

UL 224

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Extruded Insulating Tubing

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UL Standard for Safety for Extruded Insulating Tubing, UL 224

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UL 224
Fifth Edition



Extruded Insulating Tubing

December 15, 1999

Commitment for Amendments

This Standard is issued jointly by CSA International and Underwriters Laboratories Incorporated. Amendments to this Standard will be made only after processing according to the Standards writing procedures by both CSA International and Underwriters Laboratories Incorporated.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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Preface

This is the first edition of the common CSA and UL Standard *Extruded Insulating Tubing*. It is the second edition of CSA Standard C22.2 No 198.1 and the fifth edition of UL 224. It supersedes

- a) the previous edition of CSA Standard C22.2 No. 198.1, published in 1986; and
- b) UL 224.

This common Standard addresses safety requirements and industry concerns for various types of extruded insulating tubing.

This common Standard was prepared by CSA International and Underwriters Laboratories Inc., and the electrical tubing and sleeving industry. The efforts and support of the Joint NEMA/EFC Technical Committee for Electrical Tubing and Sleeving Products are gratefully acknowledged. The following is a list of individuals who participated in the Technical Committee:

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Joe Salvini	Underwriters Laboratories Inc., Research Triangle Park, North Carolina, USA	<i>UL Representative</i>

This Standard has been approved by the Joint NEMA/EFC Technical Committee for Electrical Tubing and Sleeving Products and by the Codes and Standards Committees of both NEMA and the EFC.

This Standard was prepared by the CSA Subcommittee of the Technical Committee on Wiring Products under the jurisdiction of the Strategic Resource Group and was formally approved by the Technical Committee.

Interpretations (CSA): The Strategic Resource Group has provided the following direction for the interpretation of standards under its jurisdiction: "The literal text shall be used in judging compliance of products with the safety requirements of this Standard. When literal test cannot be applied to the product, such as for new materials or construction, and when a relevant committee interpretation has not already been published, CSA's procedures for interpretation shall be followed to determine the intended safety principle".

This Standard will be submitted to the Standards Council of Canada for approval as a National Standard of Canada and to the American National Standards Institute for publication as an American National Standard.

July 1, 1999

Note: Although the intended primary application of this Standard is stated in its Scope, it is important to note that it remains the responsibility of the users of the Standard to judge its suitability for their particular purpose.

CSA Effective Date

The effective date for CSA will be announced through *CSA Informs* or a CSA Certification Notice.

UL Effective Date

As of December 15, 2001 all products Listed or Recognized by UL must comply with the requirements in this Standard.

Foreword (CSA)

The Canadian Standards Association, which operates under the name CSA International (CSA), provides certification services for manufacturers who, under license from CSA, wish to use the appropriate registered CSA Marks on certain products of their manufacture to indicate conformity with CSA Standards.

CSA Certification for a number of products is provided in the interest of maintaining agreed-upon standards of quality, performance, interchangeability and/or safety, as appropriate. Where applicable, certification may form the basis for acceptance by inspection authorities responsible for enforcement of regulations. Where feasible, programs will be developed for additional products for which certification is desired by producers, consumers or other interests.

In performing its functions in accordance with its objectives, CSA does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of the Association represent its professional judgement given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed.

Products in substantial accord with this Standard but which exhibit a minor difference or a new feature may be deemed to meet the Standard providing the feature or difference is found acceptable utilizing appropriate CSA Certification and Testing Division Operating Procedures. Products which comply with this Standard shall not be certified if they are found to have additional features which are inconsistent with the intent of this Standard. Products shall not be certifiable if they are discovered to contravene applicable laws or regulations.

Testing techniques, test procedures and instrumentation frequently must be prescribed by the CSA Certification and Testing Division in addition to the technical requirements contained in Standards of CSA. In addition to markings specified in the Standard, the CSA Certification and Testing Division may require special cautions, markings and instructions that are not specified by the Standard.

Some tests required by CSA Standards may be inherently hazardous. The Association neither assumes nor accepts any responsibility for any injury or damage that may occur during or as the result of tests, wherever performed, whether performed in whole or in part by the manufacturer or the Association, and whether or not any equipment, facility or personnel for or in connection with the test is furnished by the manufacturer or the Association.

Manufacturers should note that, in the event of the failure of the CSA Certification and Testing Division to resolve an issue arising from the interpretation of requirements, there is an appeal procedure: the complainant should submit the matter, in writing, to the Secretary of the Canadian Standards Association.

If this Standard is to be used in obtaining CSA Certification please remember, when making application for certification, to request all current Amendments, Bulletins, Notices and Technical Information Letters that may be applicable and for which there may be nominal charge. For such information or for further information concerning CSA Certification please address your inquiry to Applications and Customer Service, CSA International, 178 Rexdale Boulevard, Etobicoke, Ontario M9W 1R3.

No Text on This Page

Foreword (UL)

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

Extruded Insulating Tubing

1 Scope

1.1 This Standard specifies the requirements for insulating tubing that is usually round in cross-section and that consists entirely of extruded compounds whose characteristic constituents are thermosetting, elastomeric, or thermoplastic polymers (see Table 1 for materials and ratings). These requirements also cover heat-shrinkable and crosslinked tubing.

1.2 Tubing is intended for use only in air – in dry and damp locations – as part of the internal wiring of electrical devices and appliances in accordance with the Canadian Electrical Code, Part 1 (CE Code, Part 1) and the ANSI/NFPA 70 National Electrical Code (NEC). It may be used for insulating one or more inadequately insulated conductors, bus bars, motor leads, transformer leads, terminal lugs, or small assemblies of electronic components. Tubing is not acceptable for use in contact with sharp edges, corners, or projections, or where subject to tension, compression, or repeated flexing. Tubing is not for use where it is feasible to employ a standard insulated conductor (appliance-wiring material) intended specifically for the purpose.

1.3 These requirements do not apply to fabric tubing, polymeric tubing extruded with reinforcement, or tubing intended only for mechanical protection (unless additional tests are conducted).

1.4 These requirements do not apply to chemically dilated tubing.

1.5 The acceptability of tubing in any particular device or appliance depends upon its acceptability for continued use under the conditions that prevail in actual service. Accordingly, for a particular application, tubing device, or appliance in question, it may be necessary to employ tubing having features other than or in addition to those specified in these requirements. For example, tubing may be required to have a heavier wall thickness or a flat rather than a round cross-section; it may be required to have inherent resistance to the effects of immersion in water, oil, solvents, or other liquids (or their vapors); it may be required to be for use in an environment conducive to the development of fungi and similar organisms.

2 Definitions

2.1 The following definitions apply in this Standard:

Chlorinated polyolefin – a polymer or polymer blend based on chlorinated polyolefin(s) or chlorinated polybutadiene polymer(s).

Heat-shrinkable tubing – tubing that, upon the controlled application of heat, will reduce in diameter to a specified maximum recovered diameter.

Polyolefin – a polymer made by the polymerization of hydrocarbon olefins or copolymerization of hydrocarbon olefins with other non-halogenated monomers such as vinyl acetate or ethyl acrylate.

Sample – a quantity of material or finished product considered representative of a lot taken for the purpose of preparing specimens for test evaluation.

Secant modulus – 50 times the tensile stress at 2 percent elongation, expressed in MPa (psi).

Specimen – the actual unit of material or finished product upon which test evaluations are performed.

Tubing with meltable liner – tubing constructed of either:

- a) an outer wall that is crosslinked and a thermoplastic inner wall that flows and provides a seal when the tubing is heated or recovered by heat; or
- b) an outer wall with an adhesive or sealant liner applied to the inside, such that the liner flows and provides a seal when the tubing is heated or recovered by heat.

3 General

3.1 New Product Evaluation

3.1.1 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this Standard, and that involves a risk of fire, electric shock, or injury to persons shall be evaluated using the appropriate additional component and end-product requirements to determine that the level of safety as originally anticipated by the intent of this Standard is maintained. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this Standard shall not be judged to comply with this Standard. Where appropriate, revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this Standard.

3.2 Reference Publications

3.2.1 Where reference is made to other publications, such reference shall be considered to refer to the latest edition and all amendments published to that edition up to the time when this Standard was approved.

CSA Standards

C22.1-98,
Canadian Electrical Code, Part I;

C22.2 No. 0.3-96,
Test Methods for Electrical Wires and Cables.

UL Standard

1581,
Reference Standard for Electrical Wires, Cables, and Flexible Cords.

ANSI/NFPA¹ Standard

70-1993,
National Electrical Code

¹ANSI/NFPA – American National Standards Institute/National Fire Protection Association

ASTM² Standards

D 257-93,
Test Methods for DC Resistance or Conductance of Insulating Materials

D 412-97,
Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension;

D 471-96,
Test Method for Rubber Property – Effect of Liquids

D 876-95A,
Methods of Testing Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation

D 5374-93,
Test Methods for Forced Convection Laboratory Ovens for Evaluation of Electrical Insulation

²ASTM – American Society for Testing and Materials

4 Construction

4.1 Materials and Quality of Work

Tubing shall be made and finished with the degree of uniformity and quality of work that are practicable in a well-equipped factory. Only compounds qualified as acceptable for the manufacture of tubing complying with the requirements of this Standard shall be used.

4.2 Color

If the tubing is to be considered in a range of colors, specimens representing the full color range shall be provided for evaluation. Samples in the clear and most heavily pigmented black and white colors shall be provided and be considered representative of the color range, if the performance characteristics are essentially the same. If the performance characteristics are not essentially the same for all specimens representing the range, acceptance shall be limited to the tubing only in the colors tested, unless additional specimens in intermediate colors are provided for tests. (See Clause 6.1.2).

Exception: If the same base compound is employed for all colors of tubing, then only the clear and black samples shall be required for testing.

4.3 Minimum Wall Thickness

4.3.1 The wall thickness of the tubing (fully recovered in the case of heat-shrinkable tubing) shall not be less than that referred to in the respective Tables in this Standard.

4.3.2 For all tubing, the minimum thickness shall be determined by means of a pin-gauge dial micrometer with a presser foot 1.09 mm (0.043 inches) wide and 7.92 mm (0.312 inches) long and a pin that is 1.09 mm (0.043 inches) in diameter and 11.10 mm (0.437 inches) long. The presser foot shall exert 0.25 ± 0.02 N (0.056 ± 0.0045 lbf) on the specimen. The specimen shall be hung on the pin carefully so that the entire length of the presser foot makes contact with the specimen. The presser foot shall be brought to rest gently on the specimen and the reading shall be taken immediately. It is necessary to rotate the specimen and to make several measurements to determine the actual minimum thickness. In no case shall the presser foot be in contact with the specimen while the specimen is being rotated. As a referee or secondary method, a calibrated optical instrument that is capable of being read to the nearest 0.001 mm (or to the nearest 0.0001 inches) shall be used.

4.3.3 For tubing with a meltable liner, the thickness of the liner shall not be included when determining the wall thickness. If the liner is removable by physical or chemical means, the manufacturer shall provide instructions for its removal.

4.4 Item References

Wherever item numbers appear, the appropriate table of requirements for the specific type of tubing under investigation shall be selected.

4.5 Units of Measurement

If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

4.6 Heat-Shrinkable Tubing

Heat-shrinkable tubing shall reduce in diameter and conform to the minimum wall thickness requirements specified in Item 5 of Tables 8 to 26, as applicable, upon the controlled application of heat. For tubing with a meltable liner, the thickness of the liner shall not be included.

5 Manufacturing and Production Tests

5.1 Conformance of the tubing to the requirements of the following characteristics shall be verified for each lot of product at the time of manufacture:

- a) minimum expanded inside diameter: per manufacturer's specifications;
- b) maximum recovered inside diameter, or extruded inside diameter (in the case of not-heat-shrinkable tubing): per manufacturer's specifications;
- c) minimum recovered wall thickness, or extruded wall thickness (in the case of not-heat-shrinkable tubing): per Item 5 of Tables 8 to 26, as applicable;
- d) maximum longitudinal change: per Item 21 of Tables 8 to 26, as applicable; and
- e) maximum eccentricity: per Item 23 of Tables 8 to 26, as applicable.

5.2 Product conformance may be determined using proven test methods that may differ in execution but not intent from the specific test methods described in this Standard. In case of dispute, the test methods in this Standard shall apply.

6 Capability Tests

6.1 Samples

6.1.1 A complete set of samples and/or specimens shall be provided as scheduled in Tables 2 and 3.

6.1.2 If the tubing is to be evaluated in a range of colors, the required test samples shown in Table 2 shall be provided as specified in Clause 4.2 and its exception.

6.1.3 If different compounds are employed, samples produced from the alternative compounds shall be provided for tests. (See Clause 4.1.)

6.1.4 The inner and outer surfaces of tubing shall be smooth and free from blisters, cracks, and other defects that can be detrimental to the tubing in its intended use. Tubing shall not peel, scale, or flake.

6.1.5 Except where specified otherwise, heat-shrinkable tubing shall be examined and tested in the fully recovered condition, which is to be achieved in accordance with the manufacturer's instructions.

6.2 Physical Properties

6.2.1 General

6.2.1.1 The tensile strength and ultimate elongation of the tubing shall not be less than the values tabulated in Items 6 and 7 of Tables 8 to 26, as applicable, for unaged specimens and in Items 11 and 12 of Tables 8 to 26, as applicable, for aged specimens. Oil-resistant tubing shall comply with the requirements in Clause 6.3.

6.2.1.2 For the preparation, aging, and testing of specimens of tubing, the equipment mentioned in Clauses 6.2.2 to 6.2.6 shall be used.

6.2.2 Specimen Conditioning

Physical tests shall be made on both unaged and aged specimens at the same time and at a room temperature of $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) and a relative humidity of 50 ± 5 percent. Unaged specimens shall be maintained at this temperature and humidity for not less than 30 minutes prior to being subjected to the physical tests. Specimens that have been subjected to air-oven aging shall rest for not less than 16 and not more than 96 hours at this temperature and humidity following their removal from the oven and prior to their being subjected to the physical tests. Specimens that have been subjected to oil immersion shall be blotted lightly to remove any excess oil and shall then be suspended in air under the above-mentioned conditions for 3.5 to 4.5 hours before being subjected to the physical tests. Specimens having widely different properties or composition shall be aged in separate ovens.

6.2.3 Die for Cutting Specimens

6.2.3.1 The die for cutting specimens from lengths of finished flexible tubing shall be die C described in ASTM D 412. (See Figure 1.)

6.2.3.2 The die for cutting specimens from lengths of finished semirigid or rigid tubing shall be die D described in ASTM D 412. (See Figure 2.)

6.2.3.3 The use of a press for operating the die is recommended. If the die is struck with a mallet, care shall be taken to see that all points of the cutting edges of the die are in contact with the insulation before the die is struck. The cutting shall be done on a smooth surface of material that cannot damage the cutting edges of the die.

6.2.4 Specimen Marker

The specimen marker shall consist of a stamp with parallel metal blades capable of making fine inked lines (bench marks) on a specimen. The lines shall be 25 mm (1 inch) apart and shall be applied at right angles to the longitudinal axis of the specimen. Inasmuch as the width of a mark increases while a specimen is stretched, measurement of elongation shall be made with reference to the center of each mark – that is, halfway between the edges of each mark. The ink shall be of any color that contrasts with that of the specimen, and of a composition that does not in any way damage the specimen.

6.2.5 Apparatus for aging

6.2.5.1 General

The apparatus for the accelerated aging of specimens specified in these requirements shall include the equipment mentioned in Clauses 6.2.5.2 and 6.2.5.3. In each type of apparatus, provision shall be made for suspending the specimens vertically within the chamber without touching the sides of the chamber or any other specimens.

6.2.5.2 Air-Oven Aging

The apparatus for the air-oven aging of specimens shall circulate the air within the aging chamber at high velocity. A portion of the air may be recirculated, but a substantial amount of fresh air shall be admitted continuously (200 – 250 fresh air changes per hour is acceptable). The motor-operated fan or other means for circulating the air shall be located entirely outside the aging chamber. The oven shall maintain the specified temperature within $\pm 1.0^{\circ}\text{C}$ ($\pm 1.8^{\circ}\text{F}$).

6.2.5.3 Oil-Immersion Aging

6.2.5.3.1 The immersion vessel for tubular specimens shall be a test tube having an overall diameter of at least 25 mm (1 inch) and a length that facilitates immersion of a straight specimen at least 152 mm (6 inches) long. The tube shall be filled with the oil specified in Clause 6.2.5.3.2 and then placed in a bath having an automatic temperature control that maintains the specimens at the specified temperature. Tubing shall be filled with the maximum size of solid copper conductor that fits tightly inside the tubing without damaging the tubing wall. For tubing smaller than 8.38 mm (0.330 inches) inside diameter, specimens shall 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. After immersion for the specified length of time indicated in Clause 6.3, each specimen shall be cut in half at the center of the U-bend to result in two specimens for physical tests. For tubing larger than 8.38 mm (0.330 inches) inside diameter, die-cut specimens shall be suspended vertically in the oil.

6.2.5.3.2 The oil to be used shall be ASTM No. 2 oil, described in ASTM D 471, or IRM 902 oil. Measured at 98.9°C (210.0°F), the Saybolt Universal Viscosity of IRM 902 oil is 101.9 ± 5 seconds. It has an aniline point of $92.8 \pm 3.0^{\circ}\text{C}$ ($199.0 \pm 5.4^{\circ}\text{F}$) and an open-cup flash point of $243.3 \pm 5.6^{\circ}\text{C}$ ($470.0 \pm 10^{\circ}\text{F}$).

6.2.6 Tensile Testing Machine

Measurements for the tensile strength and ultimate elongation determinations shall be made on a power-driven machine provided with a device that indicates the maximum load applied to the specimen. If a machine of the spring-balance type is used, provision shall be made to prevent recoil of the spring. The machine shall be adjusted to provide the rate of jaw separation tabulated for each class of tubing. The indication of the applied tension as read from a dial or scale shall be accurate to within 2 percent or less of the tension actually applied to the test specimen. A set of standard weights shall be used for calibrating the machine, a method for which is included in ASTM D 412.

6.2.7 Specimen Preparation

6.2.7.1 Specimens for the tensile strength and ultimate elongation measurements shall be selected from unaged and aged samples of finished tubing. Specimens intended for accelerated aging shall be cut before being positioned in the air oven.

6.2.7.2 For tubing smaller than 8.38 mm (0.330 inches) inside diameter, fully recovered in the case of heat-shrinkable tubing, test specimens shall be prepared by cutting the sample tubing into lengths and subjecting each length to test in tubular form. For 8.38 mm (0.330 inches) inside diameter and larger tubing, die-cut specimens shall be prepared. This shall be done by cutting one wall of the tubing parallel to the longitudinal axis of the tubing, flattening the piece, and applying the die parallel to the axis on which the cut was made. Buffing of die-cut specimens may be required to remove surface imperfections, and this shall be carried out at least 30 minutes before oven aging or oil immersion.

6.2.7.3 Two marks (bench marks) shall be applied to each tubular and die-cut specimen immediately prior to the test and, in the case of oven-aged specimens, after the specimens are removed from the oven. For oil immersion, the marks shall be placed on the specimens before they are immersed in oil. The marks shall be separated by a distance of 25 mm (1 inches). This distance applies to all classes of material, and shall be an equal longitudinal distance from the center of the specimen. The bench marks shall be applied by means of the stamp described in Clause 6.2.4. They shall be perpendicular to the axis of the specimen and at right angles to the direction of pull in the testing machine. Care shall be taken that each of the marks is not more than 0.254 mm (0.010 inches) wide and that each specimen is completely at rest while being marked. The distance between the bench marks shall be checked carefully.

6.2.7.4 For tubular specimens, the cross-sectional area shall be determined as indicated in Clause 6.2.8.1 from measurements of the inside and outside diameters of the tubing before the specimen is aged. The measurements for the wall thickness used in calculation of the cross-sectional area of a die-cut specimen shall be made before aging and as described in Clauses 6.2.7.5 and 6.2.7.6. The inside diameter of the tubing shall be measured in accordance with ASTM D 876. Heat-shrinkable tubing shall be measured before and after recovery, which shall be achieved in accordance with the manufacturer's instructions. The specimens of heat-shrinkable tubing shall be recovered in an oven or equivalent in a manner that enables complete recovery without sticking. For tubing smaller than 8.38 mm (0.330 inches) inside diameter, the wall thickness T_1 shall be determined by the difference method from measurements of a 25 mm (1 inches) length of tubing into which there is inserted a solid metal rod or conductor of a diameter within 5.0 percent of the measured inside diameter of the tubing. The overall diameter of the tubing shall be measured to the nearest 0.01 mm or to the nearest 0.001 inches by means of a dead-weight dial micrometer equipped with an anvil and presser foot 2.0 mm (5/64 inches) wide and 9.5 mm (3/8 inches) long. The presser foot shall exert a load of 0.098 ± 0.020 N (0.022 ± 0.0045 lbf) on the specimen. The thickness T_1 of the tubular specimen shall be determined by subtracting the diameter of the metal from the overall diameter and dividing the result by 2.

6.2.7.5 The measurements for the thickness of a die-cut specimen shall be made with a dial micrometer graduated to the nearest 0.01 mm or the nearest 0.001 inches and actuated by a dead-weight load of 0.834 ± 0.029 N (0.187 ± 0.0065 lbf) on the specimen exerted through a flat presser foot 6.35 ± 0.25 mm (0.25 ± 0.01 inches) in diameter. The anvil of the instrument shall be at least 38.1 mm (1.5 inches) in diameter and shall be parallel to the face of the presser foot.

6.2.7.6 The thickness of a die-cut specimen shall be determined as the minimum of four measurements to the nearest 0.01 mm or to the nearest 0.001 inches, two measurements of which shall be made at 12.7 mm (1/2 inches) intervals between the bench marks on one edge of the reduced section and beginning 6.4 mm (1/4 inches) from either mark. The other two measurements shall be made at corresponding points on the opposite edge. The width of the specimen shall be taken as the distance between cutting edges of the die in the reduced section.

6.2.7.7 Each specimen shall be free from surface incisions and all other imperfections. Each specimen shall be examined carefully and, if it shows evidence of being damaged, it shall be discarded, and a new specimen shall be prepared (see Clause 6.1.4).

6.2.7.8 The specimens intended for accelerated aging shall be suspended vertically in the preheated air oven chamber so that they cannot touch one another or the sides of the oven during the aging. Specimens with widely different properties or composition shall be aged in separate ovens.

6.2.7.9 The specimens shall be subjected to the temperature in the air oven for the length of time specified in Item 9 of Tables 8 to 26, as applicable, while the air oven is operating at the specified draft. The air temperature in the oven shall be recorded throughout the aging.

6.2.7.10 The measurements for ultimate elongation and tensile strength shall be made simultaneously using specimens that have not previously been subjected to any test. Each specimen shall be clamped in position with both bench marks outside the jaws and between the two grips. The movable grip shall be adjusted to take the slack out of the specimen, but not far enough to put the specimen under tension. The grips shall be separated at the rate specified for the class of tubing being tested, until the specimen breaks. During separation, the distance between bench marks shall be observed continuously, so that the distance at the instant of rupture can be observed with an accuracy of at least 2 mm (0.1 inches). Because the width of a bench mark increases while a specimen is being stretched, the measurement for ultimate elongation shall be made with reference to the center of each mark – that is, a point halfway between the edge of each mark. The air temperature shall be recorded.

6.2.7.11 The maximum load in MN or lbf shall be recorded. If a specimen breaks within the jaws at a load small enough to result in a lower tensile strength than tabulated in Item 6 or 11 in Tables 8 to 26, as applicable, the results for that specimen shall be disregarded.

6.2.8 Calculation of Results

6.2.8.1 The cross-sectional area of a tubular specimen shall be determined by means of the formula

$$A = (\pi/4) \times (D_o^2 - D_i^2) = 0.7854 (D_o^2 - D_i^2)$$

where

A = the desired area, m² (in²)

D_o = the outside diameter of the specimen measured to the nearest 0.0001 m or 0.001 inches before aging

D_i = the inside diameter of the specimen measured to the nearest 0.0001 m or 0.001 inches before aging

6.2.8.2 For tubing with a meltable liner, the thickness of the liner shall not be included when determining the cross-sectional area.

6.2.8.3 The tensile strength of a specimen is the maximum force sustained by the specimen during the tensile test per unit of the original cross-sectional area of the specimen before aging. It shall be computed by means of one of the following formulas:

$$T_t = P/A$$

$$T_d = P/wt$$

where

T_t = the tensile strength of a tubular specimen, Mpa (psi)

T_d = the tensile strength of a die-cut specimen, Mpa (psi)

P = the maximum load, (MN) (lbf)

A = the cross-sectional area of a tubular specimen (see Clause 6.2.7.4) before aging

w = the width of a die-cut specimen (see Clauses 6.2.7.5 and 6.2.7.6)

t = the minimum thickness of a die-cut specimen (see Clauses 6.2.7.5 and 6.2.7.6)

6.2.8.4 The ultimate elongation shall be calculated by subtracting the original distance between the bench marks from the distance between the bench marks at the instant of rupture of the specimens and expressing this difference as a percentage of the original distance by means of the formula

$$U = ((R - S)/S) \times 100$$

where

U = the ultimate elongation, percent

R = the distance between the bench marks at the instant of rupture, mm (inches)

S = the original distance between the bench marks; mm (inches)

6.3 Oil Resistance (Optional)

6.3.1 Tubing shall be considered Class 01 oil-resistant if the retention of tensile strength and elongation is not less than 75 percent after being subjected to the test specified in Clause 6.3.4.

6.3.2 Tubing shall be considered Class 02 oil-resistant if the retention of tensile strength and elongation is not less than 50 percent after being subjected to the test specified in Clause 6.3.5.

6.3.3 Tubing shall be considered Class 03 oil-resistant if the retention of tensile strength and elongation is not less than 65 percent after being subjected to the test specified in Clause 6.3.6.

6.3.4 The tubing defined in Clause 6.3.1 shall be immersed in ASTM No. 2 or IRM 902 oil for 4 hours at $70.0 \pm 1.0^\circ\text{C}$ ($158 \pm 1.8^\circ\text{F}$) in accordance with the procedure in Clauses 6.2.5.1 and 6.2.5.3, and the exceptions defined in Clause 6.3.7.

6.3.5 The tubing defined in Clause 6.3.2 shall be immersed in ASTM No. 2 or IRM 902 oil for 96 hours at $100.0 \pm 1.0^\circ\text{C}$ ($212 \pm 1.8^\circ\text{F}$) in accordance with the procedure in Clauses 6.2.5.1 and 6.2.5.3, and the exceptions defined in Clause 6.3.7.

6.3.6 The tubing defined in Clause 6.3.3 shall be immersed in ASTM No. 2 or IRM 902 oil for 60 days at $80.0 \pm 1.0^\circ\text{C}$ ($176.0 \pm 1.8^\circ\text{F}$) in accordance with the procedure in Clauses 6.2.5.1 and 6.2.5.3, and the exceptions defined in Clause 6.3.7.

6.3.7 Regarding Clauses 6.3.4, 6.3.5, and 6.3.6, the following modifications shall be made to the test procedure:

- a) the bench marks shall be applied before immersion in oil, rather than just before the physical test, as in all other cases; and
- b) the physical test shall be conducted 3.5 – 4.5 hours after removal from the oil, rather than 16 – 96 hours later, as for oven aging.

6.4 Flexibility (Not-Heat-Shrinkable Tubing)

6.4.1 Tubing shall remain flexible and shall not crack or deform permanently when flexed at room temperature after aging as indicated in Item 9 of Tables 8 to 26, as applicable.

6.4.2 Three specimens, 0.30 m (1 foot) long, cut from sample lengths of tubing, shall be cooled to room temperature after aging in heated circulating air as indicated in Item 9 of Tables 8 to 26, as applicable. Each specimen then shall be bent back on itself 180° . Following release, the tubing shall return to the general circular form within 1 minute and exhibit no cracks visible to normal, or corrected-to-normal vision. Internal cracks (checks) can often be detected from circumferential depressions on the outer surface of the tubing. The tubing shall not be acceptable if any of these effects are noticed in any specimen tested. Kinking of the tubing shall not constitute failure.

6.5 Dielectric Voltage Withstand and Breakdown

6.5.1 Aged and unaged tubing shall be capable of withstanding, without breakdown, the application of a 60 Hz essentially sinusoidal potential of 2500 V applied for a period of 1 minute between a conductor or conductors inserted in the tubing and strip metal foil wrapped around the outer surface of the tubing. The potential shall then be increased until breakdown occurs. The breakdown potential of tubing that has been aged as indicated in Item 9 of Tables 8 to 26, as applicable, shall be at least 50.0 percent of the breakdown potential of the unaged tubing, but not less than 2500 V.

6.5.2 Three specimens of tubing, each 0.9 m (3 feet) in length, shall be aged in a circulating-air oven as indicated in Item 9 of Tables 8 to 26, as applicable, and are then to be cooled to room temperature. These and similar specimens conditioned for the same length of time at a temperature of $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) shall be tested. One clean, straight, bare, solid, copper conductor shall be inserted with a snug fit into each specimen of 0.305 – 3.88 mm (0.012 – 0.153 inches) tubing prior to aging. Several conductors shall be inserted with a snug fit into 4.22 mm (0.166 inches) inside diameter or larger tubing. Heat-shrinkable tubing shall be centered and recovered on a conductor, or conductors, having the same diameter, or overall diameter, as the maximum recovered inside diameter of the tubing size being tested. The center 152 mm (6 inches) portion of each specimen shall be wrapped with strip metal foil.

6.5.3 Each specimen shall be stressed by means of a testing transformer whose output potential is continuously monitored by an acceptable voltmeter that is connected in the output circuit and directly and precisely indicates the potential being applied to a specimen, is essentially sinusoidal at 50-60 Hz, and can be varied continuously from zero to at least 2500 V. The applied potential shall be increased from zero at an essentially uniform rate that is not less than 100 percent of the voltage rating for the product in 60 seconds, and not more than 100 percent in 10 seconds (the rate of increase is not to exceed 500 V/s in any case). The increase shall continue in this manner until the voltage reaches 2500 V. If this level is reached without breakdown, the potential shall be held constant at 2500 V for 60 seconds and shall then be increased at the rate mentioned above until breakdown occurs.

6.6 Deformation

6.6.1 General

The wall thickness of the tubing shall not decrease more than the value specified in Item 16 of Tables 8 to 26, as applicable, while under the load indicated in Table 4.

6.6.2 Samples

Compliance with the deformation test in Clause 6.6.1 shall be determined in accordance with the apparatus and procedure in Clauses 6.6.3, 6.6.4, and 6.6.5. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) of 4.22 mm (0.166 inches) or less, the deformation test shall be conducted on specimens of tubing with a solid metal conductor or rod having a diameter approximately equal to, but not greater than, the inside diameter of the tubing, inserted into each specimen. For larger tubing sizes, rectangular specimens 25 mm (1 inches) long and 6.4 mm (1/4 inches) wide shall be cut from the tubing.

6.6.3 Apparatus

The apparatus for the determination of percentage deformation shall consist of:

- a) an oven capable of maintaining the required air temperature and having the characteristics required by ASTM D 5374; and
- b) the necessary weights as indicated in Table 4, mounted in a metal frame so as to have free vertical movement, as illustrated in Figure 3.

The weight shall be provided with a 9.5 mm (0.37 inches) diameter flat presser foot, slightly rounded at the edges, and intended to bear upon the specimen under test.

6.6.4 Procedure

6.6.4.1 The specimen shall be measured for thickness as follows:

- a) Tubing specimen. The diameter (D_1) over the tubing at a marked position shall be measured using a dial micrometer. The diameter (d) over the conductor shall also be measured, and the thickness of insulation shall be calculated as follows:

$$T_1 = (D_1 - d)/2$$

- b) Strip specimen. The thickness (T_1) of the specimen shall be measured at a marked position using a dial micrometer.

c) Specimens of heat-shrinkable tubing shall be measured in the fully recovered state.

6.6.4.2 The appropriate weight, in accordance with Table 4, and the measured specimen shall be maintained for 1 hour in the oven, which has been preheated to the test temperature indicated in Item 16 of Tables 8 to 26, as applicable. At the end of that time, the specimen shall be placed under the foot of the weight, which is to bear on the spot previously marked on the specimen (see Figure 3). Under these conditions, the specimen shall remain in the oven at the specified temperature for a further 1 hour period, following which it shall be carefully removed from under the weight and measured within 15 seconds for thickness T_2 in the same manner as specified in Clause 6.6.4.1 (a) or (b), as applicable, for thickness T_1 .

6.6.5 Calculation of Deformation

The percentage deformation of the specimen shall be calculated according to the following formula:

$$\text{percentage deformation} = (T_1 - T_2)/T_1 \times 100$$

6.6.6 Tubing with Meltable Liner

For tubing with a meltable liner, the thickness of the liner shall not be included when determining the deformation.

6.7 Heat Shock

6.7.1 Tubing shall show no evidence of cracking, flowing, or dripping after conditioning and after being wound around a mandrel as indicated in Item 17 of Tables 8 to 26, as applicable. Side cracking of the flattened tubing or flowing from the inner wall of tubing with a meltable liner shall not be cause for rejection.

6.7.2 For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) less than 8.38 mm (0.330 inches), the test shall be performed on a 152 mm (6 inches) length of the tubing. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) 8.38 mm (0.330 inches) or larger, the test shall be performed on a 152 mm (6 inches) by 12.7 mm (0.5 inches) longitudinal strip cut from the tubing.

6.7.3 The specimen, prepared as described in Clause 6.7.2, shall be suspended vertically in a circulating-air oven by means of a small piece of wire attached to one end of the specimen, and shall then be conditioned for the time and at the temperature indicated in Item 17 of Tables 8 to 26, as applicable. After conditioning, the specimen shall be visually examined for evidence of cracking, flowing, or dripping. The specimen shall be allowed to cool to room temperature and shall then be wound 360° around a steel mandrel of the size specified in Table 7 for the tubing size being tested, at a uniform rate and within 2 to 4 seconds. The specimen shall then be visually examined for cracking.

6.8 Cold Bend

6.8.1 Tubing shall show no evidence of cracking when wound around a mandrel after conditioning as indicated in Item 18 of Tables 8 to 26, as applicable.

6.8.2 For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) less than 10.2 mm (0.4 inches), a straight, bare, solid copper conductor shall be inserted with a snug fit into a 305 mm (12 inches) length of the tubing. Heat-shrinkable tubing shall be fully recovered onto a straight,

stranded copper wire having the same diameter as the maximum recovered inside diameter of the tubing. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) 10.2 mm (0.4 inches) and larger, a 152 by 6.4 mm (6 by 0.25 inches) longitudinal strip shall be cut from the tubing.

6.8.3 The specimen, prepared as described in Clause 6.8.2, and a steel mandrel of the size specified in Table 7 for the tubing size being tested, shall be conditioned for the time and at the temperature indicated in Item 18 of Tables 8 to 26, as applicable. After conditioning, and while still at this temperature, the specimen shall be wound not less than 360° around the mandrel at a uniform rate and within 10 ± 2 seconds, and then visually examined for cracking.

6.9 Flame Test – All Tubing

6.9.1 A vertical specimen of the tubing shall not flame or glow longer than 60 seconds following any of five 15 seconds applications of the test flame, the period between applications being

- a) 15 seconds if the specimen's flaming or glowing ceases within 15 seconds; or
- b) the duration of the specimen's flaming or glowing, if it persists longer than 15 seconds.

The specimen shall not ignite combustible materials in its vicinity or damage more than 25 percent of the indicator flag during, between, or after the five applications of the test flame. Heat-shrinkable tubing shall be tested in the fully recovered state. The test shall be conducted as described in Clauses 6.9.2 to 6.9.11.

6.9.2 This test shall be performed on unaged specimens of the tubing. The test shall be conducted in a three-sided metal enclosure in an exhaust hood or cabinet. The metal enclosure shall be 305 mm (12 inches) wide, 355 mm (14 inches) deep, 610 mm (24 inches) high, and the top and front shall be open. A 457 mm (18 inches) specimen cut from a sample length of not-heat-shrinkable tubing shall be centered on a 533 mm (21 inches) straight length of a metal conductor or steel rod having the diameter indicated in Table 5. A 457 mm (18 inches) length of heat-shrinkable tubing shall be centered and recovered on a 533 mm (21 inches) straight length of metal conductor or steel rod having the same diameter as the maximum recovered inside diameter for the tubing size. The combinations of the specimen and its support shall be secured with its longitudinal axis vertical in the center of the enclosure. A flat horizontal layer of untreated surgical cotton approximately 3 mm (1/8 inches) thick shall cover the floor of the enclosure. The upper surface of the cotton shall be no more than 241 mm (9-1/2 inches) below point B, which is the point at which the tip of the blue inner cone of the test flame touches the specimen. (See Figure 4.)

6.9.3 A Tirrill gas burner (such a burner differs from a Bunsen burner in that the air flow as well as the flow of gas is adjustable) with or without a gas pilot light attached shall supply the flame. The barrel of the burner shall extend 102 mm (4 inches) above the air inlets and its inside diameter shall be 9.5 mm (3/8 inches). While the barrel is vertical and the burner is well away from the specimen, the overall height of the flame shall be adjusted to approximately 100 – 125 mm (4 – 5 inches). The blue inner cone shall be 38 mm (1-1/2 inches) high and the nominal temperature at its tip shall be 816°C (1500°F) or higher as measured using a chromel alumel (nickel chromium and nickel manganese aluminum) thermocouple. Without disturbing the adjustments for the height of the flame, the valve supplying gas to the burner flame and the separate valve supplying gas to any pilot flame shall be closed. Calibrations of the burner shall be performed in accordance with UL 1581 or CSA C22.2 No. 0.3. The flame test shall be performed in a draft-free room or chamber in accordance with the requirements of UL 1581 or CSA C22.2 No. 0.3. (See Figure 4.)

6.9.4 A wedge (acceptable dimensions are shown in Figure 6) to which the base of the burner can be secured shall be provided for tilting the barrel 20° from the vertical while the longitudinal axis of the barrel remains in a vertical plane. The burner shall be secured to the wedge and the assembly shall be placed in an adjustable support jig. A layer of untreated surgical cotton approximately 3 mm (1/8 inches) thick and 25 mm (1 inch) in diameter shall be placed on the wedge and around the base of the burner. The jig shall be adjusted toward one side or the other of the enclosure to place the longitudinal axis of the barrel in the vertical plane that contains the longitudinal axis of the specimen. The plane shall be parallel to the sides of the enclosure. The jig shall also be adjusted toward the rear or front of the enclosure to position the point A, which is the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel, 38 mm (1-1/2 inches) from the point B, at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone shall touch the center of the front of the specimen. The specimen shall be adjusted vertically to prevent point B from being any closer than 76 mm (3 inches) to the lower clamp or other support for the specimen. (See Figure 4).

6.9.5 In the absence of a gas pilot light on the burner, the support for the burner and wedge shall be arranged to enable the burner to be quickly removed from and precisely returned to the position described in Clause 6.9.4 without disturbing the layer of cotton on the floor of the enclosure or the cotton on the wedge around the base of the burner.

6.9.6 A strip of unreinforced 94 g/m² kraft paper (60 lb) that is 13 mm (1/2 inches) wide, approximately 0.1 mm (5 mils) thick, and gummed on one side shall be used to make an indicator flag. The gumming shall be moistened just enough to facilitate adhesion. With the gum toward the specimen, the strip shall be wrapped around the specimen once, with its lower edge 254 mm (10 inches) above B, the point at which the blue inner cone shall touch the specimen. The ends of the strip shall be pasted together evenly and trimmed to provide a flag that projects 19 mm (3/4 inches) from the specimen toward the rear of the enclosure, with the flag parallel to the sides of the enclosure. (See Figure 4.)

6.9.7 If the burner has a gas pilot light, the valve supplying gas to the pilot shall be opened and the pilot lit. If the burner does not have a gas pilot light, the burner shall be supported as indicated in Clause 6.9.5 in a position away from the specimen and then lit. This operation and the remainder of the test shall be conducted under a forced-draft exhaust hood or cabinet operating to provide removal of smoke and fumes, but avoiding drafts that affect the flame.

6.9.8 If the burner has a gas pilot light, the valve supplying gas to the burner shall be opened to apply the flame to the specimen automatically. This valve shall be held open for 15 seconds, closed for 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause), opened for 15 seconds, and repeated for a total of five 15 seconds applications of the gas flame to the specimen with 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause) between applications. If the burner does not have a gas pilot light, the burner shall be moved into position to apply the gas flame to the specimen, kept there for 15 seconds, removed for 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause), and repeated for a total of five 15 seconds applications of the gas flame to the specimen with 15 seconds (longer if flaming or glowing of the specimen persist – see the second paragraph of this Clause) between applications.

The gas flame shall be reapplied to the specimen 15 seconds after the previous application if flaming or glowing of the specimen ceases of its own accord within 15 seconds of the previous application. If flaming or glowing of the specimen persists longer than 15 seconds after the previous application of the gas flame, the gas flame is not to be reapplied until flaming or glowing of the specimen ceases of its own accord. In the latter case, the gas flame shall be reapplied as soon as flaming or glowing of the specimen ceases.

6.9.9 If any specimen of the tubing shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching shall be ignored) after any of the five applications of flame, the tubing shall be considered as capable of conveying flame.

6.9.10 If any specimen of the tubing emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the tubing shall be considered as capable of conveying flame to combustible materials in its vicinity.

6.9.11 If any specimen of the tubing continues to flame or glow longer than 60 seconds after any application of the gas flame, the tubing shall be considered as capable of conveying flame to combustible materials in its vicinity.

6.10 Optional VW-1 (Vertical Wire) Flame Test

6.10.1 A vertical specimen of tubing that is identified as "VW-1" shall not flame or glow longer than 60 seconds following any of the five 15 seconds applications of the test flame, the period between applications being:

- a) 15 seconds if the specimen's flaming or glowing ceases within 15 seconds; or
- b) the duration of the specimen's flaming or glowing, if it persists longer than 15 seconds.

The specimen shall not ignite combustible materials in its vicinity or damage more than 25 percent of the indicator flag during, between, or after the five applications of the test flame. Heat-shrinkable tubing shall be tested in the fully recovered state. The test shall be conducted as described in Clauses 6.10.2 to 6.10.13.

6.10.2 This test shall be performed on unaged specimens of the tubing. The test shall be conducted in a 3-sided metal enclosure in an exhaust hood or cabinet. The metal enclosure shall be 305 mm (12 inches) wide, 355 mm (14 inches) deep, 610 mm (24 inches) high, and the top and front shall be open. The enclosure shall be equipped with means for supporting a 559 mm (22 inches) straight length of tubing that is closed at one end to prevent a chimney effect and is suspended vertically.

6.10.3 A 660 mm (26 inches) length of not-heat-shrinkable tubing shall be drawn onto a wire 889 mm (35 inches) in length. For tubing whose nominal inside diameter is at least 0.81 mm (0.032 inches), a 0.74 mm (0.029 inches) diameter fine spring-steel music wire shall be used. If the nominal inside diameter of the tubing is 0.44 – 0.81 mm (0.019 – 0.032 inches), a 0.41 mm (0.016 inches) diameter fine spring-steel music wire shall be used. If the nominal inside diameter of the tubing is less than 0.44 mm (0.019 inches), a 0.25 mm (0.010 inches) diameter fine spring-steel music wire shall be used. In the case of heat-shrinkable tubing, an 889 mm (35 inches) length of the specified wire shall be used to provide a length of recovered tubing long enough to fit between the two supports 559 mm (22 inches) apart and to facilitate clamping as shown in Figure 5. The combination of the specimen and its supporting wire with its longitudinal axis vertical in the center of the enclosure shall be secured at one end to the middle of the upper support by kinking the tubing and clamping (using a paper clip or clamp) to provide a closed end to the specimen, thus preventing any chimney effects during the test. The lower end of the wire protruding from the open end of the tubing shall be passed over the middle of the lower support and secured.

6.10.4 A flat horizontal layer of untreated surgical cotton approximately 3 mm (1/8 inches) thick shall cover the floor of the enclosure. The upper surface of the cotton shall be no more than 241 mm (9-1/2 inches) below point B, which is the point at which the tip of the blue inner cone of the test flame touches the specimen. (See Figure 5.)

6.10.5 A Tirril gas burner (such a burner differs from a Bunsen burner in that the air flow as well as the flow of gas is adjustable) with or without a gas pilot light attached shall supply the flame. The barrel of the burner shall extend 102 mm (4 inches) above the air inlets and its inside diameter shall be 9.5 mm (3/8 inches). While the barrel is vertical and the burner is well away from the specimen, the overall height of the flame shall be adjusted to approximately 100 – 125 mm (4 – 5 inches). The blue inner cone shall be 38 mm (1-1/2 inches) high and the nominal temperature at its tip shall be 816°C (1500°F) or higher as measured using a chromel alumel (nickel chromium and nickel manganese aluminum) thermocouple. Without disturbing the adjustments for the height of the flame, the valve supplying gas to the burner flame and the separate valve supplying gas to any pilot flame shall be closed. Calibration of the burner shall be performed in accordance with UL 1581 or CSA C22.2 No. 0.3. The flame test shall be performed in a draft-free room or chamber in accordance with the requirements of UL 1581 or CSA C22.2 No. 0.3. (See Figure 5.)

6.10.6 A wedge (acceptable dimensions are shown in Figure 6) to which the base of the burner can be secured shall be provided for tilting the barrel 20° from the vertical while the longitudinal axis of the barrel remains in a vertical plane. The burner shall be secured to the wedge, and the assembly shall be placed in an adjustable support jig. A layer of untreated surgical cotton approximately 3 mm (1/8 inches) thick and 25 mm (1 inch) in diameter shall be placed on the wedge and around the base of the burner. The jig shall be adjusted toward one side or the other of the enclosure to place the longitudinal axis of the barrel in the vertical plane that contains the longitudinal axis of the specimen. The plane shall be parallel to the sides of the enclosure. The jig shall also be adjusted toward the rear or front of the enclosure to position the point A, which is the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel, 38 mm (1-1/2 inches) from the point B, at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone shall touch the center of the front of the specimen. The specimen shall be adjusted vertically to prevent point B from being any closer than 76 mm (3 inches) to the lower clamp or other support for the specimen. (See Figure 5.)

6.10.7 In the absence of a gas pilot light on the burner, the support for the burner and wedge shall be arranged to enable the burner to be quickly removed from and precisely returned to the position described in Clause 6.10.6 without disturbing the layer of cotton on the floor of the enclosure or the cotton on the wedge around the base of the burner.

6.10.8 A strip of unreinforced 94 g/m² (60 lb) kraft paper that is 13 mm (1/2 inches) wide, approximately 0.1 mm (5 mils) thick, and gummed on one side shall be used to make an indicator flag. The gumming shall be moistened just enough to facilitate adhesion. With the gum toward the specimen, the strip shall be wrapped around the specimen once, with its lower edge 254 mm (10 inches) above point B, the point at which the blue inner cone shall touch the specimen. The ends of the strip shall be pasted together evenly and trimmed to provide a flag that projects 19 mm (3/4 inches) from the specimen toward the rear of the enclosure, with the flag parallel to the sides of the enclosure. (See Figure 5).

6.10.9 If the burner has a gas pilot light, the valve supplying the gas to the pilot shall be opened and the pilot lit. If the burner does not have a gas pilot light, the burner shall be supported as indicated in Clause 6.10.7 in a position away from the specimen and then lit. This operation and the remainder of the test shall be conducted under a forced draft exhaust hood or cabinet operating to provide removal of smoke and fumes, but avoiding drafts that affect the flame.

6.10.10 If the burner has a gas pilot light, the valve supplying gas to the burner shall be opened to apply the flame to the specimen automatically. This valve shall be held open for 15 seconds, closed for 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause), opened for 15 seconds, and repeated for a total of five 15 seconds applications of the gas flame to the specimen with 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause) between applications. If the burner does not have a gas pilot light, the burner shall be moved into position to apply the gas flame to the specimen, kept there for 15 seconds, removed

for 15 seconds (longer if flaming or glowing of the specimen persists – see the second paragraph of this Clause), and repeated for a total of five 15 seconds applications of the gas flame to the specimen with 15 seconds (longer if flaming or glowing of the specimen persist – see the second paragraph of this Clause) between applications. If the supporting wire breaks due to the flame, the sample shall be discarded and the test shall be repeated with a new specimen.

The gas flame shall be reapplied to the specimen 15 seconds after the previous application if flaming or glowing of the specimen ceases of its own accord within 15 seconds of the previous application. If flaming or glowing of the specimen persists longer than 15 seconds after the previous application of the gas flame, the gas flame is not to be reapplied until flaming or glowing of the specimen ceases of its own accord. In the latter case, the gas flame shall be reapplied as soon as flaming or glowing of the specimen ceases.

6.10.11 If any specimen of the tubing shows more than 25 percent of the indicator flag burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching shall be ignored) after any of the five applications of flame, the tubing shall be considered capable of conveying flame along its length.

6.10.12 If any specimen of the tubing emits flaming or glowing particles or flaming drops at any time that ignite the cotton on the burner, wedge, or floor of the enclosure (flameless charring of the cotton shall be ignored), the tubing shall be considered capable of conveying flame to combustible materials in its vicinity.

6.10.13 If any specimen of the tubing continues to flame or glow longer than 60 seconds after any application of the gas flame, the tubing shall be considered capable of conveying flame to combustible materials in its vicinity.

6.11 Volume Resistivity

6.11.1 Tubing shall meet the requirement specified in Item 20 of Tables 8 to 26, as applicable, when tested for volume resistivity in accordance with ASTM D 257.

6.12 Secant Modulus

6.12.1 The secant modulus of the tubing (unrecovered in the case of heat-shrinkable tubing) shall not be outside the limit specified in Item 22 of Tables 8 to 26, as applicable, and shall be calculated from the stress in MPa (psi) that produces an elongation of 2 percent.

6.12.2 For tubing smaller than 8.38 mm (0.330 inches) inside diameter, specimens shall be prepared by cutting the sample tubing into 305 mm (12 inches) lengths and testing each length in tubing form. For larger tubing, strip specimens shall be prepared by cutting the wall of the tubing parallel to the longitudinal axis, flattening the piece, and die-cutting a strip 12.7 mm (1/2 inches) wide and 178 mm (7 inches) long parallel to the axis on which the tubing was cut.

6.12.3 The measurements for secant modulus shall be made in close succession, and at a temperature of $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$), after the specimens have been at this temperature for at least 30 minutes. For tubular specimens, the grips of the testing machine shall be set with a separation of 254 mm (10 inches). For strip specimens, the grip separation shall be 127 mm (5 inches). The rate of grip separation shall be 25.4 mm (1 inch) per minute for tubular and strip specimens. Each specimen shall be clamped in position in the grips of the testing machine; the grips shall then be separated at the specified rate with the testing machine recorder in operation. When the recorder indicates elongation of the specimen in excess of 3 percent of the original grip separation, the test may be discontinued.

6.12.4 The secant modulus shall be calculated from the following formula after determining the tensile stress necessary to produce a 2 percent strain.

$$SM_2 = (S_2/0.02) = 50S_2$$

where

SM_2 = the secant modulus at 2 percent strain

S_2 = the stress at 2 percent elongation, Mpa (psi)

The tensile stress, S_2 , is determined by dividing the load in MN (lbf) at 2 percent strain by the original cross-sectional area of the specimen.

6.12.5 For tubing with a meltable liner, the thickness of the liner shall not be included when determining the secant modulus.

6.13 Eccentricity (Heat-Shrinkable Tubing)

6.13.1 The eccentricity of fully recovered heat-shrinkable tubing shall not be more than the value specified in Item 23 of Tables 8 to 26, as applicable.

6.13.2 Both the minimum and maximum wall thicknesses shall be located on a cross-section of tubing using the measuring method of Clause 4.3.2. The eccentricity shall be calculated from the formula:

$$E = 100 - (\text{Minimum} \times 100)/\text{Maximum}$$

Where

E = the eccentricity, percent

Minimum = the minimum wall thickness measured

Maximum = the maximum wall thickness measured

6.14 Longitudinal Change

6.14.1 The longitudinal change (change in length) of the tubing shall conform to the requirement specified in Item 21 of Tables 8 to 26, as applicable.

6.14.2 Three samples of nominal 152 mm (6 inches) lengths of tubing as it comes from the manufacturer, or fully recovered heat-shrinkable tubing, shall be measured for length to the nearest 0.4 mm (1/64 inches). The measured lengths of tubing shall be heated in a full-draft circulating-air oven for the time and

at the temperature specified in Item 21 of Tables 8 to 26, as applicable. After cooling to room temperature, the length shall be remeasured and the longitudinal change calculated from the following formula:

$$LC = ((L_2 - L_1)/L_1) \times 100$$

Where

LC = the longitudinal change

L_1 = the original length

L_2 = the length after conditioning

6.15 Copper Corrosion

6.15.1 Tubing, while in contact with bare, uncoated copper, shall not cause corrosion of the copper after air-oven aging as specified in Item 14 of Tables 8 to 26, as applicable.

6.15.2 For tubing having an inside diameter (fully recovered in the case of heat-shrinkable tubing) of 3.18 mm (0.125 inches) or less, a clean, straight, bare, uncoated, copper wire shall be inserted with a snug fit into a specimen at least 152 mm (6 inches) long cut from a length of the tubing. For tubing with a meltable liner, at least two wires 1.02 mm (0.0403 inches) or smaller shall be inserted with a snug fit into the specimen, or, if this is difficult, the specimen shall be recovered onto two or more wires having the same overall diameter as the maximum recovered inside diameter of the tubing being tested. For larger sizes of tubing, several wires shall be inserted with a snug fit into a specimen at least 152 mm (6 inches) long cut from a length of the tubing. These specimens shall be placed in a humidity chamber with a relative humidity of 95 ± 5 percent at $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) for 24 hours. After this conditioning, the specimens shall be placed in a circulating-air oven for the time and at the temperature shown in Item 9 of Tables 8 to 26, as applicable.

6.15.3 After each specimen has cooled to room temperature, the conductor or conductors shall be removed and examined for pitting of the copper or other evidence of chemical attack as indicated by pronounced blackening. Discoloration of the copper from normal air oxidation shall be disregarded. The compound shall show no evidence of nonuniform discoloration that could be regarded as spotting.

6.15.4 For tubing with a meltable liner, the copper wires shall be removed by securing one end of the wires in a vise and then simultaneously rotating and pulling the tubing toward the free end of the wires. Should it prove impractical to remove the wires by this method, it is acceptable to slit the tubing longitudinally and carefully peel it away from the wires. The specimen, including the meltable liner, and the wires shall be examined as described in Clause 6.15.3.

6.16 Copper Stability

6.16.1 Tubing, while in contact with bare, uncoated copper, shall show no sign of degradation and shall have elongation no less than indicated in Item 12 of Tables 8 to 26, as applicable, after air-oven aging as specified in Item 15 of Tables 8 to 26, as applicable.

6.16.2 For tubing having an inside diameter (fully recovered in the case of heat-shrinkable tubing) of 3.18 mm (0.125 inches) or less, a clean, straight, bare, uncoated, copper wire shall be inserted with a snug fit into a specimen at least 152 mm (6 inches) long cut from a length of tubing. For tubing with a meltable liner, at least two wires 1.02 mm (0.0403 inches) or smaller shall be inserted with a snug fit into the specimen, or, if this is difficult, the specimen shall be recovered onto two or more wires having the same

overall diameter as the maximum recovered inside diameter of the tubing being tested. For larger sizes of tubing, several wires shall be inserted with a snug fit into a specimen at least 152 mm (6 inches) long cut from a length of the tubing. These specimens shall be placed in a humidity chamber with a relative humidity of 95 ± 5 percent at $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$) for 24 hours. After this conditioning, the specimens shall be placed in a circulating-air oven for the time and at the temperature specified in Item 9 of Tables 8 to 26, as applicable.

6.16.3 After aging, the specimens shall be cooled to room temperature and the tubing examined for signs of degradation (such as cracking, splitting, or grossly uneven changes in color), and then the tubing shall be removed from the wire. After conditioning at room temperature for 16 – 96 hours, the tubing shall be tested for elongation as indicated in Clause 6.2.

6.16.4 For tubing with a meltable liner, the copper wires shall be removed by securing one end of the copper wires in a vise and then simultaneously rotating and pulling the tubing toward the free end of the wires. Should it prove impractical to remove the copper wire by this method, it is acceptable to slit the tubing longitudinally and peel it away from the copper wire, as long as this does not result, through notching or overstressing of the tubing, in premature failure of the tubing when tested for elongation as described in Clause 6.2. The tubing shall be examined and tested as described in Clause 6.16.3.

6.17 Restricted Recovery (Heat-Shrinkable Tubing)

6.17.1 Tubing shall pass the dielectric test in Clause 6.5.1 for unaged specimens and shall not split when recovery is variably restricted over portions of the specimen length.

6.17.2 A 152 mm (6 inches) length of unrecovered tubing shall be placed over a metal mandrel as shown in Figure 7 and of the dimensions indicated in Table 6. The specimen on the mandrel shall be heated in a circulating-air oven for 30 minutes at the temperature recommended for recovery. After heating, the specimen on the mandrel shall be removed from the oven, allowed to cool to room temperature, examined for splitting, and dielectric-tested with the outer electrode wrapped over the largest diameter of the specimen. Because of the difficulty in making a very small shaped mandrel, tubing with a diameter smaller than 2.54 mm (0.100 inches) (expanded) shall be tested on a 34.93 mm (1.375 inches) long straight cylindrical mandrel with a diameter equal to 75 percent of the minimum expanded inside diameter.

6.18 Heat-Resistant Properties (Not-Heat-Shrinkable Tubing)

6.18.1 Tubing in trade sizes 12 mm (1/2 inches) and smaller shall show no cracks, either externally or internally, when a straight specimen of tubing into which has been inserted a copper conductor is subjected to the following:

- a) exposure to air-oven aging as specified in Item 28 of Tables 8 to 26, as applicable;
- b) cooled to $23.0 \pm 2.0^\circ\text{C}$ ($73.4 \pm 3.6^\circ\text{F}$);
- c) wound six adjacent turns around a stainless steel (AISI 304) mandrel having a diameter equal to the outside of the tubing; and
- d) unwound from the mandrel and straightened.

The portion of the tubing subjected to the winding shall then withstand, without breakdown, a dielectric strength test of 1500 V for 1 minute between the conductor and metal foil that has been wrapped over the portion of the tubing subjected to the winding (see Clause 6.18.3).

6.18.2 Tubing in trade sizes 12 mm (1/2 inches) and smaller shall show no cracks, either externally or internally, when a straight specimen of tubing into which has been inserted a copper conductor is wound six adjacent turns around a stainless steel (AISI 304) mandrel having a diameter equal to the outside diameter of the tubing, and subjected to the following:

- a) exposure to air-oven aging as specified in Item 28 of Tables 8 to 26, as applicable;
- b) cooled to $23.0 \pm 2.0^{\circ}\text{C}$ ($73.4 \pm 3.6^{\circ}\text{F}$); and
- c) unwound from the mandrel and straightened.

The portion of the tubing subjected to the winding shall then withstand, without breakdown, a dielectric strength test of 1500 V for 1 minute between the conductor and metal foil that has been wrapped over the portion of the tubing subjected to the winding (see Clause 6.18.3).

6.18.3 The copper conductor referred to in Clauses 6.18.1 and 6.18.2 shall have a diameter approximately equal to, but not greater than, the inside diameter of the tubing under test. Compliance with the dielectric strength test in Clauses 6.18.1 and 6.18.2 shall be determined by wrapping the portion of the specimen subjected to the winding with metal foil, and applying an ac voltage of 1500 V for 1 minute between the conductor and the metal foil, in accordance with the procedure described in Clause 6.5.3.

7 Markings

7.1 Product Marking

Product marking shall not be required.

7.2 Package Marking

All sizes of extruded insulating tubing shall be marked with the following information on tags attached to both ends of the tubing, on the shipping spool label, or on the smallest unit container:

- a) the organization responsible for the product;
- b) the manufacturer's name or private labeller's name, trade name, and/or trademark;
- c) catalog number or equivalent;
- d) temperature rating in $^{\circ}\text{C}$;
- e) voltage rating;
- f) date of manufacture (or a lot number, if the date of manufacture can be traced from this number);
- g) flammability rating (if VW-1);
- h) "oil resistant" or "oil res"
- i) inside diameter (before and after recovery, for heat-shrinkable tubing).

Table 1 – Tubing covered by this Standard

Material	Form	Temperature rating(s)	Voltage rating(s)
PVC	Not-heat-shrinkable	90 and 105°C (194 and 221°F)	300 and 600 V
	Heat-shrinkable	90 and 105°C (194 and 221°F)	300 and 600 V
Polyolefin	Flexible and heat-shrinkable	105°C (221°F)	600 V
	Flexible and heat-shrinkable	125°C (257°F)	150 and 600 V
	Semirigid and heat-shrinkable	125°C (257°F)	600 V
	Flexible or semirigid and heat-shrinkable with meltable liner	125°C (257°F)	600 V
FEP	Not-heat-shrinkable	200°C (392°F)	150, 300, and 600 V
	Heat-shrinkable	200°C (392°F)	150, 300, and 600 V
PTFE	Not-heat-shrinkable	200°C (392°F)	150, 300, and 600 V
	Heat-shrinkable	200°C (392°F)	150, 300, and 600 V
PVF ₂	Heat-shrinkable	150°C (302°F)	600 V
	Heat-shrinkable with meltable liner	150°C (302°F)	600 V
Modified fluoropolymer	Flexible and heat-shrinkable	150°C (302°F)	600 V
Chlorinated polyolefin	Flexible and heat-shrinkable	75 and 90°C (167 and 194°F)	600 V
Silicone rubber	Not-heat-shrinkable	150 and 200°C (302 and 392°F)	300 and 600 V
	Heat-shrinkable	150 and 200°C (302 and 392°F)	300 and 600 V
NOTE – See Clause 1.1			

Table 2 — Required test samples

Item	Quantity and sizes	Test to be used for
1.	21 m (70 feet) of the largest inside diameter produced for the tubing having the smallest wall thickness	All tests (including flammability)
2.	3 m (10 feet) of tubing with inside diameter (recovered diameter for heat-shrinkable tubing) equal to a size between 6.4 mm (1/4 inches) and 12.7 mm (1/2 inches)	Flammability (Clauses 6.9 and 6.10)
3.	6 m (20 feet) of the largest inside diameter produced	Wall Thickness (Clause 4.3), VW-1 Flammability-Optional (Clause 6.10)
NOTE – See 6.1.1		

Table 3 – Number of samples per test

Test	Number of samples
Detailed examination	3
Physical properties	3
Dielectric withstand	3
Secant modulus	3
Copper stability	3
Copper corrosion	1
Flexibility	3
Eccentricity	3
Longitudinal change	3
Volume resistivity	3
Heat-resistance	1
Heat shock	1
Cold bend	1
Deformation	1
Restricted recovery	3
Flame test – all tubing	3
VW-1 flame test	3
Oil resistance	3
Crush	10
Impact	10
Penetration	1
NOTE – See Clauses 6.1.1 and 6.1.2	

Table 4 – Specimen loading

Tubing size, not-heat-shrinkable or recovered heat-shrinkable inside diameter, mm (inches)	Load exerted on specimen by presser foot, N (lbf)
≤1.6 mm (0.063 inches)	2.95 (0.66)
>1.6 mm (0.063 inches), ≤3.18 mm (0.125 inches)	4.91 (1.10)
>3.18 mm (0.125 inches)	19.61 (4.40)
NOTE – See Clauses 6.6.1, 6.6.3b), 6.6.4.2	

Table 5 – Means of support for specimen

Tubing size, inside diameter, mm (inches)	Size of conductor or diameter of solid steel rod to be inserted into test specimen, mm (inches)
0.305 – 1.68 mm, (0.012 – 0.066 inches)	Use a solid wire of the same size as the tubing under test.
1.93-8.38 (0.076-0.330)	Use a solid or stranded wire two sizes smaller than the tubing under test.
7.94 (5/16)	5.95 (15/64)
9.53 (3/8)	7.14 (9/32)
11.11 (7/16)	8.33 (21/64)
12.70 (1/2)	9.53 (3/8)
14.28 (9/16)	10.72 (27/64)
15.87 (5/8)	11.90 (15/32)
19.05 (3/4)	14.28 (9/16)
22.22 (7/8)	16.67 (21/32)
25.40 (1)	19.05 (3/4)
26.98 (1-1/16)	20.24 (51/64)
31.75 (1-1/4)	23.81 (15/16)
38.10 (1-1/2)	28.58 (1-1/8)
44.45 (1-3/4)	31.75 (1-1/4)
50.80 (2)	38.75 (1-1/2)
57.15 (2-1/4)	42.86 (1-11/16)
63.50 – 102.0 (2-1/2 – 4)	47.62 (1-7/8)
NOTE – See Clause 6.9.2	

Table 6 – Lengths of portions of mandrel

Minimum expanded inside diameter of tubing A, mm (inches)	Length of end portions of mandrel D, mm (inches)	Length of center portion of mandrel E, mm (inches)
2.54 (0.100) < A ≤ 6.36 (0.250)	12.7 (0.5)	6.35 (0.25)
6.35 (0.250) < A ≤ 19.1 (0.750)	25.4 (1.0)	12.7 (0.5)
A > 19.1 (0.750)	50.8 (2.0)	50.8 (2.0)
NOTE – See Clause 6.17.2 and Figure 7		

Table 7 – Mandrel sizes for bend tests

Inside diameter of tubing (maximum recovered, for heat-shrinkable tubing), mm (inches)		Mandrel diameter, mm (inches)	
0.5 – 3.2	(0.020 – 0.125)	7.9 ± 0.05	(5/16 ± 0.002)
3.3 – 6.4	(0.126 – 0.250)	9.5 ± 0.08	(3/8 ± 0.003)
6.5 – 25.4	(0.251 – 1.000)	11.1 ± 0.10	(7/16 ± 0.004)
25.5 – 50.8	(1.001 – 2.000)	22.2 ± 0.13	(7/8 ± 0.005)
50.9 – 76.2	(2.001 – 3.000)	25.4 ± 0.13	(1 ± 0.005)
76.3 – 101.6	(3.001 – 4.000)	28.6 ± 0.13	(1-1/8 ± 0.005)
101.7 – 127.0	(4.001 – 5.000)	31.8 ± 0.13	(1-1/4 ± 0.005)
127.1 – 152.4	(5.001 – 6.000)	34.9 ± 0.13	(1-3/8 ± 0.005)
NOTE – See Clauses 6.7.3 and 6.8.3			

Table 8 – Requirements for 90°C (194°F) not-heat-shrinkable PVC tubing

Item	Information
1. Material	Polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate
2. Form	Not-heat-shrinkable
3. Temperature rating	90°C (194°F)
4. Voltage rating	300 V or 600 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in circulating-air oven	7 days at 121.0 ± 1.0°C (249.8 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at 131.0 ± 1.0°C (267.8 ± 1.8°F) under the load indicated in Table 4
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 180.0 ± 1.0°C (356.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁰ ohms-centimeter
21. Maximum longitudinal change	±5 percent after 2 hours in a circulating-air oven at 100.0 ± 1.0°C (212.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable

Table 8 – Requirements for 90°C (194°F) not-heat-shrinkable PVC tubing Continued on Next Page

Table 8 – Requirements for 90°C (194°F) not-heat-shrinkable PVC tubing Continued

Item	Information
24. Restricted recovery	Not applicable
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	No cracking of specimens aged 14 days at $121.0 \pm 1.0^\circ\text{C}$ ($249.8 \pm 1.8^\circ\text{F}$) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29. Oil resistance	See Clause 6.3

Table 9 – Requirements for 105°C (221°F) not-heat-shrinkable PVC tubing

Item	Information
1. Material	Polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate
2. Form	Not-heat-shrinkable
3. Temperature rating	105°C (221°F)
4. Voltage rating	300 V or 600 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging in circulating-air oven	7 days at $136.0 \pm 1.0^\circ\text{C}$ ($276.8 \pm 1.8^\circ\text{F}$)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at $131.0 \pm 1.0^\circ\text{C}$ ($267.8 \pm 1.8^\circ\text{F}$) under the load indicated in Table 4
17. Heat shock	No cracking, flowing, or dripping after 4 hours at $180.0 \pm 1.0^\circ\text{C}$ ($356.0 \pm 1.8^\circ\text{F}$) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at $\text{minus } 30 \pm 1.0^\circ\text{C}$ ($\text{minus } 22 \pm 1.8^\circ\text{F}$) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10^{10} ohms-centimeter
21. Maximum longitudinal change	± 5 percent after 2 hours in a circulating-air oven at $100.0 \pm 1.0^\circ\text{C}$ ($212.0 \pm 1.8^\circ\text{F}$)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	Not applicable

Table 9 – Requirements for 105°C (221°F) not-heat-shrinkable PVC tubing Continued on Next Page

Table 9 – Requirements for 105°C (221°F) not-heat-shrinkable PVC tubing Continued

Item	Information
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	No cracking of specimens aged 14 days at $131.0 \pm 1.0^\circ\text{C}$ ($267.8 \pm 1.8^\circ\text{F}$) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29. Oil resistance	See Clause 6.3

Table 10 – Requirements for 90°C (194°F) heat-shrinkable PVC tubing

Item	Information
1. Material	Polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate
2. Form	Heat-shrinkable
3. Temperature rating	90°C (194°F)
4. Voltage rating	300 V or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at $121.0 \pm 1.0^\circ\text{C}$ ($249.8 \pm 1.8^\circ\text{F}$)
10. Flexibility	Not applicable
11. Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at $131.0 \pm 1.0^\circ\text{C}$ ($267.8 \pm 1.8^\circ\text{F}$) under the load indicated in Table 4
17. Heat shock	No cracking, flowing, or dripping after 4 hours at $180.0 \pm 1.0^\circ\text{C}$ ($356.0 \pm 1.8^\circ\text{F}$) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at $\text{minus } 30 \pm 1.0^\circ\text{C}$ ($\text{minus } 22 \pm 1.8^\circ\text{F}$) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10^{10} ohms-centimeter
21. Maximum longitudinal change	± 3 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at $100.0 \pm 1.0^\circ\text{C}$ ($212.0 \pm 1.8^\circ\text{F}$)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (see Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable

Table 10 – Requirements for 90°C (194°F) heat-shrinkable PVC tubing Continued on Next Page

Table 10 – Requirements for 90°C (194°F) heat-shrinkable PVC tubing Continued

Item	Information
29. Oil resistance	See Clause 6.3

Table 11 – Requirements for 105°C (221°F) heat-shrinkable PVC tubing

Item	Information
1. Material	Polyvinyl chloride or a copolymer of vinyl chloride and vinyl acetate
2. Form	Heat-shrinkable
3. Temperature rating	105°C (221°F)
4. Voltage rating	300 V or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging in a circulating-air oven	7 days at 136.0 ± 1.0°C (276.8 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at 131.0 ± 1.0°C (267.8 ± 1.8°F) under the load indicated in Table 4
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 180.0 ± 1.0°C (356.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁰ ohms-centimeter
21. Maximum longitudinal change	±3 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 100.0 ± 1.0°C (212.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (see Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 12 – Requirements for 105°C (221°F) flexible heat-shrinkable polyolefin tubing

Item		Information
1.	Material	Flexible polyolefin
2.	Form	Heat-shrinkable
3.	Temperature rating	105°C (221°F)
4.	Voltage rating	600 V
5.	Minimum recovered wall thickness	See Tables 28 and 30
6.	Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7.	Minimum ultimate elongation	200 percent – simultaneous with Item 6 using gauge marks 25.4 mm (1 inch) apart
8.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9.	Aging (separate specimens) in a circulating-air oven	7 days at 136.0 ± 1.0°C (276.8 ± 1.8°F)
10.	Flexibility	Not applicable
11.	Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12.	Minimum ultimate elongation	100 percent – simultaneous with Item 11
13.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14.	Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15.	Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16.	Deformation	Not applicable
17.	Heat shock	No cracking, flowing, or dripping after 4 hours at 250 ± 1.0°C (482.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18.	Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19.	Flammability	See Clauses 6.9 and 6.10
20.	Minimum volume resistivity	10 ¹⁴ ohms-centimeter
21.	Maximum longitudinal change	±3 percent after fully recovered specimens have spent 3 minutes in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22.	Maximum secant modulus	173 MPa (25 000 psi)
23.	Maximum eccentricity	30 percent (see Clause 6.13)
24.	Restricted recovery	See Clause 6.17
25.	Crushing	Not applicable
26.	Impact	Not applicable
27.	Penetration	Not applicable
28.	Heat-resistance properties	Not applicable
29.	Oil resistance	See Clause 6.3

Table 13 – Requirements for 125°C (257°F) flexible heat-shrinkable polyolefin tubing

Item	Information	
1.	Material	Flexible polyolefin, with or without meltable liner
2.	Form	Heat-shrinkable
3.	Temperature rating	125°C (257°F)
4.	Voltage rating	150 V or 600 V
5.	Minimum recovered wall thickness	See Tables 28 and 30
6.	Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7.	Minimum ultimate elongation	200 percent – simultaneous with Item 6 using gauge marks 25.4 mm (1 inch) apart
8.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9.	Aging (separate specimens) in a circulating-air oven	7 days at 158.0 ± 1.0°C (316.4 ± 1.8°F)
10.	Flexibility	Not applicable
11.	Minimum tensile strength	7.3 MPa (1050 psi). Specimens aged per Item 9 tested at 508 mm/min (20 in/min)
12.	Minimum ultimate elongation	100 percent – simultaneous with Item 11
13.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14.	Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15.	Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16.	Deformation	Not applicable
17.	Heat shock	No cracking, flowing, or dripping after 4 hours at 250.0 ± 1.0°C (482.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18.	Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19.	Flammability	See Clauses 6.9 and 6.10
20.	Minimum volume resistivity	10 ¹⁴ ohms-centimeter
21.	Maximum longitudinal change	±3 percent after fully recovered specimens have spent 3 minutes in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22.	Maximum secant modulus	173 MPa (25 000 psi)
23.	Maximum eccentricity	30 percent (see Clause 6.13)
24.	Restricted recovery	See Clause 6.17
25.	Crushing	Not applicable
26.	Impact	Not applicable
27.	Penetration	Not applicable
28.	Heat-resistance properties	Not applicable
29.	Oil resistance	See Clause 6.3

Table 14 — Requirements for 125°C (257°F) semirigid heat-shrinkable polyolefin tubing

Item	Information
1. Material	Semirigid or rigid polyolefin, with or without meltable liner
2. Form	Heat-shrinkable
3. Temperature rating	125°C (257°F)
4. Voltage rating	600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	13.8 MPa (2000 psi) when tested at 50.8 mm/min (2 in/min)
7. Minimum ultimate elongation	200 percent – simultaneous with Item 6 using gauge marks 25.4 mm (1 inch) apart
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 158.0 ± 1.0°C (316.4 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	9.7 MPa (1400 psi). Specimens aged per Item 9 and tested at 50.8 mm/min (2 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 250.0 ± 1.0°C (482.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁴ ohms-centimeter
21. Maximum longitudinal change	±3 percent after fully recovered specimens have spent 3 minutes in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Maximum secant modulus	Greater than 173 MPa (25 000 psi)
23. Maximum eccentricity	30 percent (see Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 15 – Requirements for 200°C (392°F) not-heat-shrinkable PTFE tubing

Item	Information	
1.	Material	PTFE (polytetrafluoroethylene)
2.	Form	Not-heat-shrinkable
3.	Temperature rating	200°C (392°F)
4.	Voltage rating	150 V, 300 V, or 600 V
5.	Minimum wall thickness	See Tables 27 and 29
6.	Minimum tensile strength	17.3 MPa (2500 psi) when tested at 508 mm/min (20 in/min)
7.	Minimum ultimate elongation	200 percent – simultaneous with Item 6
8.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9.	Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10.	Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11.	Minimum tensile strength	12.1 MPa (1750 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12.	Minimum ultimate elongation	100 percent – simultaneous with Item 11
13.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14.	Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15.	Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16.	Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at 260 ± 1.0°C (500.0 ± 1.8°F) under the load indicated in Table 4
17.	Heat shock	No cracking, flowing, or dripping after 4 hours at 260.0 ± 1.0°C (500.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18.	Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19.	Flammability	See Clauses 6.9 and 6.10
20.	Minimum volume resistivity	10 ¹⁵ ohms-centimeter
21.	Maximum longitudinal change	±1 percent after 3 minutes in a circulating-air oven at 260.0 ± 1.0°C (500.0 ± 1.8°F)
22.	Maximum secant modulus	Not applicable
23.	Maximum eccentricity	Not applicable
24.	Restricted recovery	Not applicable
25.	Crushing	Not applicable
26.	Impact	Not applicable
27.	Penetration	Not applicable
28.	Heat-resistance properties	No cracking of specimens aged 7 days at 260.0 ± 1.0°C (500.0 ± 1.8°F) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29.	Oil resistance	See Clause 6.3

Table 16 – Requirements for 200°C (392°F) not-heat-shrinkable FEP tubing

Item	Information
1. Material	FEP (fluorinated ethylene propylene)
2. Form	Not-heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	150 V, 300 V, or 600 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	13.8 MPa (2000 psi) when tested at 508 mm/min (20 in/min)
7. Minimum ultimate elongation	200 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	9.7 MPa (1400 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 260.0 ± 1.0°C (500.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁵ ohms-centimeter
21. Maximum longitudinal change	±3 percent after 2 hours in a circulating-air oven at 260 ± 1.0°C (500.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	No cracking of specimens aged 7 days at 260.0 ± 1.0°C (500.0 ± 1.8°F) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29. Oil resistance	See Clause 6.3

Table 17 – Requirements for 200°C (392°F) heat-shrinkable PTFE tubing

Item	Information
1. Material	PTFE (polytetrafluoroethylene)
2. Form	Heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	150 V, 300 V, or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	17.3 MPa (2500 psi) when tested at 508 mm/min (20 in/min)
7. Minimum ultimate elongation	200 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	12.1 MPa (1750 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of the bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	35 percent maximum acceptable decrease in wall thickness after 1 hour at 260 ± 1.0°C (500.0 ± 1.8°F) under the load indicated in Table 4
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 260.0 ± 1.0°C (500.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁵ ohms-centimeter
21. Maximum longitudinal change	±1 percent after 3 minutes in a circulating-air oven at 260.0 ± 1.0°C (500.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 18 – Requirements for 200°C (392°F) heat-shrinkable FEP tubing

Item	Information
1. Material	FEP (fluorinated ethylene propylene)
2. Form	Heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	150 V, 300 V, or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	13.8 MPa (2000 psi) when tested at 508 mm/min (20 in/min)
7. Minimum ultimate elongation	200 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	9.7 MPa (1400 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 260.0 ± 1.0°C (500.0 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁵ ohms-centimeter
21. Maximum longitudinal change	±3 percent after 2 hours in a circulating-air oven at 260 ± 1.0°C (500 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 19 – Requirements for 150°C (302°F) rigid heat-shrinkable PVF₂ tubing

Item	Information
1. Material	Rigid polyvinylidene fluoride, with or without meltable liner
2. Form	Heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	20.7 MPa (3000 psi) when tested at 50.8 mm/min (2 in/min)
7. Minimum ultimate elongation	150 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 180.0 ± 1.0°C (356.0 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	14.5 MPa (2100 psi). Specimens aged per Item 9 and tested at 50.8 mm/min (2 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 200 ± 1.0°C (392 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±3 percent after fully recovered specimens have spent 3 minutes in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Minimum secant modulus	828 MPa (1.2 × 10 ⁵ psi)
23. Maximum eccentricity	30 percent (See Clause 6.3)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 20 – Requirements for 150°C (302°F) flexible heat-shrinkable modified fluoropolymer tubing

Item	Information
1. Material	Flexible modified fluoropolymer
2. Form	Heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	17.3 MPa (2500 psi) when tested at 50.8 mm/min (2 in/min)
7. Minimum ultimate elongation	150 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 225.0 ± 1.0°C (437.0 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	8.6 MPa (1250 psi). Specimens aged per Item 9 and tested at 50.8 mm/min (2 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (see Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 275 ± 1.0°C (527 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹¹ ohms-centimeter
21. Maximum longitudinal change	±3 percent after fully recovered specimens have spent 3 minutes in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Minimum secant modulus	173 to 828 MPa (2.5 × 10 ⁴ to 1.2 × 10 ⁵ psi)
23. Maximum eccentricity	30 percent (See Clause 6.3)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 21 – Requirements for 75°C (167°F) flexible heat-shrinkable chlorinated polyolefin tubing

Item	Information
1. Material	Chlorinated polyolefin
2. Form	Heat-shrinkable
3. Temperature rating	75°C (167°F)
4. Voltage rating	600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	10.4 MPa (1500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	225 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 121.0 ± 1.0°C (249.8 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	5.2 MPa (750 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12. Minimum ultimate elongation	100 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged in an air circulating oven for 168 hours at 113.0 ± 1.0°C (235.4 ± 1.8°F) (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged in an air circulating oven for 168 hours at 113.0 ± 1.0°C (235.4 ± 1.8°F) shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 4 hours at 150 ± 1.0°C (249.8 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹⁰ ohms-centimeter
21. Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 100.0 ± 1.0°C (212.0 ± 1.8°F)
22. Maximum secant modulus	173 MPa (25 000 psi)
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 22 – Requirements for 90°C (194°F) flexible heat-shrinkable chlorinated polyolefin tubing

Item	Information	
1.	Material	Chlorinated polyolefin
2.	Form	Heat-shrinkable
3.	Temperature rating	90°C (194°F)
4.	Voltage rating	600 V
5.	Minimum recovered wall thickness	See Tables 28 and 30
6.	Minimum tensile strength	8.28 MPa (1200 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7.	Minimum ultimate elongation	225 percent – simultaneous with Item 6
8.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9.	Aging (separate specimens) in a circulating-air oven	240 hours at 121.0 ± 1.0°C (249.8 ± 1.8°F)
10.	Flexibility	Not applicable
11.	Minimum tensile strength	6.2 MPa (900 psi). Specimens aged per Item 9 and tested at 508 mm/min (20 in/min)
12.	Minimum ultimate elongation	100 percent absolute value – simultaneous with Item 11
13.	Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14.	Corrosion of bare copper	Humidity-conditioned specimens aged in an air circulating oven for 168 hours at 121.0 ± 1.0°C (249.8 ± 1.8°F) (See Clause 6.15)
15.	Copper stability	Humidity-conditioned specimens aged in an air circulating oven for 168 hours at 121.0 ± 1.0°C (249.8 ± 1.8°F) shall comply with Item 12 (see Clause 6.16)
16.	Deformation	Not applicable
17.	Heat shock	No cracking, flowing, or dripping after 4 hours at 150.0 ± 1.0°C (249.8 ± 1.8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18.	Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19.	Flammability	See Clauses 6.9 and 6.10
20.	Minimum volume resistivity	10 ¹⁰ ohms-centimeter
21.	Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 100.0 ± 1.0°C (212.0 ± 1.8°F)
22.	Maximum secant modulus	173 MPa (25 000 psi)
23.	Maximum eccentricity	30 percent (See Clause 6.13)
24.	Restricted recovery	See Clause 6.17
25.	Crushing	Not applicable
26.	Impact	Not applicable
27.	Penetration	Not applicable
28.	Heat-resistance properties	Not applicable
29.	Oil resistance	See Clause 6.3

Table 23 – Requirements for 150°C (302°F) not-heat-shrinkable silicone rubber tubing at least 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Not-heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	300 V or 600 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 181.0 ± 1.0°C (357.8 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572 ± 8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after 2 hours in a circulating-air oven at 150.0 ± 1.0°C (302.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	No cracking of specimens aged 7 days at 180.0 ± 1.0°C (357.8 ± 1.8°F) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29. Oil resistance	See Clause 6.3

Table 24 – Requirements for 200°C (392°F) not-heat-shrinkable silicone rubber tubing at least 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Not-heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	300 V or 600 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572 ± 8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after 2 hours in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	No cracking of specimens aged 7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F) and wound per Clause 6.18. No breakdown after 60 seconds at 1500 V
29. Oil resistance	See Clause 6.3

Table 25 – Requirements for 150°C (302°F) heat-shrinkable silicone rubber tubing at least 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	300 V or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 181.0 ± 1.0°C (357.8 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent (simultaneous with Item 11)
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572 ± 8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 150.0 ± 1.0°C (302.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 26 – Requirements for 200°C (392°F) heat-shrinkable silicone rubber tubing at least 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	300 V or 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V (specimens aged per Item 9)
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens aged per Item 9 shall comply with Item 12 (see Clause 6.16)
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572 ± 8°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	Not applicable
26. Impact	Not applicable
27. Penetration	Not applicable
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table 27 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary US sizes)

Maximum inside diameter, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*			
		PVC	PTFE/FEP	Silicone rubber	
				≥0.711 (0.028)	<0.711 (0.028)
0.30 (0.012)	150		0.114 (0.0045)		
	300	0.254 (0.010)	0.229 (0.009)		0.381 (0.015)
	600	0.431 (0.017)	0.229 (0.009)	0.762 (0.030)	
0.48 (0.019)	150				
	300				
	600		0.229 (0.009)		
0.69 (0.027)	150				
	300	0.254 (0.010)			
	600		0.305 (0.012)		
1.07 (0.042)	150				
	300				
	600	0.431 (0.017)	0.381 (0.015)		
1.50 (0.059)	150		0.114 (0.0045)		
	300				
	600				
2.69 (0.106)	150				
	300	0.330 (0.013)	0.229 (0.009)		
	600		0.406 (0.016)		
3.38 (0.133)	150		0.165 (0.0065)		
	300				
	600				
3.76 (0.148)	150		0.179 (0.007)		
	300				
	600				
5.94 (0.234)	150				
	300				0.381 (0.015)
	600				
6.68 (0.263)	150		0.203 (0.008)		
	300				
	600				
7.47 (0.294)	150		0.229 (0.009)		
	300		0.279 (0.011)		
	600		0.483 (0.019)		
7.92 (0.312)	150				
	300				0.559 (0.022)
	600				
8.38 (0.330)	150				
	300	0.431 (0.017)			
	600				

Table 27 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary US sizes) Continued on Next Page

Table 27 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary US sizes) Continued

Maximum inside diameter, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*			
		PVC	PTFE/FEP	Silicone rubber	
				≥0.711 (0.028)	<0.711 (0.028)
9.53 (0.375)	150				
	300				
	600		0.508 (0.020)		
11.1 (0.438)	150				
	300				
	600				0.686 (0.027)
12.7 (0.500)	150		0.279 (0.011)		
	300	0.559 (0.022)	0.356 (0.014)	0.711 (0.028)	
	600	0.559 (0.022)	0.559 (0.022)		
15.9 (0.626)	150		0.356 (0.014)		
	300	0.686 (0.027)	0.432 (0.017)	0.711 (0.028)	
	600	0.686 (0.027)	0.635 (0.025)	0.762 (0.030)	
22.2 (0.875)	150				
	300			0.762 (0.030)	
	600			0.889 (0.035)	
26.9 (1.06)	150		0.381 (0.015)		
	300	0.762 (0.030)	0.508 (0.020)		
	600	0.762 (0.030)	0.762 (0.030)		
31.8 (1.25)	150		0.432 (0.017)		
	300	0.889 (0.035)	0.762 (0.030)	0.889 (0.035)	
	600	0.889 (0.035)	0.889 (0.035)	1.09 (0.043)	
38.1 (1.50)	150		0.508 (0.020)		
	300	0.991 (0.039)	0.889 (0.035)		
	600	0.991 (0.039)	0.991 (0.039)		
44.5 (1.75)	150		0.635 (0.025)		
	300	1.19 (0.047)	1.14 (0.045)	1.09 (0.043)	
	600	1.19 (0.047)	1.19 (0.047)	1.68 (0.066)	
50.8 (2.00)	150		0.762 (0.030)		
	300	1.27 (0.050)	1.27 (0.050)		
	600	1.27 (0.050)	1.27 (0.050)		
57.2 (2.25)	150				
	300	1.47 (0.058)	1.47 (0.058)	1.68 (0.066)	
	600	1.47 (0.058)	1.47 (0.058)		
63.5 (2.50)	150		1.02 (0.040)		
	300		1.60 (0.063)	1.93 (0.076)	
	600		1.60 (0.063)	1.93 (0.076)	
152.4 (6.00)	150				
	300	1.60 (0.063)			
	600	1.60 (0.063)			

**For tubing diameters between two given wall thicknesses for a given tubing type and rating, the larger wall thickness shall apply.*

Table 28 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary USA sizes)

Maximum inside diameter*, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂ fluoropolymer	Modified polypropylene	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.028)
0.58 (0.023)	150		0.180 (0.007)	0.114 (0.005)					
	300	0.254 (0.010)		0.229 (0.009)					0.381 (0.015)
	600	0.432 (0.017)	0.330 (0.013)	0.381 (0.015)	0.203 (0.008)	0.203 (0.008)		0.762 (0.030)	0.508 (0.020)
0.79 (0.031)	150			0.114 (0.005)					
	300								
	600	0.432 (0.017)	0.356 (0.014)		0.203 (0.008)				
1.57 (0.062)	150		0.180 (0.007)						
	300			0.229 (0.009)					
	600						0.635 (0.025)		
2.36 (0.093)	150			0.165 (0.007)					
	300	0.330 (0.013)							
	600		0.432 (0.017)		0.229 (0.009)	0.203 (0.008)			0.508 (0.020)
3.18 (0.125)	150			0.203 (0.008)					
	300								
	600						0.635 (0.025)		0.635 (0.025)
4.75 (0.187)	150		0.250 (0.010)	0.229 (0.009)					
	300	0.431 (0.017)		0.279 (0.011)					0.381 (0.015)
	600			0.483 (0.019)			0.762 (0.030)	0.762 (0.030)	
6.35 (0.250)	150		0.279 (0.011)	0.279 (0.011)					
	300	0.559 (0.022)		0.356 (0.014)					0.432 (0.017)
	600	0.559 (0.022)	0.559 (0.022)	0.559 (0.022)	0.279 (0.011)	0.229 (0.009)	0.838 (0.033)	0.838 (0.033)	

Table 28 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary USA sizes) Continued on Next Page

Table 28 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary USA sizes) Continued

Maximum inside diameter*, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂ fluropolymer	Modified polypropylene	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.028)
9.53 (0.375)	150		0.350 (0.014)	0.356 (0.014)					
	300	0.686 (0.027)		0.432 (0.017)					0.533 (0.021)
	600	0.686 (0.027)	0.686 (0.027)	0.686 (0.027)	0.356 (0.014)	0.356 (0.014)	0.940 (0.037)		
12.7 (0.500)	150		0.400 (0.016)	0.381 (0.015)					
	300			0.508 (0.020)					0.635 (0.025)
	600		0.762 (0.030)	0.762 (0.030)	0.406 (0.016)	0.406 (0.016)	1.27 (0.050)	1.27 (0.050)	
15.9 (0.625)	150								
	300							0.864 (0.034)	
	600						1.70 (0.067)	1.70 (0.067)	
19.1 (0.750)	150			0.432 (0.017)					
	300	0.762 (0.030)		0.762 (0.030)				0.965 (0.038)	
	600	0.762 (0.030)	0.864 (0.034)	0.889 (0.035)			1.91 (0.075)	1.91 (0.075)	
22.2 (0.875)	150								
	300							1.12 (0.044)	
	600						2.21 (0.087)	2.21 (0.087)	
25.4 (1.000)	150			0.508 (0.020)					
	300	0.991 (0.039)		0.889 (0.035)					
	600	0.991 (0.039)	0.965 (0.038)	0.991 (0.039)	0.432 (0.017)		2.29 (0.090)		
38.1 (1.500)	150								
	300	1.47 (0.058)							
	600	1.47 (0.058)	1.07 (0.042)		0.533 (0.021)		2.67 (0.105)		
50.8 (2.000)	150		0.500 (0.020)						
	300							1.14 (0.045)	
	600				0.635 (0.025)		3.05 (0.120)	2.29 (0.090)	

Table 28 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary USA sizes) Continued on Next Page

Table 28 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary USA sizes) Continued

Maximum inside diameter*, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂ fluoropolymer	Modified polyolefin	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.028)
76.2 (3.000)	150								
	300	1.63 (0.063)							
	600	1.63 (0.063)	1.17 (0.046)						

**Measured after the tubing has been fully recovered.*

†For tubing diameters between two given wall thicknesses for a given tubing type and rating, the larger wall thickness shall apply.

Table 29 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes)

Maximum inside diameter, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*			
		PVC	PTFE/FEP	Silicone rubber	
				≥0.711 (0.028)	<0.711 (0.028)
0.30 (0.012)	150		0.114 (0.0045)		
	300	0.254 (0.010)	0.229 (0.009)		0.381 (0.015)
	600	0.431 (0.017)	0.229 (0.009)	0.762 (0.030)	
0.40 (0.016)	150				
	300				
	600		0.229 (0.009)		
0.60 (0.024)	150				
	300	0.254 (0.010)			
	600				
1.00 (0.039)	150				
	300				
	600	0.431 (0.017)	0.305 (0.012)		
1.50 (0.059)	150		0.114 (0.0045)		
	300				
	600				
2.60 (0.102)	150				
	300	0.330 (0.013)	0.229 (0.009)		
	600		0.406 (0.016)		
3.20 (0.126)	150		0.165 (0.0065)		
	300				
	600				
3.60 (0.142)	150		0.179 (0.007)		
	300				
	600				

Table 29 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued on Next Page

Table 29 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued

Maximum inside diameter, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*			
		PVC	PTFE/FEP	Silicone rubber	
				≥0.711 (0.028)	<0.711 (0.028)
6.00 (0.236)	150				
	300				
	600				0.381 (0.015)
6.50 (0.256)	150		0.203 (0.008)		
	300				
	600				
7.00 (0.276)	150		0.229 (0.009)		
	300		0.279 (0.011)		
	600		0.483 (0.019)		
8.00 (0.315)	150				
	300				
	600				0.559 (0.022)
7.50 (0.295)	150				
	300	0.431 (0.017)			
	600				
9.00 (0.354)	150				
	300				
	600		0.508 (0.020)		
11.00 (0.433)	150				
	300				
	600				0.686 (0.027)
12.00 (0.472)	150		0.279 (0.011)		
	300	0.559 (0.022)	0.356 (0.014)	0.711 (0.028)	
	600	0.559 (0.022)	0.599 (0.022)		
14.00 (0.551)	150		0.356 (0.014)		
	300		0.432 (0.017)		
	600				
16.00 (0.630)	150				
	300				
	600		0.635 (0.025)	0.762 (0.030)	
18.00 (0.709)	150				
	300	0.686 (0.027)		0.711 (0.028)	
	600	0.686 (0.027)			
22.00 (0.886)	150				
	300			0.762 (0.030)	
	600			0.889 (0.035)	
26.00 (1.02)	150		0.381 (0.015)		
	300	0.762 (0.030)	0.508 (0.020)		
	600	0.762 (0.030)	0.762 (0.030)		

Table 29 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued on Next Page

Table 29 – Wall thickness requirements for not-heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued

Maximum inside diameter, mm (inches)	Voltage rating	Minimum wall thickness at any point, mm (inches)*			
		PVC	PTFE/FEP	Silicone rubber	
				≥0.711 (0.028)	<0.711 (0.028)
30.00 (1.18)	150		0.432 (0.017)		
	300	0.889 (0.035)	0.762 (0.030)		
	600	0.889 (0.035)	0.889 (0.035)	1.09 (0.043)	
35.00 (1.38)	150		0.508 (0.020)		
	300	0.991 (0.039)	0.889 (0.035)	0.889 (0.035)	
	600	0.991 (0.039)	0.991 (0.039)		
40.00 (1.57)	150		0.635 (0.025)		
	300	1.19 (0.047)	1.14 (0.045)		
	600	1.19 (0.047)	1.19 (0.047)	1.68 (0.066)	
45.00 (1.77)	150				
	300				
	600				
50.00 (1.97)	150		0.762 (0.030)		
	300	1.27 (0.050)	1.27 (0.050)	1.68 (0.066)	
	600	1.27 (0.050)	1.27 (0.050)		
60.00 (2.36)	150		1.02 (0.040)		
	300		1.60 (0.063)	1.93 (0.076)	
	600		1.60 (0.063)	1.93 (0.076)	
100.00 (3.94)	150				
	300	1.60 (0.063)			
	600	1.60 (0.063)			

**For tubing diameters between two given wall thicknesses for a given tubing type and rating, the larger wall thickness shall apply.*

Table 30 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes)

Maximum inside diameter, mm (inches)*	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂	Modified fluoropolymer	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.015)
0.50 (0.020)	150			0.114 (0.0045)					
	300	0.254 (0.010)		0.229 (0.009)					0.381 (0.015)
	600	0.431 (0.017)	0.330 (0.013)	0.381 (0.015)	0.203 (0.008)	0.203 (0.008)		0.762 (0.030)	
0.75 (0.030)	150								
	300								
	600	0.431 (0.017)	0.356 (0.014)						

Table 30 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued on Next Page

Table 30 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued

Maximum inside diameter, mm (inches)*	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂	Modified fluoropolymer	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.015)
1.0 (0.039)	150								
	300			0.229 (0.009)					
	600								
2.0 (0.079)	150			0.165 (0.0065)					
	300	0.330 (0.013)							
	600		0.432 (0.017)		0.229 (0.009)	0.203 (0.008)	0.635 (0.025)		
4.0 (0.157)	150			0.229 (0.009)					
	300	0.431 (0.017)		0.279 (0.011)					
	600			0.483 (0.019)	0.279 (0.011)	0.229 (0.009)	0.762 (0.030)		
5.5 (0.217)	150								
	300								0.381 (0.015)
	600								
6.0 (0.236)	150								
	300	0.559 (0.022)							
	600	0.559 (0.022)	0.559 (0.022)						
8.0 (0.315)	150			0.356 (0.014)					
	300	0.686 (0.027)		0.432 (0.017)				0.711 (0.028)	
	600	0.686 (0.027)	0.686 (0.027)	0.686 (0.027)	0.356 (0.014)	0.356 (0.014)	0.940 (0.037)	0.762 (0.030)	
11.0 (0.433)	150								
	300							0.762 (0.030)	
	600							0.889 (0.035)	
12.5 (0.492)	150								
	300								
	600		0.762 (0.030)						

Table 30 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued on Next Page

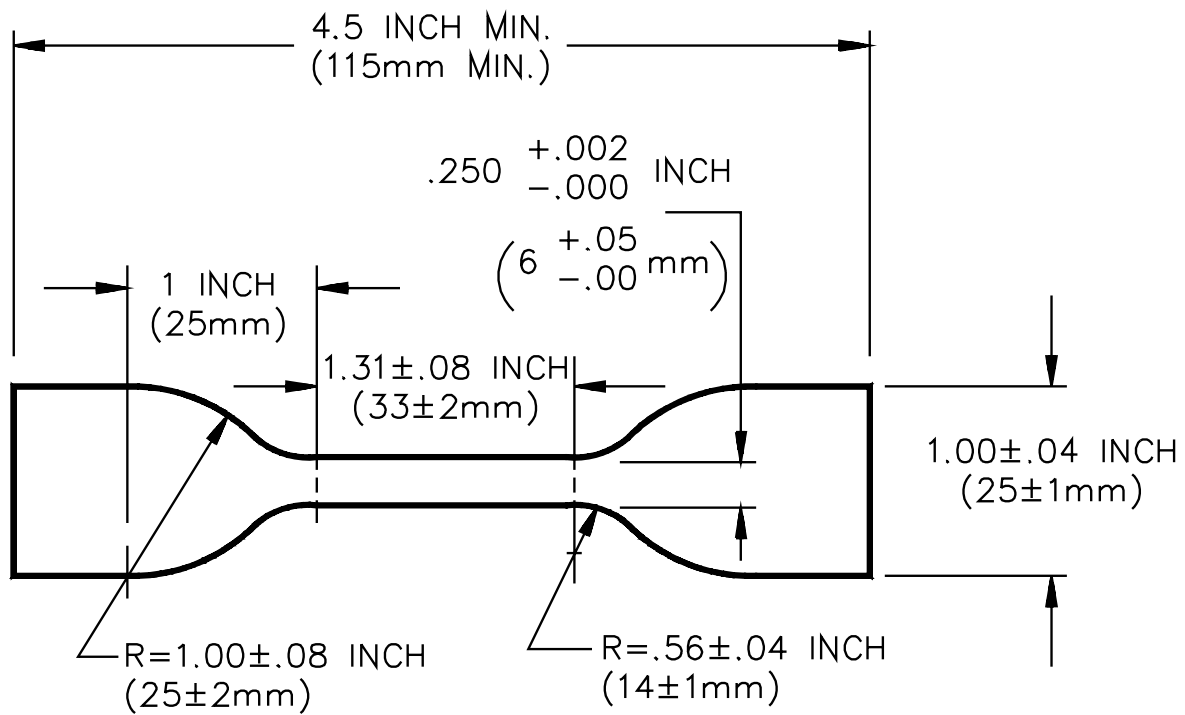
Table 30 – Wall thickness requirements for heat-shrinkable tubing, per material type and voltage rating (Customary metric sizes) Continued

Maximum inside diameter, mm (inches)*	Voltage rating	Minimum wall thickness at any point, mm (inches)*†							
		PVC	Polyolefin	PTFE/FEP	PVF ₂	Modified fluoropolymer	Chlorinated polyolefin	Silicone rubber	
								≥0.711 (0.028)	<0.711 (0.015)
16.0 (0.630)	150			0.432 (0.017)					
	300	0.762 (0.030)		0.762 (0.030)				0.889 (0.035)	
	600	0.762 (0.030)		0.889 (0.035)			1.70 (0.067)	1.09 (0.043)	
20.0 (0.787)	150								
	300								
	600		0.864 (0.034)						
23.0 (0.906)	150								
	300							1.09 (0.043)	
	600							1.68 (0.066)	
25.0 (0.975)	150								
	300	0.991 (0.039)							
	600	0.991 (0.039)	0.965 (0.038)						
32.0 (1.26)	150			0.508 (0.020)					
	300	1.47 (0.058)		0.889 (0.035)				1.68 (0.066)	
	600	1.47 (0.058)	1.07 (0.042)	0.991 (0.039)	0.406 (0.016)	0.406 (0.016)	2.29 (0.090)	1.93 (0.076)	
52.0 (2.05)	150								
	300	1.60 (0.063)							
	600	1.60 (0.063)	1.17 (0.046)						

*Measured after the tubing has been fully recovered.

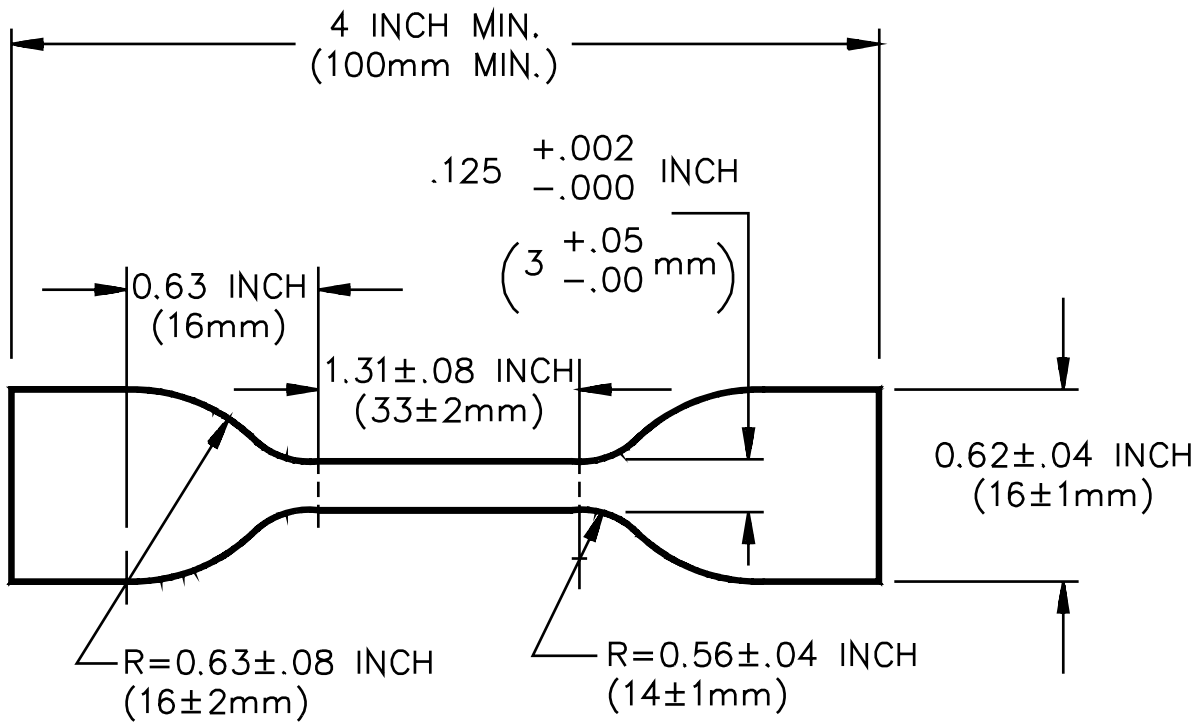
†For tubing diameters between two given wall thicknesses, the larger wall thickness shall apply.

Figure 1 – Metal die for cutting flexible specimens
 (See Clause 6.2.3.1.)



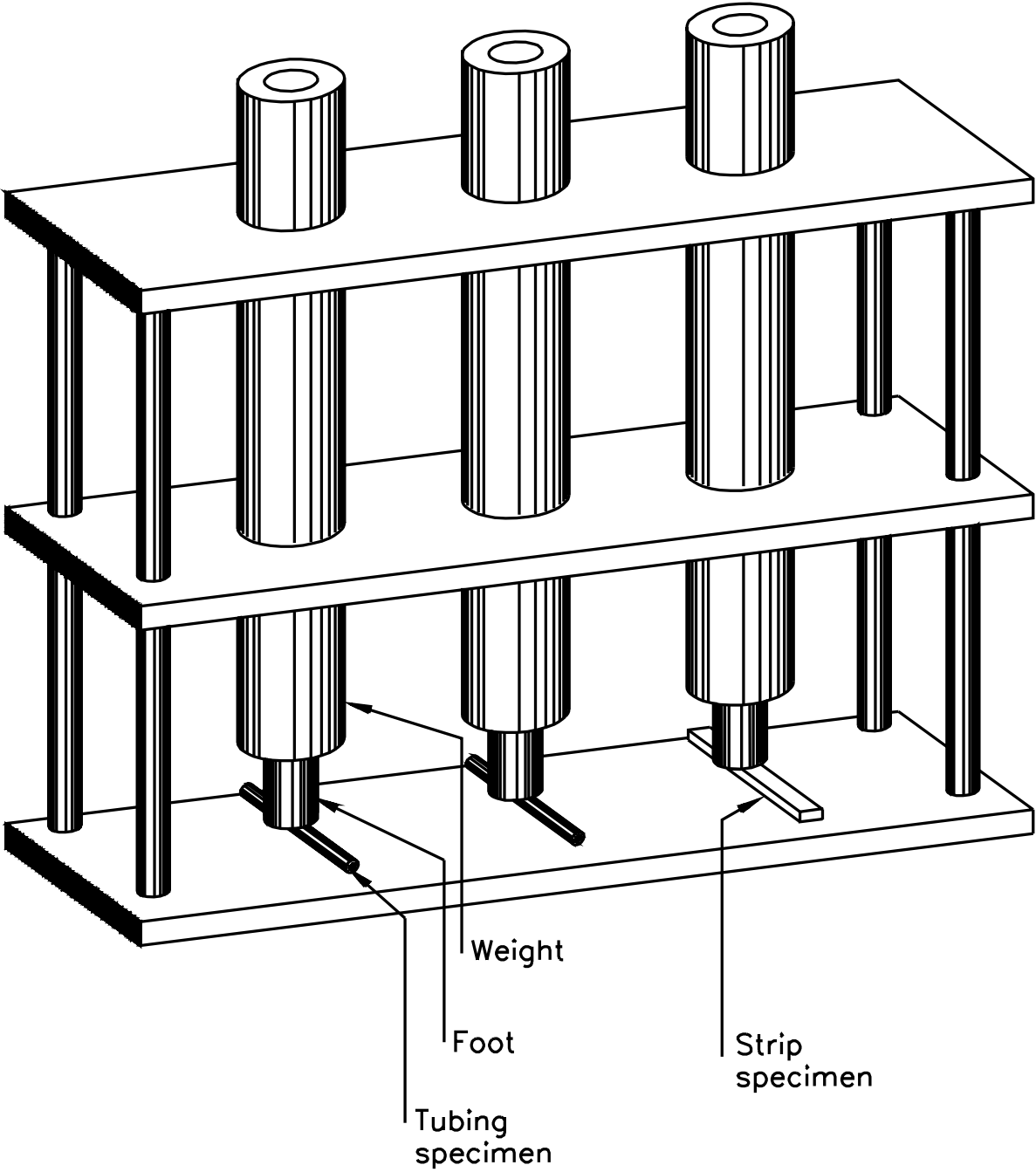
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Figure 2 – Metal die for cutting semirigid and rigid specimens
(See Clause 6.2.3.2.)



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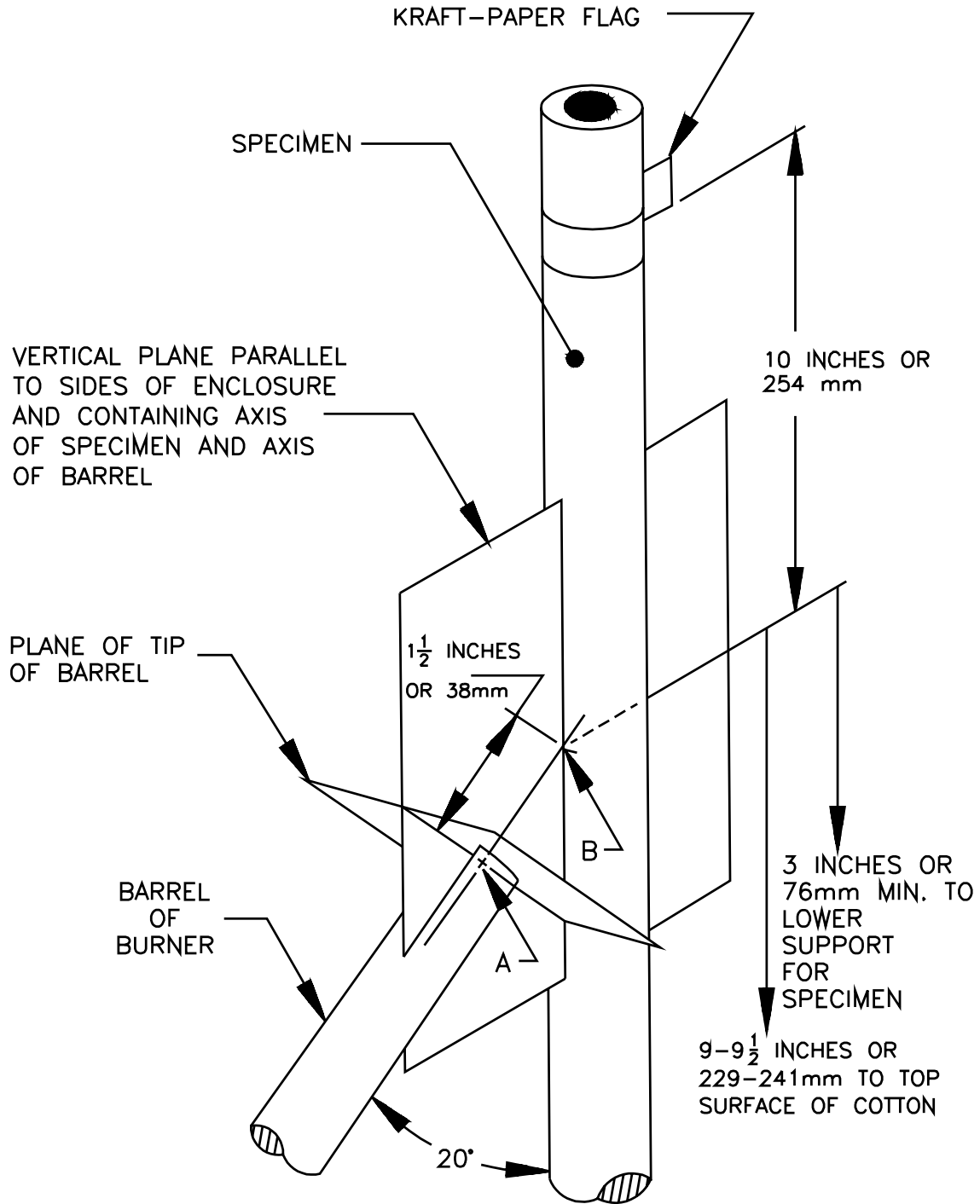
Figure 3 – Weights and specimens in supporting frame for deformation test
(See Clauses 6.6.3b) and 6.6.4.2.)



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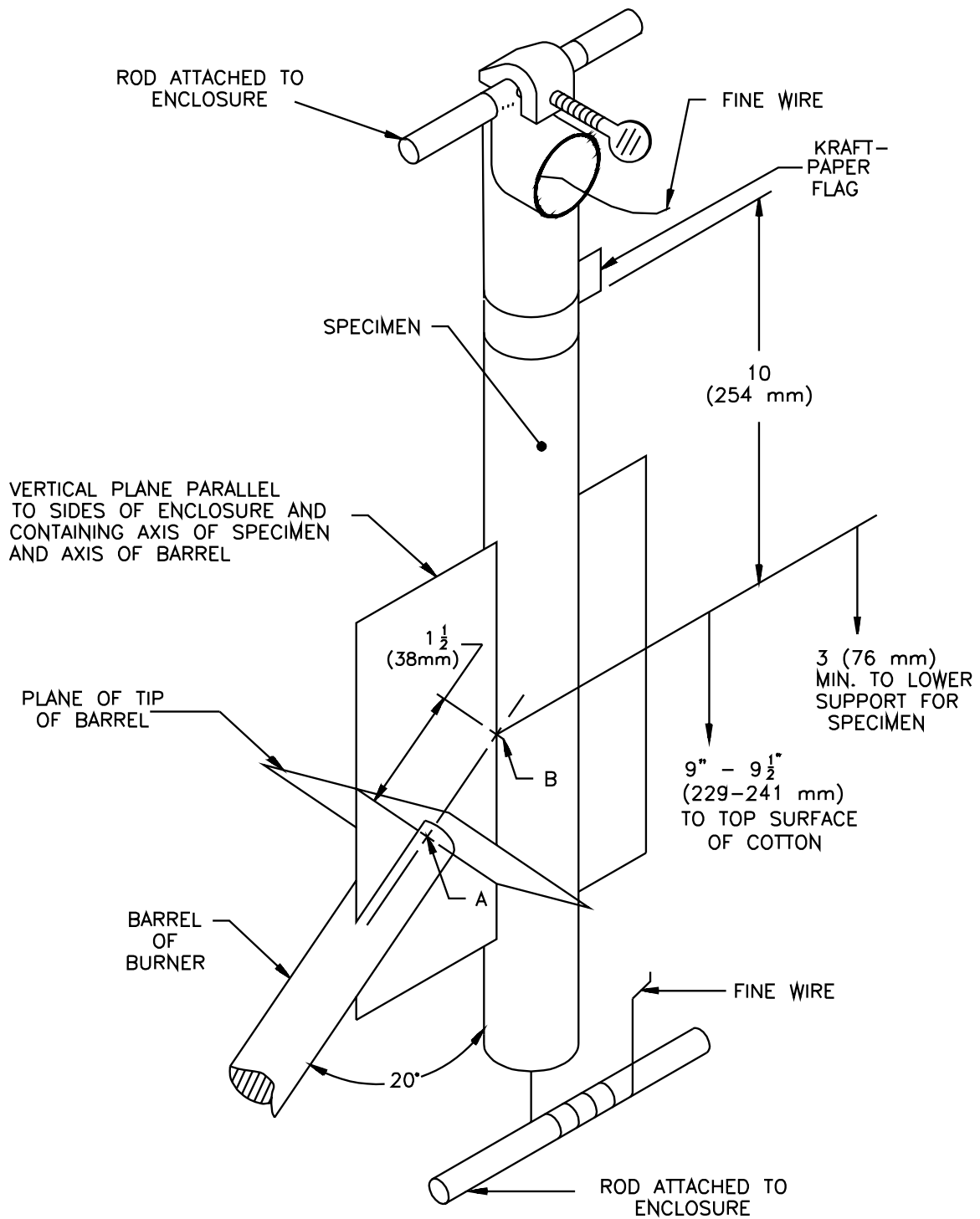
Figure 4 – Essential dimensions in mm (inches) for flame test, all tubing
(See Clauses 6.9.2 – 6.9.6.)

Proportions exaggerated for clarity of detail



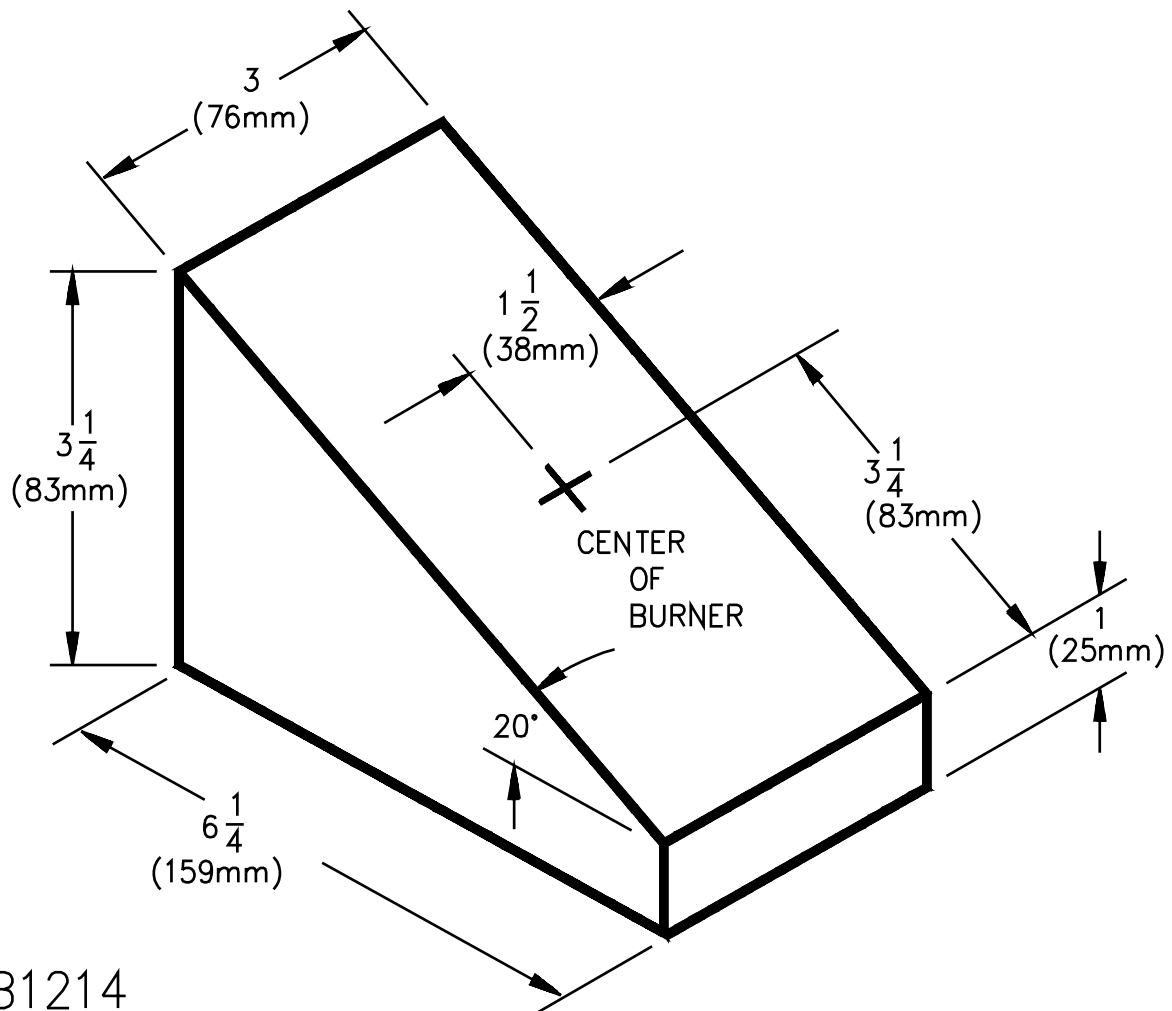
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Figure 5 – VW-1 flame test
(See Clauses 6.10.3 – 6.10.8.)

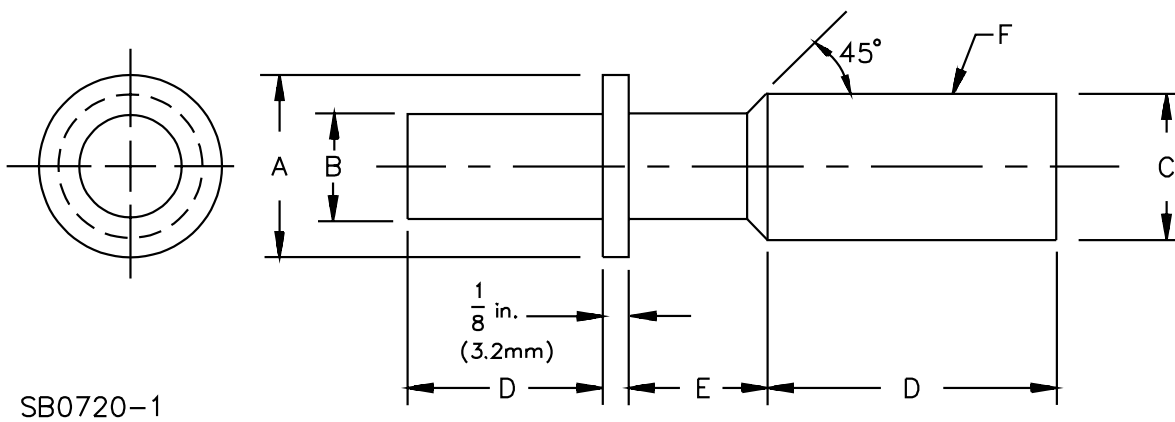


FT160

Figure 6 – Acceptable dimensions of wedge in mm (inches)
(See Clauses 6.9.4 and 6.10.6.)



**Figure 7 – Metal mandrel for restricted recovery test
(See Clause 6.17.2.)**



A – Minimum expanded inside diameter of tubing plus 10 minus 5 percent.

B – Maximum recovered inside diameter of tubing plus 5 minus 0 percent.

$$C = (A + B)/2$$

D, E – See Table 6

F – That part of the mandrel shaped as shown with a 45 angle between the C and B dimensions.

Notes: All edges shall be deburred and free of sharp edges.

Section F can be provided with a longitudinal V-groove to allow easy cutting off of the sample with a knife or razor blade after the testing is complete.

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Appendix A

Silicone Rubber Tubing That Has a Wall Thickness Less Than 0.711 mm (0.028 inches)

NOTE: This Appendix is a mandatory part of this Standard.

A1 General

A1.1 Silicone rubber tubing that has a wall thickness less than 0.711 mm (0.028 inches) shall comply with the requirements in Tables A1 to A4, as appropriate, and shall also be investigated to determine the acceptability of the silicone rubber as compared with the properties of a control tubing that is known to be acceptable in the thickness being considered.

A1.2 Wherever "not applicable" appears beside an item number in Tables A1 to A4, that particular item does not apply to the tubing under consideration.

A2 Performance

A2.1 Crushing Test

A2.1.1 The candidate tubing (with the maximum intended size solid copper conductor inserted) shall be capable of withstanding a crushing force of at least the value for the control tubing.

A2.1.2 The crushing test shall be conducted on 10 specimens, using the apparatus and method described in clauses A2.1.3 and A2.1.4. The tubing shall be filled with the intended maximum size solid copper conductor that tightly fits inside the tubing without causing mechanical damage to the tubing walls.

A2.1.3 The tubing shall be crushed between two flat 50.8 mm (2 inches) wide, rigid, parallel, horizontal steel plates. The rate of compression of the steel plates shall be 2.54 mm/minute (0.1 inches/minute).

A2.1.4 The test specimen shall be crushed until the conductor is grounded to either of the plates, as indicated by a low-voltage buzzer circuit. The force at grounding shall be recorded, and the average of 10 readings (each on a different specimen of tubing) shall be the crush strength.

A2.2 Impact Test

A2.2.1 The candidate tubing (with the maximum intended size solid copper conductor inserted) shall be capable of withstanding an impact of at least the value for the control tubing.

A2.2.2 The impact test shall be conducted using the apparatus and method described in clause A2.2.3. The tubing shall be filled with the intended maximum size solid copper conductor that will tightly fit inside the tubing without causing mechanical damage to the tubing wall.

A2.2.3 Specimens to be tested shall be laid on a flat steel plate and subjected to the impact of a free-falling flat-faced 31.8 mm (1-1/4 inches) diameter cylindrical steel weight. For each test, a new section of each specimen shall be laid across the flat plate. A 0.9 kg (2 lbf) weight shall be dropped from the required height. Rupture of the insulation by grounding of the conductor to the flat plate shall be considered to have occurred when indicated by a low-voltage buzzer circuit.

A2.2.4 The tubing shall be considered to have the numerical impact resistance corresponding to the impact level if not more than 4 out of 10 specimens rupture. Ten specimens shall be tested.

A2.3 Penetration Test

A2.3.1 The candidate tubing shall be capable of withstanding for a period of 10 minutes, in an oven, essentially free from vibration, and operating at rated temperature, a vertically applied force of 350 g (0.771 lbf) when tested with the apparatus and according to the method described in clause A2.3.2.

A2.3.2 The oven for the penetration test equipment shall be brought to the rated temperature of the tubing. Then, after a preheating period of 5 minutes, a specimen of the tubing, with the maximum size solid copper conductor inserted, shall be placed under and at right angles to the cutting edge of a metal plunger having a sharp 90° V-edge maximum radius of 0.076 mm (0.003 inches) and held in a vertical position in a guide. The total weight exerted on the specimen, including the plunger, shall be 350 g (0.771 lbf). The time required for the plunger to cut through the insulation and make contact with the conductor shall be measured with a stop watch. Contact of the plunger with the conductor shall be determined by means of a low-voltage buzzer, or equivalent, connected in series with the plunger and energized from a supply source. The acceptability of the tubing shall be contingent on the successful application of the specified force to three different specimens. Each specimen shall be individually subjected to the applied force for 10 minutes, with no specified time limit required between tests.

Table A1 – Requirements for 150°C (302°F) not-heat-shrinkable silicone rubber tubing less than 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organosiloxane
2. Form	Not-heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	300 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 181.0 ± 1.0°C (357.8 ± 1.8°F) and 60 days at 158.0 ± 1.0°C (316.48 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	3.45 MPa (500 psi) (specimen aged per Item 9)
12. Minimum ultimate elongation	50 percent (simultaneous with Item 11)
13. Dielectric voltage withstand and breakdown	(Specimens aged per Item 9) 60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half of the breakdown voltage of unaged specimens but not less than 2500 V
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens (see Clause 6.16) aged per Item 9 shall comply with Item 12
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572.0 ± 8.0°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after 2 hours in a circulating-air oven at 150.0 ± 1.0°C (302.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	See Clause A2.1
26. Impact	See Clause A2.2
27. Penetration	See Clause A2.2
28. Heat-resistance properties	60 seconds at 1500 V and no cracking (specimens aged and wound per Clause 6.10)
29. Oil resistance	See Clause 6.3

Table A2 – Requirements for 200°C (392°F) not-heat-shrinkable silicone rubber tubing less than 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Not-heat-shrinkable
3. Temperature rating	200°C (392°F)
4. Voltage rating	300 V
5. Minimum wall thickness	See Tables 27 and 29
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F) and 60 days at 210.0 ± 1.0°C (410.0 ± 1.8°F)
10. Flexibility	Shall remain flexible with no cracking or permanent deformation (specimens aged per Item 9)
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	(Specimens aged per Item 9) 60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half of the breakdown voltage of unaged specimens, but not less than 2500 V
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens (see Clause 6.16) aged per Item 9 shall comply with Item 12
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572.0 ± 8.0°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after 2 hours in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	Not applicable
24. Restricted recovery	Not applicable
25. Crushing	See Clause A2.1
26. Impact	See Clause A2.2
27. Penetration	See Clause A2.3
28. Heat-resistance properties	60 seconds at 1500 V and no cracking (specimens aged and wound per Clause 6.10)
29. Oil resistance	See Clause 6.3

Table A3 – Requirements for 150°C (302°F) heat-shrinkable silicone rubber tubing less than 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Heat-shrinkable
3. Temperature rating	150°C (302°F)
4. Voltage rating	300 V and 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 181.0 ± 1.0°C (357.8 ± 1.8°F) and 60 days at 158.0 ± 1.0°C (316.4 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	(Specimens aged per Item 9) 60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens (see Clause 6.16) aged per Item 9 shall comply with Item 12
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572.0 ± 8.0°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 150.0 ± 1.0°C (302.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	See Clause A2.1
26. Impact	See Clause A2.2
27. Penetration	See Clause A2.3
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3

Table A4 – Requirements for 200°C (392°F) heat-shrinkable silicone rubber tubing less than 0.711 mm (0.028 inches) thick

Item	Information
1. Material	Heat-cured silicone rubber, the basic constituent of which is poly-organo-siloxane
2. Form	Heat-shrinkable, Class I or Class II
3. Temperature rating	200°C (392°F)
4. Voltage rating	300 V and 600 V
5. Minimum recovered wall thickness	See Tables 28 and 30
6. Minimum tensile strength	3.45 MPa (500 psi) when tested at 508 mm/min (20 in/min) on unaged specimens
7. Minimum ultimate elongation	100 percent – simultaneous with Item 6
8. Dielectric voltage withstand and breakdown	60 seconds at 2500 V (unaged specimens) and then breakdown
9. Aging (separate specimens) in a circulating-air oven	7 days at 232.0 ± 1.0°C (449.6 ± 1.8°F) and 60 days at 210.0 ± 1.0°C (410.0 ± 1.8°F)
10. Flexibility	Not applicable
11. Minimum tensile strength	3.45 MPa (500 psi) (specimens aged per Item 9)
12. Minimum ultimate elongation	50 percent – simultaneous with Item 11
13. Dielectric voltage withstand and breakdown	(Specimens aged per Item 9) 60 seconds at 2500 V and then breakdown, breakdown voltage to be at least half the breakdown voltage of unaged specimens but not less than 2500 V
14. Corrosion of bare copper	Humidity-conditioned specimens aged per Item 9 (See Clause 6.15)
15. Copper stability	Humidity-conditioned specimens (see Clause 6.16) aged per Item 9 shall comply with Item 12
16. Deformation	Not applicable
17. Heat shock	No cracking, flowing, or dripping after 1 hour at 300.0 ± 4.0°C (572.0 ± 8.0°F) and when wound 360° around a mandrel of the diameter indicated in Table 7
18. Cold bend	No cracking of specimens cooled for 1 hour at minus 30 ± 1.0°C (minus 22 ± 1.8°F) and then wound 360° around a cold mandrel of the diameter indicated in Table 7
19. Flammability	See Clauses 6.9 and 6.10
20. Minimum volume resistivity	10 ¹² ohms-centimeter
21. Maximum longitudinal change	±5 percent after fully recovered specimens have spent 2 hours in a circulating-air oven at 200.0 ± 1.0°C (392.0 ± 1.8°F)
22. Maximum secant modulus	Not applicable
23. Maximum eccentricity	30 percent (See Clause 6.13)
24. Restricted recovery	See Clause 6.17
25. Crushing	See Clause A2.1
26. Impact	See Clause A2.2
27. Penetration	See Clause A2.3
28. Heat-resistance properties	Not applicable
29. Oil resistance	See Clause 6.3