A rectangular specimen 1 inch long and 9/16 inch wide or 25 mm by 14 mm is to be sliced from the sample and then buffed or planed or split or skived as indicated in 440.3 to a uniform thickness of not more than 0.060 inch or 1.52 mm, with both surfaces smooth. At a marked position, the thickness  $T_1$  of a rectangular specimen is to be measured to the nearest 0.001 inch or 0.01 mm by means of the dead-weight dial micrometer described in 560.1. The entire surface of the presser foot is to be in contact with the rectangular specimen during each measurement.

560.3 The insulated conductors of a parallel cord are to be separated. The insulation thickness  $T_1$  of an insulated conductor from a parallel or jacketed cord or from a fixture wire is to be determined as indicated in 560.1 from measurements made at a marked position on a 1-inch or 25-mm length of insulated conductor from the finished flexible cord or fixture wire.

560.4 The apparatus for this test is illustrated in Figure 560.1. The apparatus is to be of brass and is to consist of three rods that are free to move vertically in a support frame. The assembly is to be constructed for use in a heated oven. Each rod is to be straight and  $0.750 \pm 0.010$  inch or  $19.0 \pm 0.2$  mm in diameter. The weight of each rod is to be 250 g. The lower end of each rod is to be reduced in diameter to  $0.375 \pm 0.010$  inch or  $9.5 \pm 0.2$  mm for the final 3/4-inch or 19-mm length of the rod. The lower end of the reduced-diameter section is to be flat, round, without sharp edges, and both concentric with and perpendicular to the longitudinal axis of the rod. The lower end of the reduced section is to serve as the foot that presses on a specimen during a test. The force on the specimen is to be the sum of the force exerted by the rod (250 g or 2.45 N) plus that of any weight to be placed on the upper end of the rod to make the total force equal the load specified in the wire standard. Each weight is to be indent stamped with its exact weight.



**Figure 560.1**  
**Deformation test apparatus with specimens in place**  
Added weights are not shown



SM378

560.5 The frame is to consist of three flat, rectangular plates spaced 2-1/4 inches or 57 mm apart (vertical separation) and parallel to one another in a rigid assembly. The dimensions of the plates are to be the same (plates measuring 8-1/2 inches by 2-3/4 inches by 1/4 inch or 216 mm by 70 mm by 6 mm are typical). The upper surface of the lower plate is to be the surface against which each rod presses a specimen during a test. That surface is to be horizontal during a test. That surface is to be smooth (the surface is to be refinished when repeated testing indents the surface or makes it rough to the touch). Identically located holes are to be provided through the center and upper plates to serve as guides and supports for the rods, which are to be free to move vertically and not otherwise. The diameter of each hole is to be larger than the 3/4-inch-diameter or 19-mm-diameter portion of a rod for clearance of vertical movement of a rod in the hole. Horizontal separation (2-3/4 inches or 70 mm is typical) between the rods is to enable weights to be in place on all three rods at the same time with a clearance (1/4 inch or 6 mm is typical) between the weights. Each rod is to project a distance above the upper plate that enables a weight to be placed on the upper end of the rod without the weight touching the upper plate while the rod is resting on the lower plate (no specimen under the rod). Means integral with the frame is to keep the frame above the floor of the oven and stable during a test (3/8 inch or 9.5 mm is typical).

560.6 With the applicable weight (where needed) in place on each rod that is to be used for a test, the apparatus is to be placed beside one or more test specimens in an air oven (a dead-air, full-draft, or internal-fan oven is appropriate) that has been preheated to a temperature of  $150.0 \pm 1.0^\circ\text{C}$  ( $302.0 \pm 1.8^\circ\text{F}$ ) for specimens from wire or cord with Class 36 TPE insulation or jacket,  $100.0 \pm 1.0^\circ\text{C}$  ( $212.0 \pm 1.8^\circ\text{F}$ ) for specimens of Class 30 PE insulation,  $136.0 \pm 1.0^\circ\text{C}$  ( $276.8 \pm 1.8^\circ\text{F}$ ) for specimens from Type THHN wire, and  $121.0 \pm 1.0^\circ\text{C}$  ( $249.8 \pm 1.8^\circ\text{F}$ ) for all other specimens. The specimens and the loaded apparatus are to remain side by side in the oven for 60 min of preliminary heating at full draft. At the end of the 60 min, one rod is to be lifted and a specimen is to be centered under it. The loaded rod is to be lowered and gently bear on the specimen at the marked position. The rod is to continue to bear on the specimen while the apparatus and the specimen remain in the oven for an additional 60 min. The entire surface of the foot of the rod is to be in contact with any specimen that is rectangular.

560.7 At the end of the second 60 min, the rod is to be lifted and the specimen under it is to be removed. The specimen diameter (round specimen) or thickness (rectangular specimen) is to be measured for determination of the specimen thickness  $T_2$  to the nearest 0.001 inch or 0.01 mm. The measurement is to be made at the marked position in the same way as the specimen was measured for determining  $T_1$ . In the case of a round specimen, the diameter  $d$  over the conductor or any separator is not to be remeasured – that is, in the calculation of  $T_2$ , it is appropriate to use the measured value of  $d$  that was used in calculating  $T_1$ . To minimize the time that the specimen has to recover before its deformed diameter or thickness is measured, measurement is to be made in a short time after the rod is lifted. Where more than 15 s elapses between the time at which the rod is lifted and the time of measurement, the specimen is to be discarded and the test is to be repeated with a new specimen. The percent deformation is to be calculated for the specimen from the following formula. The calculated percentage is to be compared with the maximum deformation stated in the requirement in the wire standard.

$$\text{Deformation in percent} = \frac{100 \times (T_1 - T_2)}{T_1}$$

560.8 Where the calculation for the single specimen shows a greater deformation than the maximum stated in the requirement, the test is to be repeated using three new specimens (see special case in 560.9). At the end of the second 60 min, these three specimens are not to be removed from under the rods at the same time. Instead, the procedure of lifting the rod, removing the specimen, and quickly making the measurement is to be followed for each specimen in turn. Each of the three specimens is to show a deformation equal to or less than the maximum stated in the requirement in the wire standard.

560.9 In the event that a single round specimen containing a stranded conductor deforms more than stated in the requirement in the wire standard, it is appropriate to conduct a test using a single new specimen in which the stranded conductor has been replaced with a solid conductor of a diameter that fits snugly inside the insulation and not tightly enough to stress the tube of insulation. A test is not to be made on an insulation into which a solid conductor has been inserted to replace the original stranded conductor without there first being noncompliance of that insulation tested with the stranded conductor in place – that is, a stranded conductor is to be replaced with a solid conductor for referee testing only. Where a single referee specimen shows a greater deformation than the maximum stated in the requirement, the referee testing is to be repeated as described in 560.7 using three new specimens in which the conductor has similarly been replaced. Each of the three new referee specimens is to comply.

**561 – 579 Reserved for Future Use**

## **COLD BEND**

### **580 Test**

580.1 The test of single-conductor insulation is to be made using specimens of finished individual conductors. The test of parallel-cord insulation and of jacket material is to be made using specimens of the complete construction. After the specimens, together with a metal mandrel(s) having the specified diameter, have been cooled for a period of 4 h in a cold chamber maintained at the specified low temperature, and while they are at that low temperature, each specimen is to be tightly wound for six complete turns (except as specified for the larger sizes of jacketed constructions) onto the mandrel. The winding is to be done at a rate of about 3 seconds per turn ( $18 \pm 3$  seconds for six turns), and successive turns are to be in contact with one another. The test is to be performed in the cold chamber where space and mounting means are available in the chamber. Where this is not practical, it is appropriate to remove a specimen and a mandrel from the test chamber and perform the test outside the chamber. In either case, the winding is to be completed within 30 seconds of the time that the cold chamber is opened. Insulating gloves are to be worn by the person performing the test. Circumferential depressions in the outer surface indicate cracks on the inside surface of the insulation or jacket of most materials. Circumferential depressions in a fluoropolymer surface are yield marks (locally stronger points) rather than indicators of cracking.

**581 and 582** *Reserved for Future Use*

## **FLEXIBILITY AT LOW TEMPERATURE**

### **583 Test**

583.1 After cooling for 4 h to  $-25.0 \pm 2.0^{\circ}\text{C}$  ( $-13.0 \pm 3.6^{\circ}\text{F}$ ), finished cable shall be undamaged by the bending described in 583.2 – 583.15.

583.2 Two straight specimens at least 30 inches or 760 mm long are to be cut from a sample length of finished cable without bending the cut ends of any conductor. Both specimens are to be bent (see 583.12) around one diameter of mandrel (see 583.3) where the cable is round. Where the cable is flat, two different diameters of mandrel (see 583.3) are required, one of the specimens being bent flatwise around the smaller mandrel and the other being bent edgewise around the larger mandrel.

583.3 A series of mandrels is to be stocked in which the diameters are either within 1 mil of being integral multiples of 200 mils (0.2 inch) or within 0.01 mm of being integral multiples of 5 mm. The method by which the particular diameter or diameters of mandrel for a test are to be determined is explained in 583.4– 583.9. Measurements for use in the determination are to be made on only one of the specimens of cable.

583.4 In testing a round cable, the diameter over the outer surface of the cable is to be measured. In testing a flat cable, measurements are to be made of the lengths of the major and minor axes over the outer surface of the cable. The instruments specified in 583.5 and 583.6 for making these measurements are to be calibrated to facilitate estimation of each measurement to 0.1 mil or 0.001 mm.

583.5 A dead-weight dial micrometer is to be used to measure a diameter or length of axis that is not larger than 0.500 inch or 12.7 mm. The anvil and presser foot are to be 0.078 inch or 1.98 mm wide and 0.375 inch or 9.52 mm long. The foot is to exert a total of  $10 \pm 2$  gf or  $0.10 \pm 0.02$  N on a specimen.

583.6 A machinist's micrometer caliper with a ratchet is to be used to measure a diameter or length of axis that is longer than 0.500 inch or 12.7 mm. The surfaces of the anvil and the end of the spindle are to be flat.

583.7 The measurements are to be made in a plane that is perpendicular to the longitudinal axis of the cable. Except in the case indicated in 583.8, at least four measurements are to be made of each length of axis or diameter. Each measurement is to be estimated to the nearest 0.1 mil or 0.001 mm and recorded. The largest and smallest recorded measurements of the diameter or of each length of axis are to be identified as such on the data sheet, and the two are to be averaged. Each average is to be recorded.

583.8 Where, on the smaller cables, only one measurement of the length of the major axis is practical, the single measurement is to be recorded as the average length of the major axis.

583.9 The two diameters of mandrel that are to be used with a flat cable are to be determined by first multiplying the average length of the major axis by 20 and multiplying the average length of the minor axis by 4. The single diameter of mandrel that is to be used with a round cable is to be determined by first multiplying the average diameter by 6. The result of each multiplication is to be rounded as indicated in 240.5 (measurements in inches) or 240.6 (measurements in millimeters) to the nearest integral multiple of 200 mils or 5 mm. In each case, the rounded result is the diameter of mandrel that is to be used in the test.

583.10 The apparatus for this test is to consist of a sharp knife for opening the cable; round metal cylinders for use as the mandrels specified in 583.3 – 583.9; and a dry-ice cabinet or a mechanical refrigerator, either one of which is to be capable of sustained operation at a low temperature of  $-25.0 \pm 2.0^\circ\text{C}$  ( $-13.0 \pm 3.6^\circ\text{F}$ ). The mandrels are to be secured within the cold chamber in a manner that enables the bending operation to be conducted in the chamber and at the low temperature, and facilitates the release of mandrels from the chamber while the bent specimens are securely in place on them.

583.11 The cold chamber is to be precooled to the low temperature before the specimens are placed in the chamber. Both straight specimens are to be cooled for 4 h to the low temperature.

583.12 After the full period of cooling, each specimen is to be bent for  $180^\circ$  around the applicable mandrel (see 583.3) while both the mandrel and specimen are maintained at the low temperature. While in the bent position, each specimen is to be secured to the mandrel. The assemblies of mandrel and specimen are then to be removed from the chamber and, while it is still on the mandrel, the overall covering is to be examined for the damage described in 583.15.

583.13 A separate specimen is to be used for each size of mandrel, and no specimen is to be bent more than once.

583.14 Both specimens are to be cut open and their interiors examined for the damage described in 583.15.

583.15 Any cable from which a specimen exhibits any of the damage described in this paragraph does not comply. There are not to be ruptures of any fibrous material in the cable. There is not to be a part, split, or crack larger than  $1/16$  inch or 1.5 mm in the tape-and-finish outer covering on Type SE cable. In the absence of rubbing, there is not to be any flaking of the treating or finishing compounds used with the fibrous outer layer of a layered covering. No cracks, tears, or splits are to be in the insulation, any individual jacket over the insulation, in any web, or in any overall jacket. Circumferential depressions in the outer surface of a jacket or the insulation indicate cracks on the inside surface. Circumferential depressions in a fluoropolymer surface are yield marks (locally stronger points) rather than indicators of cracking.

**584 – 592** *Reserved for Future Use*

## **IMPACT AT ABNORMALLY LOW TEMPERATURE**

### **593 Test**

593.1 Specimens are to be impacted on anvils consisting of 8-inch or 203-mm lengths of 2x4 spruce lumber having no surface imperfections or knots. The wood anvil is to be inspected after each specimen is impacted and replaced where it shows any indentations.

593.2 The impact energy is to be provided by a weight of 3 lb or 1.36 kg in the form of a circular steel cylinder having a diameter of 1 inch or 25 mm and a flat impact face that is perpendicular to the longitudinal axis of the weight and has rounded edges.

593.3 The impact specimens are to consist of ten separate 5-inch or 130-mm sections cut from a straight sample length of the finished wire or cable.

593.4 The specimens and wood anvils are to be cooled for at least 4 h in a cold chamber maintained at a temperature of  $-40.0 \pm 2.0^{\circ}\text{C}$  ( $-40.0 \pm 3.6^{\circ}\text{F}$ ). The impact weight and the remainder of the test apparatus are to be in thermal equilibrium with the surrounding air in the test room at a temperature of  $24.0 \pm 8.0^{\circ}\text{C}$  ( $75.2 \pm 14.4^{\circ}\text{F}$ ).

593.5 At the conclusion of at least 4 h of cooling, one of the wood anvils is to be removed from the cold chamber and is to be secured to a concrete floor, the building framework, or another solid support that does not absorb the impact. The impact weight is to be supported with its lower face horizontal. A vertical line through the centers of gravity of the impact weight and the stationary anvil is to be coincident with a vertical line through the dimensional center of the lower face of the impact weight and the dimensional center of the upper face of the stationary anvil. A set of rails or other vertical guide(s) is to constrain the impact weight and keep its lower face horizontal while the weight is falling and after it has struck the wire or cable. The rails or other guide(s) are not to interfere with the free fall of the impact weight. The top of the guide(s) is to have a means for releasing the impact weight to fall freely from any chosen height and strike the wire or cable. The weight is also to be kept from striking the wire or cable more than once during each drop.

593.6 One of the test specimens of the wire or cable is to be removed from the cold chamber and is to be tested as follows without delay and within 15 s of being removed from the chamber. Insulating gloves are to be worn by the person conducting the test. The time in seconds between removal of the specimen from the chamber and the impact is to be noted and recorded. The impact weight is to be secured several specimen diameters (several times the length of the minor axis in the case of a flat cable) above the anvil and the specimen is to be placed and held on the cold anvil with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the anvil, and in the vertical plane containing the coincident vertical lines described in 593.5. In the case of a flat cable, the specimen is to be flatwise on the anvil. The position of the impact weight is to be adjusted to place the lower face of the weight 36 inches or 915 mm above the upper surface of the specimen. The impact weight is to be released from this height, is to fall freely in the guides, is to strike the specimen once, and is then immediately to be raised up to and secured at the 36-inch or 915-mm height. After warming in still air at a temperature of  $24.0 \pm 8.0^{\circ}\text{C}$  ( $75.2 \pm 14.4^{\circ}\text{F}$ ) for 24 h, the specimen is to be examined for cracks, ruptures, and like damage in each of its nonmetallic components – insulation, jacket, other covering, etc. The examinations are to be made with normal or corrected vision without magnification.

593.7 Each of the remaining nine specimens is to be tested in succession as described in 593.6 for a total of ten strikes. The wire or cable does not comply where more than two out of ten specimens show any cracking, rupturing, or like damage.

**594** *Reserved for Future Use***CRUSHING RESISTANCE****595 Test**

595.1 The test specimen is to consist of a minimum 100-inch or 2540-mm straight length of the finished solid 14 AWG wire without any conditioning. The specimen is to be tested at each of ten points evenly spaced along its length. These points are not to be closer together than 10 inches or 254 mm, and no point is to be closer than 5 inches or 127 mm to an end of the specimen. At each test point, the specimen is to be crushed between a flat, horizontal steel plate and a solid steel rod in a compression machine whose jaws close at the rate of  $0.50 \pm 0.05$  in/min or  $10 \pm 1$  mm/min. Each plate is to be 2 inches or 50 mm wide. A solid steel rod 3/4 inch or 19 mm in diameter and of the same length as the plates is to be bolted or otherwise secured to the upper face of the lower plate. The longitudinal axes of the plates and the rod are to be in the same vertical plane. The specimen, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of  $25.0 \pm 5.0^\circ\text{C}$  ( $77.0 \pm 9.0^\circ\text{F}$ ) throughout the test.

595.2 The specimen is to be connected in series with a buzzer or other low-voltage indicator and a supply circuit, one leg of which is to be earth-grounded. All metal parts of the crushing apparatus are to be connected to earth ground.

595.3 The upper steel plate in the compression machine is to be raised several specimen diameters above the steel rod, and the first test point on the specimen is to be placed and held on the steel rod with the longitudinal axis of the specimen horizontal, perpendicular to the longitudinal axis of the rod, and in the vertical plane that laterally bisects the plates and the rod. The upper steel plate is to be moved down until it is snug against the specimen. The downward motion of the plate is then to be continued at the rate of  $0.50 \pm 0.05$  in/min or  $10 \pm 1$  mm/min increasing the force on the specimen until the indicator signals that contact has occurred between the specimen conductor and the plate or rod. The force indicated by the dial on the compression machine at the moment of contact is to be recorded. The crushing procedure is to be repeated at each of the remaining nine test points. The wire does not comply where the average of the ten crushing forces is less than 225 lbf or 1000 N or 102 kgf.

**596 – 600** *Reserved for Future Use***601 Crushing-Resistance Test of Round Type NM Cable**

601.1 The cable is to be crushed between flat, horizontal steel plates in a compression machine whose jaws close at the rate of  $0.50 \pm 0.05$  in/min or  $10 \pm 1$  mm/min. Each plate is to be 2 inches or 50 mm wide. The cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of  $23.0 \pm 5.0^\circ\text{C}$  ( $73.4 \pm 9.0^\circ\text{F}$ ) throughout the test.

601.2 The cable is to be tested in a continuous length of at least 100 inches or 2.55 m, with the cable being crushed at ten points along that length. The first test is to be conducted 9 inches or 230 mm from one end of the test length and the nine remaining tests are to be conducted at succeeding intervals of at least 9 inches or 230 mm down the length of the cable.

601.3 The insulated circuit conductors and the two steel plates are to be connected to low-voltage indicators (buzzers or the like) and to power supplies for the purpose of indicating a short circuit between circuit conductors or between any circuit conductor and the steel plates. The grounding conductor in the test length of the cable is to be out of the circuit.

601.4 The upper steel plate in the compression machine is to be raised several cable diameters above the lower plate, and the cable at the first test point is to be placed and held on the lower plate with the longitudinal axis of the cable horizontal, perpendicular to the longitudinal axes of the plates, and in the vertical plane that laterally bisects the plates. The upper steel plate is to be moved down until it is snug against the cable. The downward motion of the plate is then to be continued at the rate of  $0.50 \pm 0.05$  in/min or  $10 \pm 1$  mm/min increasing the force on the cable until one or more of the indicators signal that contact has occurred between the circuit conductors or between one or more of the circuit conductors and ground. The force indicated by the dial on the compression machine at the moment of contact is to be recorded.

601.5 The length of cable being tested is to be advanced to and crushed at each of the successive test points for a total of ten crushes. The average of the ten crushing trials is to be calculated and recorded.

**602 – 619** *Reserved for Future Use*

## **620 Crushing-Resistance Test of Types XHHW-2, XHHW, and XHH**

620.1 Ten specimens of the finished wire in each of the sizes 14 and 2 AWG are to be tested. Each specimen is to be placed between 2-inch-wide or 50-mm-wide, flat, horizontal steel plates in a compression machine whose jaws close at the rate of  $0.50 \pm 0.05$  in/min or  $10 \pm 1$  mm/min. The length of the specimen is to be parallel to the 2-inch or 50-mm dimension of the plates. The plates are to be connected together, to the metal of the testing machine, and to earth. The wire, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of  $24.0 \pm 8.0^\circ\text{C}$  ( $75.2 \pm 14.4^\circ\text{F}$ ) throughout the test. Each specimen is to be tested separately and is to be subjected to an increasing force until a short circuit occurs (as indicated by a low-voltage buzzer circuit or the equivalent) between the conductor in the wire and one or both of the earth-grounded plates. The force at which a short circuit occurs is to be recorded in each case.

**621 – 699** *Reserved for Future Use*

## **DIELECTRIC TESTS**

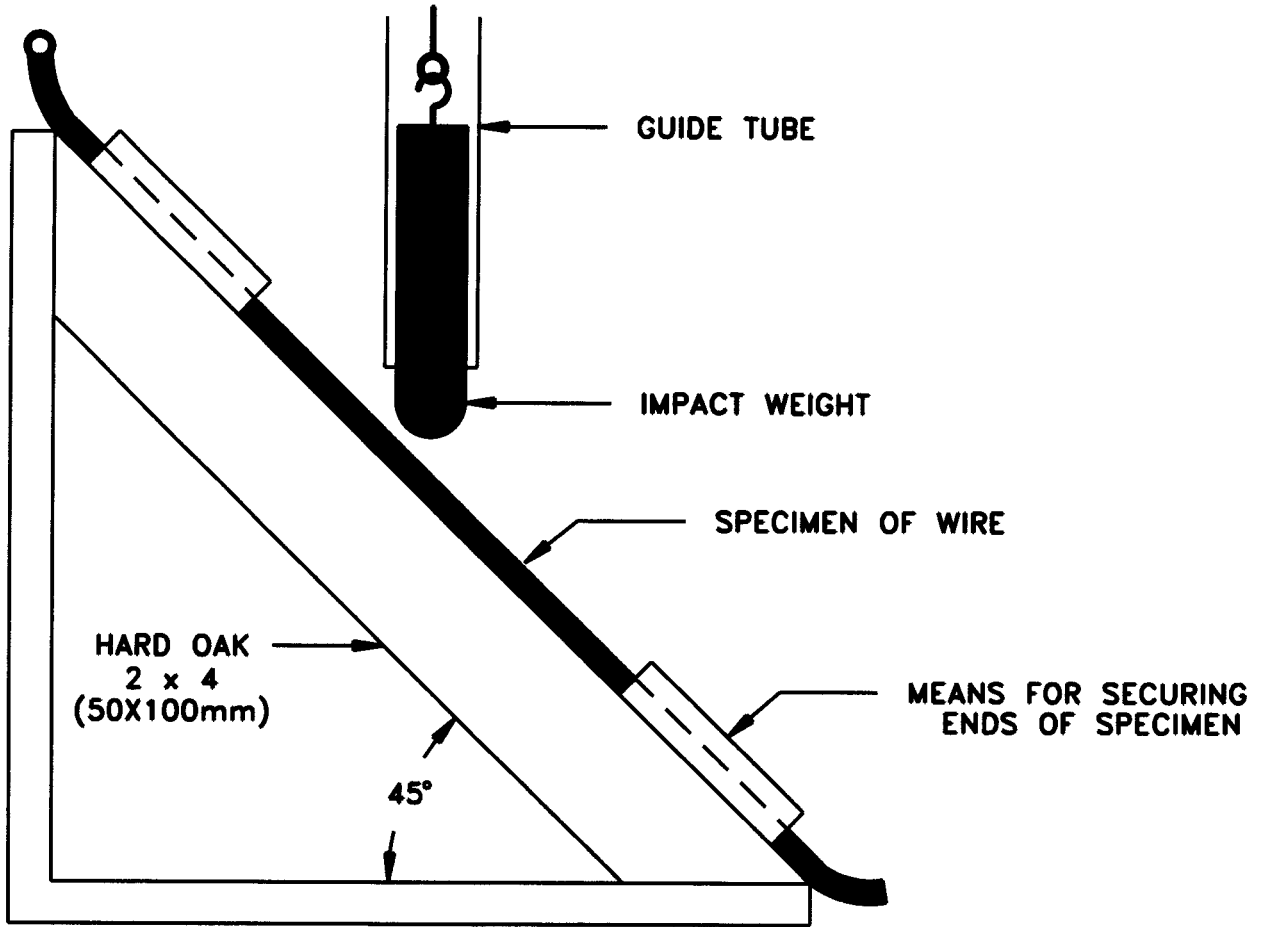
### **700 Dielectric Breakdown Test of Types XHHW-2, XHHW, and XHH after Glancing Impact**

700.1 Both ends of each of six 15-inch or 380-mm specimens of the finished solid 14 AWG wire are to be secured to one of the broad faces of a hard oak board measuring 2 inches by 4 inches or 50 mm by 100 mm in cross section without damage to the insulation and in a manner that results in the wires being straight and parallel to the longitudinal axis of the board. The board is to be rigidly supported, with the plane formed by the wires inclined  $45^\circ$  from the horizontal and each wire in a vertical plane.

700.2 A weight of 1 lb or 0.454 kg consisting of a solid circular steel cylinder that is  $3/4$  inch or 20 mm in diameter, has all surfaces smooth, and has one end rounded to a hemisphere is to be supported with its longitudinal axis vertical and in a vertical plane containing one of the wires. The hemispherical end is to be down and centered 18 inches or 460 mm above the midpoint of the length of the wire. A straight vertical tube having a  $13/16$ -inch or 22-mm inside diameter is to surround the cylinder and serve as a guide to keep the cylinder vertical while the cylinder is falling and after it has struck the wire. The inside surface of the guide tube is to be smooth and the tube is to be of a length that keeps the cylinder from coming out of the guide tube. See Figure 700.1.



Figure 700.1  
Glancing-impact apparatus



SB1251

Dimensions are shown in inches (millimeters)