



UL 224

Underwriters Laboratories Inc.
Standard for Safety

Extruded Insulating Tubing



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UL Standard for Safety for Extruded Insulating Tubing, UL 224

Sixth Edition, Dated March 6, 2006

Summary of Topics

This revision of ANSI/UL 224 includes the following change in requirements:

Clarification of Requirements for Long-Term Heat-Aging Testing

Correction of a Typographical Error for the Secant Modulus Requirement in Table 21

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated November 6, 2009.

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Third Edition



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ANSI/UL 224-2010

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This ANSI/UL Standard for Safety consists of the Sixth edition including revisions through August 12, 2010.

The most recent designation of ANSI/UL 224 as an American National Standard (ANSI) occurred on August 12, 2010. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

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Preface

This is the harmonized CSA and UL standard for Extruded Insulating Tubing. It is the third edition of CSA C22.2 No. 198.1 and the sixth edition of UL 224. This harmonized standard has been jointly revised on August 12, 2010. For this purpose, CSA and UL are issuing revision pages dated August 12, 2010.

This harmonized standard was prepared by the Canadian Standards Association (CSA) and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee 15C, Electrical Tubing and Sleeving Products, of the Council on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

This Standard is considered suitable for use for conformity assessment within the stated scope of the Standard.

This standard was reviewed by the CSA Subcommittee on Insulation Systems, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on Requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee.

This standard has been approved by the Standards Council of Canada (SCC) as a National Standard of Canada.

This standard has been approved by the American National Standards Institute (ANSI) as an American National Standard.

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

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.*

Level of harmonization

This standard uses the IEC format but is not based on, nor is it to be considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for CSA and UL.

An equivalent standard is a standard that is substantially the same in technical content, except as follows: Technical national differences are allowed for codes and governmental regulations as well as those recognized as being in accordance with NAFTA Article 905, for example, because of fundamental climatic, geographical, technological, or infrastructural factors, scientific justification, or the level of protection that the country considers appropriate. Presentation is word for word except for editorial changes.

Reasons for differences from IEC

The Technical Harmonization Subcommittee identified the following standard as being within the scope of this standard: IEC 60684, Flexible Insulating Sleeving. IEC 60684 and CSA C22.2 No. 198.1/UL 224 are similar but not identical. Both standards cover multiple, but not identical, products and similar methods. The THC agreed to address the issues involved in the harmonization of these standards during the next revision of CSA C22.2 No. 198.1/UL 224.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

CSA effective date

The effective date for CSA International will be announced through CSA Informs or a CSA certification notice.

UL effective date

As of August 12, 2010 all products Listed or Recognized by UL must comply with the requirements in this standard.

A UL effective date is one established by Underwriters Laboratories Inc. and is not part of the ANSI approved standard.

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 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 intended for use in contact with sharp edges, corners, or projections, or where subject to tension, compression, or repeated flexing. Tubing is not intended 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, chemically dilated tubing, polymeric tubing extruded with reinforcement, or tubing intended only for mechanical protection.

1.4 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, it will in some cases 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 used in an environment conducive to the development of fungi and similar organisms.

2 Reference Publications and Definitions

2.1 Reference publications

For undated references to standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this standard was approved.

For dated references to standards, such reference shall be considered to refer to the dated edition and all revisions published to that edition up to the time the standard was approved.

CSA (Canadian Standards Association)

C22.1-02

Canadian Electrical Code, Part I

CAN/CSA C22.2 No. 0.17-00

Evaluation of Properties of Polymeric Materials

C22.2 No. 0.3-01

Test Methods for Electrical Wires and Cables

UL (Underwriters Laboratories Inc.)

UL 746B

Standard for Polymeric Materials – Long Term Property Evaluations

UL 1581

*Reference Standard for Electrical Wires, Cables, and Flexible Cords***ANSI/NFPA (American National Standards Institute/National Fire Protection Association)**

NFPA-70-2002

*National Electrical Code***ASTM (American Society for Testing and Materials)**

D 257-99

Test Methods for DC Resistance or Conductance of Insulating Materials

D 412-98a (2002)e1

Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension

D 471-98e1

Test Method for Rubber Property – Effect of Liquids

D 876-00

Test Methods for Nonrigid Vinyl Chloride Polymer Tubing Used for Electrical Insulation

D 2671-00

Standard Test Methods for Heat-Shrinkable Tubing for Electrical Use

D 5025-99

Standard Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials

D 5207-03

Standard Practice for Confirmation of 20 mm (50 W) and 125 mm (500 W) Test Flames for Small-Scale Burning Tests on Plastic Materials

D 5374-93 (99)

Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

D 5423-93 (99)

Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

2.2 Definitions

2.2.1 The following definitions apply in this Standard:

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

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

2.2.4 **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.

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

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

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

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

3 General

3.1 Item references

Wherever Item numbers appear in a capability test description, the appropriate table of requirements for the specific type of tubing under investigation shall be selected.

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3.2 Units of measurement

The values given in SI (metric) units shall be normative. Any other values given shall be for information purposes only, except for conductor sizes where the equivalent metric values are in parentheses.

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 Colour

4.2.1 If the tubing is to be considered in a range of colours, specimens representing the full colour range shall be provided for evaluation. Samples in the clear and most heavily pigmented black and white colours shall be provided and be considered representative of the colour 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 colours tested, unless additional specimens in intermediate colours are provided for tests. (See Clause 5.2.2.)

4.2.2 Notwithstanding Clause 4.2.1, if the same base compound is employed for all colours 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 single-wall tubing, the minimum thickness shall be determined by means of a dead-weight pin gauge micrometer having a resolution of at least 0.01 mm (0.0004 in) with a presser foot 1.09 mm (0.043 in) wide and 7.92 mm (0.312 in) long and a pin that is 1.09 mm (0.043 in) in diameter and 11.10 mm (0.437 in) 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 micrometer microscope that can be read to the nearest 0.001 mm (0.0001 in) shall be used.

4.3.3 For tubing with a meltable liner, the thickness of the inner wall shall not be included when determining the wall thickness. If the inner wall is removable by physical or chemical means, the manufacturer shall provide instructions for its removal. If the inner wall is not removable, measurements of the outer wall shall be made using a calibrated micrometer microscope that can be read to the nearest 0.001 mm (0.0001 in).

4.4 Heat-shrinkable tubing

Heat-shrinkable tubing shall reduce in diameter and conform to the minimum wall thickness requirements specified in Tables 34 and 36, as applicable, upon the controlled application of heat. For tubing with a meltable liner, the thickness of the inner wall shall not be included.

5 Capability tests

5.1 Circulating air-oven

The apparatus for the air-oven aging of specimens shall be in accordance with ASTM D 5423 Type II. 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 ± 1.0 °C (± 1.8 °F).

5.2 Samples

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

5.2.2 If the tubing is to be evaluated in a range of colours, the required test samples shown in Table 2 shall be provided as specified in Clause 4.2.

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

5.2.4 The inner and outer surfaces of tubing (excluding the meltable liner) 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.

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

5.2.6 The minimum expanded inside diameter and the maximum recovered inside diameter of heat shrinkable tubing referred to in the capability tests of Clauses 5.3 to 5.19 shall be the values specified for the product by the manufacturer.

5.3 Physical properties

5.3.1 General

5.3.1.1 The tensile strength and ultimate elongation of the tubing shall not be less than the values tabulated in Items 6 and 7 of Tables 7 to 32, as applicable, for unaged specimens and in Items 11 and 12 of Tables 7 to 32, as applicable, for aged specimens. Oil-resistant tubing shall comply with the requirements in Clause 5.4.

5.3.1.2 For the preparation, aging, and testing of specimens of tubing, the equipment mentioned in Clauses 5.3.2 to 5.3.6 shall be used.

5.3.2 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 ± 2.0 °C (73.4 ± 3.6 °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 hours 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 conditioned as indicated above 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.

5.3.3 Die for cutting specimens

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

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

5.3.3.3 The use of a press for operating the die is recommended. The cutting shall be done on a smooth surface of material that cannot damage the cutting edges of the die.

5.3.4 Specimen marker

The specimen marker shall consist of a stamp with parallel metal blades capable of making fine inked lines (benchmarks) on a specimen. The lines shall be 25 mm (1 in) apart and shall be applied at right angles to the longitudinal axis of the specimen. The ink shall be of any colour that contrasts with that of the specimen, and of a composition that does not in any way damage the specimen.

5.3.5 Apparatus for aging

5.3.5.1 General

The apparatus for the aging of specimens specified in these requirements shall include the equipment mentioned in Clauses 5.1 and 5.3.5.2. 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.

5.3.5.2 Oil-immersion aging

5.3.5.2.1 The immersion vessel for tubular specimens shall be a test tube having an overall diameter of at least 25 mm (1 in) and a length that facilitates immersion of a straight specimen at least 152 mm (6 in) long. The tube shall be filled with the oil specified in Clause 5.3.5.2.2 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 diameter of solid copper conductor that fits tightly inside the tubing without damaging the tubing wall. For tubing smaller than 8.38 mm (0.330 in) inside diameter, specimens shall be bent at the centre to form a narrow U and shall then 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 Clauses 5.4.4 to 5.4.6, each specimen shall be cut in half at the centre of the U-bend to provide two specimens for physical tests. For tubing larger than 8.38 mm (0.330 in) inside diameter, die-cut specimens shall be suspended vertically in the oil.

5.3.5.2.2 The oil to be used shall be IRM 902 oil as described in ASTM D 471. 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 ± 3.0 °C (199.0 ± 5.4 °F) and an open-cup flash point of 243.3 ± 5.6 °C (470.0 ± 10 °F).

5.3.6 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.

5.3.7 Specimen preparation

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

5.3.7.2 For tubing smaller than 8.38 mm (0.330 in) 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. As an alternative for tubing with meltable liner, samples shall be slit longitudinally in half prior to aging as long as the adhesive remains in contact with the inner surface of the tubing during conditioning. For 8.38 mm (0.330 in) 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. Die-cut specimens may be buffed to remove surface imperfections, and this shall be carried out at least 30 minutes before oven aging or oil immersion.

5.3.7.3 Two benchmarks 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 benchmarks shall be placed on the specimens before they are immersed in oil. The benchmarks shall be separated by a distance of 25 mm (1 in). This distance applies to all classes of material, and shall be an equal longitudinal distance from the centre of the specimen. The benchmarks shall be applied by means of the stamp described in Clause 5.3.4. 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 benchmarks is not more than 0.254 mm (0.010 in) wide and that each specimen is completely at rest while being marked. The distance between the benchmarks shall be checked carefully.

5.3.7.4 For tubular specimens, the cross-sectional area shall be determined as indicated in Clause 5.3.8.1 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 5.3.7.5 and 5.3.7.6. The inside diameter of the tubing shall be measured in accordance with ASTM D 876. Heat-shrinkable tubing shall be measured 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 in) inside diameter, the wall thickness, T_1 , shall be determined by the difference method from measurements of a 25 mm (1 in) length of tubing into which there is inserted a solid metal rod or conductor of a diameter within 5 percent of the measured inside diameter of the tubing. The overall diameter of the tubing shall be measured to the nearest 0.01 mm (0.001 in) by means of a dead-weight dial micrometer equipped with an anvil and presser foot 2.0 mm (5/64 in) wide and 9.5 mm (3/8 in) long. The instrument shall have a resolution of at least 0.01 mm (0.0004 in). The presser foot shall exert a load of 0.098 ± 0.020 N (0.022 ± 0.0045 lbf) on the specimen. As a referee or secondary method, a calibrated micrometer microscope that can be read to the nearest 0.001 mm (0.0001 in) shall be used. The thickness, T_1 , of the tubular specimen shall be determined by subtracting the diameter of the metal mandrel from the overall diameter and dividing the result by 2. The overall inner and outer diameters of the outer wall of a tubing with meltable liner shall be made using a calibrated micrometer microscope that can be read to the nearest 0.001 mm (0.0001 in). A minimum of three specimens shall be measured and the average value shall be calculated.

5.3.7.5 The measurements for the thickness of a die-cut specimen shall be made with a micrometer graduated to the nearest 0.01 mm or the nearest 0.001 inch 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 in) in diameter. The anvil of the instrument shall be at least 38.1 mm (1.5 in) in diameter and shall be parallel to the face of the presser foot.

5.3.7.6 The thickness of a die-cut specimen shall be determined as the minimum of four measurements to the nearest 0.01 mm (0.001 in), two measurements of which shall be made at 12.7 mm (1/2 in) intervals between the benchmarks on one edge of the reduced section and beginning 6.4 mm (1/4 in) 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.

5.3.7.7 Each specimen shall be free from surface inclusions 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 5.2.4).

5.3.7.8 The specimens intended for 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.

5.3.7.9 The specimens shall be subjected to the temperature in the air oven for the length of time specified in Item 9 of Tables 7 to 32, as applicable, while the air oven is operating at the specified draft. The air temperature in the oven shall be recorded throughout the aging. For polymers not found in Tables 7 to 32, aging shall be conducted for 7 days at the temperature calculated from the following formula:

$$T_{\text{test}} (^{\circ}\text{C}) = 1.02 \times (296 + T_{\text{rated}} (^{\circ}\text{C})) - 273$$

The rated temperature shall be determined in accordance with the relative thermal index test of UL 746B or CAN/CSA-C22.2 No. 0.17.

5.3.7.10 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 benchmarks 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 benchmarks 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 in). Because the width of a benchmark increases while a specimen is being stretched, the measurement for ultimate elongation shall be made with reference to the centre of each mark – that is, a point halfway between the edges of each mark. As an alternative method to the benchmark procedure for measuring elongation, the elongation measurement may be made by means of an extensometer. A video or laser extensometer may be used. A mechanical extensometer may be used where the length of the specimen provides room between the grips for the sensor carriages to be connected. The contact force of each sensor carriage on the specimen shall be adjusted to the minimum that keeps the carriage from slipping on the specimen. That minimum force shall not damage the specimen or result in the specimen's parting at either carriage contact.

5.3.7.11 The maximum load in N (lbf) and the length between the benchmarks in mm (in) shall be recorded. If a specimen breaks outside the benchmarks at a value small enough to result in a lower tensile strength or elongation than tabulated in Item 6, 7, 11, or 12 in Tables 7 to 32, as applicable, the results for that specimen shall be disregarded.

5.3.8 Calculation of results

5.3.8.1 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 = area, mm² (in²)

D_o = outside diameter, mm (in), of the specimen measured to the nearest 0.01 mm (0.001 in) before aging

D_i = the inside diameter, mm (in), of the specimen measured to the nearest 0.01 mm (0.001 in) before aging

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

5.3.8.2 The tensile strength of a specimen shall be calculated as 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, N (lbf)

A = the cross-sectional area of a tubular specimen (see Clause 5.3.7.4) before aging, mm² (in²)

w = the width of a die-cut specimen (see Clauses 5.3.7.5 and 5.3.7.6), mm (in)

t = the minimum thickness of a die-cut specimen (see Clauses 5.3.7.5 and 5.3.7.6), mm (in)

5.3.8.3 The ultimate elongation shall be calculated by subtracting the original distance between the benchmarks from the distance between the benchmarks 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 benchmarks at the instant of rupture, mm (in)

S = the original distance between the benchmarks, mm (in)

5.4 Oil resistance (optional)

5.4.1 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 5.4.4.

5.4.2 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 5.4.5.

5.4.3 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 5.4.6.

5.4.4 The tubing defined in Clause 5.4.1 shall be immersed in IRM 902 oil for 4 hours at 70.0 ± 1.0 °C (158 ± 1.8 °F) in accordance with the procedure in Clauses 5.3.5.1 and 5.3.5.2.

5.4.5 The tubing defined in Clause 5.4.2 shall be immersed in IRM 902 oil for 96 hours at 100.0 ± 1.0 °C (212 ± 1.8 °F) in accordance with the procedure in Clauses 5.3.5.1 and 5.3.5.2.

5.4.6 The tubing defined in Clause 5.4.3 shall be immersed in IRM 902 oil for 60 days at 80.0 ± 1.0 °C (176.0 ± 1.8 °F) in accordance with the procedure in Clauses 5.3.5.1 and 5.3.5.2.

5.5 Flexibility (not-heat-shrinkable tubing)

5.5.1 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 7 to 32 or after 7 days at the temperature determined from the formula in Clause 5.3.7.9, as applicable.

5.5.2 Three specimens 0.30 m (1 ft) 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 7 to 32, as applicable. Each specimen then shall be bent back on itself 180 degrees. Following immediate release, the tubing shall return to the general circular form (an oval shape shall be acceptable) 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.

5.6 Dielectric voltage withstand and breakdown

5.6.1 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 7 to 32 or after 7 days at the temperature determined from the formula in Clause 5.3.7.9, as applicable, shall be at least 50 percent of the breakdown potential of the unaged tubing, but not less than 2500 V.

5.6.2 Three specimens of tubing, each 460 mm (18 in) in length, shall be aged in a circulating-air oven as indicated in Item 9 of Tables 7 to 32 or after 7 days at the temperature determined from the formula in Clause 5.3.7.9, as applicable, and shall then be cooled to room temperature. These and similar specimens conditioned for the same length of time at a temperature of 23.0 ± 2.0 °C (73.4 ± 3.6 °F) shall be tested. One clean, straight, bare, solid, copper conductor shall be inserted with a snug fit into each specimen of 0.305 to 3.88 mm (0.012 to 0.153 in) tubing prior to aging. Several conductors shall be inserted with a snug fit into 3.89 mm (0.154 in) inside diameter or larger tubing. Heat-shrinkable tubing shall be centred and recovered on a conductor or conductors having the same overall diameter as the maximum recovered inside diameter of the tubing being tested (including adhesive for tubing with meltable liner, as specified by the manufacturer). The centre 152 mm (6 in) portion of each specimen shall be wrapped with strip metal foil.

5.6.3 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 to 60 Hz, and can be varied continuously from 0 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 shall not 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.

5.7 Deformation

5.7.1 General

The wall thickness of the tubing shall not decrease more than the value specified in Item 16 of Tables 7 to 32, as applicable, while under the load indicated in Table 4.

5.7.2 Samples

Compliance with the requirement of Clause 5.7.1 shall be determined in accordance with the apparatus and procedure in Clauses 5.7.3, 5.7.4, and 5.7.5. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) of 4.22 mm (0.166 in) 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, rectangular specimens 25 mm (1 in) long and a maximum width of 14 mm (0.56 in) shall be cut from the tubing.

5.7.3 Apparatus

The apparatus for the determination of percentage deformation shall consist of

- a) a circulating-air oven; 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 in) diameter flat presser foot, slightly rounded at the edges, and intended to bear upon the specimen under test.

5.7.4 Procedure

5.7.4.1 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 micrometer that can read to at least 0.01 mm (0.0004 in). 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 micrometer.

5.7.4.2 The appropriate weight, in accordance with Table 4, the apparatus shown in Figure 3, and the measured specimen shall be maintained for 1 hour in the oven that has been preheated to the test temperature indicated in Item 16 of Tables 7 to 32, as applicable. At the end of that time, the specimen shall be placed under the foot of the weight, which shall 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 5.7.4.1 Item (a) or (b), as applicable, for thickness T_1 .

5.7.5 Calculation of deformation

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

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

5.7.6 Tubing with meltable liner

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

5.8 Heat shock

5.8.1 Tubing shall show no evidence of flowing or dripping after conditioning, nor of cracking after conditioning and being wound around a mandrel as indicated in Table 6. Flowing is defined as an extension greater than 10 percent of the original length. Side cracking of the flattened tubing (as indicated by discoloration), or flowing from the inner wall of tubing with a meltable liner, shall not be cause for rejection.

5.8.2 For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) less than 8.38 mm (0.330 in), the test shall be performed on a 150 mm (6 in) length of the tubing. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) 8.38 mm (0.330 in) or larger, the test shall be performed on a 150 mm (6 in) by 13 mm (0.5 in) longitudinal strip cut from the tubing.

5.8.3 The specimen, prepared as described in Clause 5.8.2, 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 7 to 32, as applicable. After conditioning, the specimen shall be visually examined for evidence of cracking, flowing, or dripping, and measured to determine if a change in length has occurred. The specimen shall be allowed to cool to room temperature and shall then be wound 360 degrees around a steel mandrel of the diameter specified in Table 6 for the tubing being tested, at a uniform rate and within 2 to 4 seconds. The specimen shall exhibit no cracks when examined using normal or corrected-to-normal vision (without magnification). Side cracking of the flattened sleeve shall not be cause for rejection.

5.9 Cold bend

5.9.1 Tubing shall show no evidence of cracking when wound around a mandrel after conditioning as indicated in Item 18 of Tables 7 to 32, as applicable.

5.9.2 For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) of 3.00 mm (0.12 in) and smaller, one bare copper conductor having a diameter that will provide a close fit shall be inserted into the specimen. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) larger than 3.00 mm (0.12 in) but less than 10.2 mm (0.4 in), several bare copper conductors, each no larger than size 0.8 mm² (18 AWG), shall be inserted with a close fit into the specimen. For tubing with an inside diameter (fully recovered in the case of heat-shrinkable tubing) 10.2 mm (0.4 in) and larger, a 152 by 6.4 mm (6 by 0.25 in) longitudinal strip shall be cut from the tubing.

5.9.3 The specimen, prepared as described in Clause 5.9.2, and a steel mandrel of the diameter specified in Table 6 for the tubing being tested, shall be conditioned for the time and at the temperature indicated in Item 18 of Tables 7 to 32, as applicable. After conditioning, and while still at this temperature, the specimen shall be wound not less than 360 degrees around the mandrel at a uniform rate and within 10 ± 2 seconds. The specimen shall exhibit no cracks when examined using normal or corrected-to-normal vision (without magnification).

5.10 Flame test – all tubing

5.10.1 A vertical specimen of the tubing shall not flame or glow longer than 60 seconds following any of five 15-second 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 5.10.2 to 5.10.11.

5.10.2 This test shall be performed on unaged specimens of the tubing. The test shall be conducted in a three-sided metal enclosure. The metal enclosure shall be 305 mm (12 in) wide, 355 mm (14 in) deep, and 610 mm (24 in) high, and the top and front shall be open. A 460 mm (18 in) specimen cut from a sample length of not-heat-shrinkable tubing shall be centred on a 530 mm (21 in) straight length of a solid metal mandrel having the diameter equal to the inside diameter of the tubing for sizes up to 1.68 mm (0.066 in) and 75 percent of the inside diameter for tubing larger than 1.68 mm (0.066 in). A 460 mm (18 in) length of heat-shrinkable tubing shall be centred and recovered on a 533 mm (21 in) straight length of solid metal mandrel having the same diameter as the maximum recovered inside diameter for the tubing (including adhesive for tubing with meltable liner, as specified by the manufacturer). The combinations of the specimen and its support shall be secured with its longitudinal axis vertical in the centre of the enclosure. A flat horizontal layer of untreated surgical cotton approximately 3 mm (1/8 in) thick shall cover the floor of the enclosure. The upper surface of the cotton shall be no more than 240 mm (9-1/2 in) 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.)

5.10.3 A burner conforming to ASTM D 5025 having a bore of 9.5 ± 0.3 mm (0.375 ± 0.012 in) and a length of 100 ± 10 mm (4 ± 0.394 in) from the top of the air-inlet openings to the top of the mixing tube, or an equivalent that meets the calibration of ASTM D 5207, shall supply the flame. 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 to 125 mm (4 to 5 in). The blue inner cone shall be 38 mm (1-1/2 in) high. 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. The burner and its calibrations shall be performed in accordance with ASTM D 5025 and D 5207. The flame test shall be performed in a draft free chamber in accordance with the requirements of UL 1581, Section 1060, or CSA C22.2 No. 0.3, Clause 4.11.1.

5.10.4 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 degrees 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 in) thick and 25 mm (1 in) 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 in) 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 centre of the front of the specimen. The specimen shall be adjusted vertically to prevent point B from being any closer than 76 mm (3 in) to the lower clamp or other support for the specimen. (See Figure 4.)

5.10.5 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 5.10.4 without disturbing the layer of cotton on the floor of the enclosure or the cotton on the wedge around the base of the burner.

5.10.6 A strip of unreinforced 94 g/m² kraft paper (60 lb) that is 13 mm (1/2 in) wide, approximately 0.1 mm (0.005 in) 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 in) 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 in) from the specimen toward the rear of the enclosure, with the flag parallel to the sides of the enclosure. (See Figure 4.)

5.10.7 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 5.10.5 in a position away from the specimen and then lit.

5.10.8 The flame shall be applied to the specimen for 15 seconds and removed for 15 seconds (or longer if flaming or glowing of the specimen persists). This cycle shall be repeated for a total of 5 times. If flaming or glowing of the specimen persists longer than 15 seconds after the previous application of the gas flame, the gas flame shall not be reapplied until flaming or glowing of the specimen ceases of its own accord. A gas burner with a pilot light having a valve supplying gas to the burner that can be turned on or off to apply the flame, or a burner without a pilot light that is moved into position to apply the flame, may be used. If the supporting wire breaks due to the flame, the sample shall be discarded and the test shall be repeated with a new specimen.

5.10.9 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 capable of conveying flame.

5.10.10 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 capable of conveying flame to combustible materials in its vicinity.