UL 2556

STANDARD FOR SAFETY

Wire and Cable Test Methods

UL Standard for Safety for Wire and Cable Test Methods, UL 2556

Fourth Edition, Dated December 15, 2015

Summary of Topics

This New Edition of ANSI/UL 2556 is being issued to incorporate several substantive changes.

The new requirements are substantially in accordance with Proposal(s) on this subject dated May 1, 2015 and September 11, 2015.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the preface. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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Association of Standardization and Certification
NMX-J-556-ANCE-2015
Fourth Edition

CSA Group
CSA C22.2 No. 2556-15
Fourth Edition

Underwriters Laboratories Inc.
UL 2556
Fourth Edition

Wire and Cable Test Methods

December 15, 2015

ANSI/UL 2556-2015

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

ISBN 978-1-77139-930-2 © 2015 CSA Group

This Standard is subject to review five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquires@csagroup.org and include ″Proposal for change″ in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

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This ANSI/UL Standard for Safety consists of the Fourth Edition including revisions through December 15, 2015. The most recent designation of ANSI/UL 2556 as an American National Standard (ANSI) occurred on December 15, 2015. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface. The National Difference Page and IEC Foreword are also excluded from the ANSI approval of IEC-based standards.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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Annex A (informative) Conductor removal from insulation for tubular specimens

PREFACE

This is the harmonized ANCE, CSA Group, and UL standard for Wire and Cable Test Methods. It is the Fourth edition of NMX-J-556-ANCE, the Fourth edition of CSA C22.2 No. 2556, and the Fourth edition of UL 2556. This edition of NMX-J-556-ANCE supersedes the previous edition published on March 22, 2013. This edition of CSA C22.2 No. 2556 supersedes the previous edition published on March 22, 2013. This edition of UL 2556 supersedes the previous edition published on March 22, 2013.

This harmonized standard was prepared by the Association of Standardization and Certification (ANCE), CSA Group, and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Committee for Wire and Cable Test Methods, 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.

The present Mexican standard was developed by the WG Metodos de Prueba para Conductores, from CT 20 Conductores belonging the Comite de Normalización de la Asociación de Normalización y Certificación, A.C., CONANCE, with the collaboration of the manufacturers and users of electric conductors.

This standard was reviewed by the CSA Integrated Committee on Test Methods for Wires and Cables, 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 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 considered equivalent to, an IEC standard.

This standard is published as an equivalent standard for ANCE, CSA Group, 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

This standard provides requirements for insulated wires and cables for use in accordance with the electrical installation codes of Canada, Mexico, and the United States. At present there is no IEC standard for wires and cables for use in accordance with these codes. Therefore, this standard does not employ any IEC standard for base requirements.

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.

Wire and Cable Test Methods

1 Scope

1.1 This standard describes the apparatus, test methods, and formulas to be used in carrying out the tests and calculations required by wire and cable standards.

1.2 Specific acceptance requirements are found in individual product standards.

1.3 Where a test method indicates a “specified” test parameter or condition, the parameter or condition is found in the individual product standard.

2 General

2.1 Units of measure

The unit of measure shall be SI. If a value for measurement is followed by a value in other units in parentheses, the second value represents a direct conversion or an alternative value. Except for conductor size, the first stated value is the requirement.

2.2 Normative references

Where reference is made to any Standards, such reference shall be considered to refer to the latest editions and revisions thereto available at the time of printing, unless otherwise specified.

> **Note:** *In Mexico, NMX-J-556-ANCE is organized with the same clause numbering as UL 2556/CSA C22.2 No. 2556. Separate ANCE standards are published for test methods not covered in NMX-J-556-ANCE. Annex J provides a list of the harmonized NMX test method standards that apply to each test method.*

ANCE (Association of Standardization and Certification)

NMX-E-034-SCFI
Plastic Industry – Carbon Black Contents on Polyethylene Materials – Test Methods

NMX-J-178-ANCE
Wires and Cables – Ultimate Strength and Elongation of Insulation, Semiconducting Shields and Jackets of Electrical Conductors – Test Method

NMX-J-192-ANCE
Flame Test on Electrical Wires – Test Method

NMX-J-417-ANCE
Wires and Cables – Convection Laboratory Ovens for Evaluation of Electrical Insulation – Specifications and Test Methods

NMX-J-437-ANCE
Wires and Cables – Determination of Light Absorption Coefficient of Polyethylene Pigmented with Carbon Black – Test Methods

NMX-J-474-ANCE
Electrical Products – Wires and Cables – Determination of Specific Optical Density of Smoke Generated by Electrical Wires and Cables – Test Methods

NMX-J-498-ANCE
Vertical Tray – Flame Test – Test Method

NMX-J-553-ANCE
Wires and Cables – Weather Resistance of Insulation or Jacket of Electrical Conductors – Test Method

CSA Group

C22.1
Canadian Electrical Code, Part I

CAN/CSA-C22.2 No. 0
General Requirements – Canadian Electrical Code, Part II

CSA-C22.2 No. 126.1
Metal cable tray systems

ASTM International

A29/A29M
Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for

D412
Standard Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers – Tension

D470
Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable

D471
Standard Test Method for Rubber Property-Effect of Liquids

D1603
Standard Test Method for Carbon Content in Olefin Plastics

D1835
Standard Specification for Liquefied Petroleum (LP) Gases

D4218
Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique

D5025
Standard Specification for Laboratory Burner Used for Small-Scale Burning Tests on Plastic Materials

D5207
Standard Practice for Confirmation of 20-mm (50-W) and 125-mm (500-W) Test Flames for Small-Scale Burning Tests on Plastic Materials

D5374
Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

D5423
Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation

D6370
Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry

E8/E8M
Standard Test Methods for Tension Testing of Metallic Materials

E662
Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials

E1131
Standard Test Method for Compositional Analysis by Thermogravimetry

G151
Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources

G153
Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials

G155
Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

GPA (Gas Processors Association)

GPA 2140
Liquefied Petroleum Gas Specifications and Test Methods

IEC (International Electrotechnical Commission)

IEC 60695-11-3
Fire hazard testing – Part 11-3: Fire hazard testing – Part 11-3: Test flames – 500 W flames – Apparatus and confirmational test methods

ISO (International Organization for Standardization)

ISO 10093
Plastics – Fire tests – Standard ignition sources

NEMA (National Electrical Manufacturers Association)

VE 1
Metal Cable Tray Systems

2.3 Safety

2.3.1 General

It is not the intent of this standard to address all of the safety issues associated with its use. It is the responsibility of the user of this standard to train personnel, establish proper health and safety procedures and be aware of, and comply with, local, state/provincial, and national regulatory restrictions that apply.

2.3.2 Chemical hazards

Some tests use materials that local, state/provincial, and national regulatory agencies have determined to be hazardous. These tests shall be performed under controlled conditions, which allow for proper safety and protection of personnel. Information and instructions contained in material safety data sheets (MSDS) for handling, working, and disposal of hazardous chemicals shall be followed. Furthermore, discharges of these chemicals to the environment, that is, the air, water, or ground, shall comply with the latest applicable regulations.

2.3.3 Electrical hazards

Certain test procedures require high voltage. It is important that the equipment be designed to comply with good engineering practices, with safety being an integral part of the design. To avoid electric shocks in such cases, necessary precautions shall be taken and test equipment manufacturers' recommendations shall be followed.

2.3.4 Mechanical hazards

Some tests utilizing mechanical equipment can expose the operator to mechanical hazards. Care shall be exercised to protect eyes, fingers, hands, and other body parts from injury.

2.3.5 Thermal hazards

In tests requiring elevated temperatures, precautions shall be taken to avoid skin burns when handling materials exposed to heat.

2.3.6 Fire and explosion hazards

Some tests use materials that local, state/provincial, and national regulatory agencies have determined to be hazardous. These tests shall be performed under controlled conditions that allow for proper safety and protection of personnel. Information and instructions contained in material safety data sheets (MSDS) for handling shall be followed. Some gases can settle and become an explosion hazard. Consult the gas supplier for special precautions to be taken.

2.4 Definitions

The following definitions apply in this standard. Terms used throughout this standard which have been defined in this clause are in capital-type reduced font:

DIRECTION OF LAY: The direction, designated as left-hand (counterclockwise) or right-hand (clockwise), in which any component recedes from an observer looking along the longitudinal axis of the conductor or assembly.

FLAME: To undergo combustion in the gaseous phase with emission of light.

GLOWING COMBUSTION: Combustion of a material in the solid phase without flame but with emission of light from the combustion zone.

LENGTH OF LAY: The length along the longitudinal axis of the conductor or assembly for any component to complete one revolution.

MICROMETER: As used in this document, ″micrometer″ means a device for measuring dimensions to small tolerances. This device may utilize mechanical, optical, video, or other technology.

NORMAL VISION: Vision without any aid other than the examiner's normal corrective lenses, if any.

ROOM TEMPERATURE: 25 ±10 °C (77 ±18 °F).

2.5 Test temperature

Tests shall be conducted at ROOM TEMPERATURE unless otherwise specified.

2.6 Reports

In addition to the specific reporting requirements for each test, the following shall be included as a minimum in all reports:

a) name of test facility;

b) date of report;

c) product description;

d) name of test conducted; and

e) test result.

2.7 General requirements

In Canada, general requirements applicable to this standard are given in CAN/CSA-C22.2 No. 0.

3 Conductor tests

3.1 Conductor diameter

3.1.1 Scope

This test establishes the method for determining conductor diameter.

3.1.2 Apparatus

The apparatus shall consist of the following:

a) a micrometer having flat surfaces on both the anvil and the end of the spindle, with a resolution and accuracy of 0.001 mm (0.0001 in);

b) a caliper with a resolution and accuracy of 0.001 mm (0.0001 in); or

c) a laser micrometer with a resolution and accuracy of 0.001 mm (0.0001 in).

3.1.3 Preparation of specimens

The specimen shall be taken from a sample of wire, cable, or cord, finished or during manufacture, and shall be removed from its surrounding insulation or coverings (when present) and straightened, with care being taken not to stretch it.

3.1.4 Procedure

Three measurements of the maximum and minimum diameters shall be made. All measurements of a stranded conductor shall be made over the strands and not at the interstices. The diameter measurements shall be taken near each end and in the center of the specimen.

3.1.5 Results and calculations

3.1.5.1 The diameter shall be the average of the six measurements.

3.1.5.2 When a member diameter cannot be directly measured in a Rope-lay conductor, the outside diameter of the Rope-lay conductor is measured and member outside diameter is calculated using the following formula:

$$D_1 = \sqrt{\frac{D^2}{n}}$$

where:

D1 = The calculated outside diameter of the member (mm)

D = The outside diameter of a Rope-lay conductor (mm)

N = The number of members

3.2 Cross-sectional area by mass (weight) method

3.2.1 Scope

This test establishes the method for determining the cross-sectional area of a conductor by the mass (weight) method.

3.2.2 Apparatus

The apparatus shall consist of the following:

a) a balance accurate to 0.1% of mass measured; and

b) a length-measuring device accurate to 0.1% of length measured.

3.2.3 Preparation of specimens

The specimen shall be taken from a sample of wire, cable or cord, finished or during manufacture, and shall be removed from its surrounding insulation or coverings (when present) and straightened, with care being taken not to stretch it.

3.2.4 Procedure

3.2.4.1 The test specimen shall consist of a straight length of a conductor cut from a sample of the wire, cable, or cord, finished or during manufacture. The length of specimen shall be a minimum of 1 m (3 ft) for up to 8.37 mm^2 (8 AWG) and 0.5 m for larger than 8.37 mm^2 (8 AWG).

3.2.4.2 The specimen shall be at ROOM TEMPERATURE and shall have both of its ends perpendicular to the longitudinal axis of the conductor. The specimen shall be weighed and the density of conductor material shall be used to calculate the cross-sectional area.

3.2.5 Results and calculations

3.2.5.1

$$\text{Area} = \frac{(1000/L)(100M)}{\rho\,(100 + k)}\ \text{mm}^2\ (\text{cmil})$$

where

M = mass, g (lb)

L = length, mm (ft)

p = density, g/cm^3 (lb/(cmil•1000 ft))

= for copper, bare or tin, lead, lead-alloy or nickel-coated, 8.89 g/cm^3 (0.003027 lb/(cmil•1000 ft))

= for copper, silver-coated, 8.95 g/cm^3 (0.003049 lb/(cmil•1000 ft))

= for copper-clad aluminum, annealed, 3.32 g/cm^3 (0.001130 lb/(cmil•1000 ft))

= for aluminum, Alloy 1350, 2.70 g/cm^3 (0.000919 lb/(cmil•1000 ft))

= for aluminum, ACM, 2.71 g/cm^3 (0.000924 lb/(cmil•1000 ft))

= for nickel, 8.80 g/cm^3 (0.002996 lb/(cmil•1000 ft))

= for iron, 7.87 g/cm^3 (0.002680 lb/(cmil•1000 ft))

k = increment (increase) of weight in percent due to stranding

= 0 for solid

= 2 for concentric and bunch-stranded

= 3 to 6 for rope-lay-stranded conductors having concentric stranded members (Classes G and H) as follows:

49 wires or less, k = 3

133 wires, k = 4

259 wires, k = 4.5

427 wires, k = 5

over 427 wires, k = 6

= 4 to 7 for rope-lay-stranded conductors having bunch-stranded members (Classes I, K, and M) as follows:

7 by bunch-stranded members, k = 4

19 by bunch-stranded members, k = 5

7 x 7 by bunch-stranded members, k = 6

19 x 7 by bunch-stranded members, k = 7

37 x 7 by bunch-stranded members, k = 7

61 x 7 by bunch-stranded members, k = 7

3.2.5.2 In case of a question regarding area compliance, the actual weight increment due to stranding shall be calculated using the following formula:

$$k = 100\ (m - 1)$$

The value of m shall be calculated as follows:

a) For concentric unit or conductor

$$m_c = \frac{1 + n_1 m_1 + n_2 m_2 + \ldots + n_x m_x}{1 + n_1 + n_2 + \ldots + n_x}$$

where

m_c = ratio increase due to concentric stranding

n_x = number of wires in layer x

$$m_x = \sqrt{1 + \left(\frac{\pi(D - d)}{L}\right)^2}$$

where

m_x = ratio increase due to stranding

D = diameter over the layer

d = diameter of individual wire or component

L = lay length of layer

Note: *Dimensions may be in mm or inches, provided that they are consistent throughout the calculation.*

b) For bunched unit or conductor

$$m_b = \sqrt{1 + \left(\frac{\pi(D - d)}{\sqrt{2}\,L}\right)^2}$$

where

m_b = ratio increase due to bunching

D = diameter over bunched unit

d = diameter of individual wire

L = lay length of bunch

Note: *Dimensions may be in mm or inches, provided that they are consistent throughout the calculation.*

c) For rope-stranded conductors with one roping operation, calculate m_R, based on m_b and m_c above, treating the individual units as if they were solid conductors:

$$m_R = m_u\, m_c \text{ or } m = m_u\, m_b$$

where

m_u = ratio increase due to unitizing (single roping), where m_u is calculated for the single roped assembly in the same way as m_c or m_b, treating each concentric or bunched component as solid

d) For multiple rope-stranded conductors with two roping operations, calculate m_m, based on m_b and m_c above, treating the individual ropes as if they were solid conductors:

$$m_m = m_r\ m_u\ m_c \text{ or } m = m_r\ m_u\ m_b$$

where

m_r = ratio increase due to multiple roping (second roping operation), and is calculated for the multiple rope assembly in the same way as m_u x m_c or m_u x m_b, treating each single rope component as solid

e) For a 19-wire combination round-wire unilay-stranded conductor (this variety of unilay conductor consists of a straight central wire of diameter D, an inner layer of six wires of diameter D with each wire having a LENGTH OF LAY designated as LOL, and an outer layer consisting of six wires of diameter D alternated with six smaller wires having a diameter of 0.732 x D and with all twelve wires of the outer layer having the same LENGTH OF LAY LOL and DIRECTION OF LAY as the six wires of the inner layer), application of the first formula in Item (a) gives

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

where

m_2 = the ratio increase (layer lay factor) for the inner layer

m_3 = the ratio increase for the wires of diameter D in the outer layer

m_4 = the ratio increase for the wires of 0.732 x D in the outer layer

As in item (a)

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

where

n = the lay ratio:

= for the central wire of diameter D, n_1 = infinity

= for the 6 wires of diameter D in the inner layer

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

= for the 6 wires of diameter D in the outer layer

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

= for the 6 wires of diameter 0.732 x D in the outer layer

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

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

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

is

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

Then

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

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

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

and

$$M_{\substack{combo\\uniloy}} = 1 + 42.8422 \times \frac{D^2}{(LOL)^2}$$

and

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

3.3 Cross-sectional area by diameter method

3.3.1 Scope

This test establishes the method for determining the cross-sectional area of any solid or stranded conductor consisting of round conductor or strand only, using diameter measurement(s).

3.3.2 Apparatus

The apparatus shall be as described in 3.1.2.

3.3.3 Preparation of specimens

The preparation of the specimen shall be as described in 3.1.3.

3.3.4 Procedure

The maximum and minimum diameters shall be determined at each end and in the center of the conductor or strand being measured. The diameter shall be the average of six measurements.

3.3.5 Results and calculations

The area of the solid wire shall be calculated as follows:

$$A = \pi d^2/4$$

where

A = cross-sectional area, mm^2

d = diameter, mm

or

$$cma = d^2 \times 10^6$$

where

cma = circular mil area

d = diameter, in

The cross-sectional area of the conductor shall be calculated as the sum of the area(s) of the solid conductor or strand.

3.3.6 Report

The report shall include, as a minimum, the cross-sectional area of the conductor.

3.4 DC resistance

3.4.1 Scope

This test establishes the method for determining the DC resistance of a conductor.

3.4.2 Apparatus

The apparatus shall consist of the following:

a) a 4-terminal measuring device for specimens of resistance of 1 Ω or less, with an accuracy of ±0.5%;

b) a 4- or 2-terminal measuring device for specimens of resistance greater than 1 Ω, with an accuracy of ±0.5%;

c) a temperature-measuring device with an accuracy of ±1 °C; and

d) a length-measuring device accurate to 0.1% of length measured.

3.4.3 Preparation of specimens

3.4.3.1 The specimen shall be a length taken from a wire, cable, or cord, finished or during manufacture, and shall have the following characteristics:

a) a resistance of at least 0.000 01 Ω (10 μΩ) in the test length between voltage contacts;

b) no surface cracks or defects visible with NORMAL VISION, and substantially free from surface oxide, dirt, and grease; and

c) no joints of splices.

d) a test length of at least 1 m (3.3 ft)

3.4.3.2 The test equipment and the test specimen shall be allowed to come to the same temperature as the surrounding medium.

3.4.4 Procedure

3.4.4.1 The electrical resistance of the conductor shall be determined using the measuring device described in 3.4.2. When a 4-terminal measuring device is used, the distance between each voltage contact and the corresponding current contact shall be at least 4.7 times the diameter of the specimen.

Care shall be taken to keep the magnitude of the current low and to minimize measurement time to avoid a change in resistance.

3.4.4.2 The test temperature, which shall be in the range of 10 – 35°C, shall be recorded at the time the resistance measurement is taken.

3.4.4.3 The length of the specimen under test, between the voltage contact points, shall be recorded.

3.4.5 Results and calculations

3.4.5.1 The resistance of a specimen measured at a temperature other than 20°C (or 25°C), as determined by the product standard, shall be corrected to the resistance at 20°C (or 25°C) by means of the applicable multiplying factor from Table 1.

3.4.5.2 Resistance per unit length (R) of the conductor shall be calculated from the following formula:

$$R = r/L$$

where

R = resistance per unit length of the conductor at 20 °C (or 25 °C), Ω/km

r = measured resistance of specimen corrected to 20 °C (or 25 °C), mΩ

L = length of specimen between voltage contact points, m

3.4.6 Report

The report shall include, as a minimum, DC resistance.

3.5 Physical properties of conductors (tensile strength, elongation at break, and ultimate strength)

3.5.1 Maximum tensile strength and elongation at break

3.5.1.1 Scope

This test establishes the method for determining the maximum tensile strength and the elongation at break, of a solid conductor, a single strand removed from a stranded conductor, or a stranded conductor as a unit.

Note: *The test on a stranded conductor as a unit applies only to 8000 Series aluminum alloy conductors.*

3.5.1.2 Apparatus

The apparatus shall consist of the following:

a) a power-driven machine provided with a device that indicates the actual maximum load at which a specimen breaks. The machine shall be capable of operating at power-actuated jaw speeds of 12 to 305 mm/min (0.5 to 12 in/min) and having a precision of 20% of the set speed. The applied tension as indicated shall be accurate to 2 percent or less of the value read; and

Note 1: *A method for calibrating the machine is specified in ASTM D412***.**

Note 2: *Jaws as described in ASTM E8 have been found to be acceptable.*

b) a length-measuring device with an accuracy of 1% of the length measured.

3.5.1.3 Preparation of specimens

The test shall be made on a single wire that has been carefully removed from the cable or cord, finished or during manufacture, while not altering the properties of the test specimen. The specimen shall be carefully straightened and cut to a length sufficient to allow a space of approximately 0.3 m (12 in) between the jaws of the tensile testing machine when the specimen is in the initial test position. The straight specimen shall be gauge marked at two points 250 ±2 mm (10 ±0.08 in) apart.

3.5.1.4 Procedure

The specimen shall be gripped in the jaws of the machine with the gauge marks between the jaws, and the jaws shall be caused to separate at the rate indicated in Table 2 until the specimen breaks. In order to be accepted as valid, the break shall take place between the gauge marks and shall be no closer than 25 mm (1 in) to either gauge mark. The maximum load before break shall be recorded. The distance between the gauge marks at the time of break shall be recorded to the nearest 2 mm (0.08 in).

3.5.1.5 Results and calculations

The tensile strength shall be calculated from the following formula using the original specimen diameter d, measured as described in 3.1:

$$\frac{4W}{\pi d^2} \text{ MPa}(\text{lbf/in}^2)$$

where

W = maximum load before break, N (lb)

d = diameter, mm (in)

The percent elongation shall be calculated from the following formula:

$$\frac{L-250}{250} X100$$

where

L = distance between gauge marks at the time of break, mm

or

$$\frac{L-10}{10} X100$$

where

L = distance between gauge marks at the time of break, in

3.5.1.6 Report

The report shall include, as a minimum, the following:

a) maximum tensile strength; and

b) elongation at break.

3.5.2 Ultimate strength

3.5.2.1 Scope

This test determines the load at which any component of an aluminum conductor steel reinforced (ACSR) conductor breaks.

3.5.2.2 Apparatus

The apparatus shall consist of the following:

a) a power-driven machine provided with a device that indicates the actual maximum load at which a specimen breaks. The machine shall be capable of operating at power-actuated jaw speeds of 12 to 305 mm/min (0.5 to 12 in/min) and having a precision of 20% of the set speed. The applied tension as indicated shall be accurate to 2 percent or less of the value read; and

b) compression type or other suitable connectors.

3.5.2.3 Preparation of specimens

3.5.2.3.1 The test shall be made on a finished ACSR conductor, with the insulation, if any, removed.

3.5.2.3.2 The connectors shall be applied to a length of finished conductor so that there is a distance of 1.2 m (48 in) between the connectors. If a failure occurs, as indicated in the product standard, a referee test shall be conducted using a minimum distance of 15 m (50 ft) between the connectors.

3.5.2.4 Preparation of specimens

The connectors shall be gripped in the jaws of the machine and the specimen shall be pulled at a rate of 12 ±2 mm/min (0.5 ±0.1 in/min) until breakage of any wire occurs.

3.5.2.5 Results and calculations

The maximum load shall be recorded.

3.5.2.6 Report

The report shall include, as a minimum, maximum load.

3.5.3 Bending fatigue

3.5.3.1 Scope

This test determines the resistance to bending fatigue of a solid conductor.

3.5.3.2 Apparatus

The apparatus shall consist of the following:

a) a clamping device;

b) a metal plate for bending the specimen; and

c) two metal mandrels each having a diameter equal to that of the specimen +0, −10%, fixed to the clamping device, as shown in Figure 1.

3.5.3.3 Preparation of specimen

All coverings shall be removed from the specimen. The specimen shall be straightened, then secured firmly in the clamping device with a minimum of 150 mm (6 in) protruding above the mandrels.

3.5.3.4 Procedure

3.5.3.4.1 Using the metal plate, the specimen shall be bent over one mandrel to an angle of 90°, straightened, then bent in the reverse direction over the other mandrel to an angle of 90°, and again straightened. This shall be considered one cycle.

3.5.3.4.2 The procedure in 3.5.3.4.1 shall be repeated until the specimen breaks.

Note: *The metal plate is used to ensure that the specimen conforms closely to the surface of the mandrel.*

3.5.3.5 Results and calculations

The number of completed cycles, including partial cycles, shall be recorded.

3.5.3.6 Report

The report shall include, as a minimum, the number of completed cycles, including partial cycles.

3.6 High-current heat cycling for aluminum conductors

3.6.1 Scope

This test establishes the method for determining the connectivity of solid aluminum conductors.

3.6.2 Apparatus

The apparatus shall be in accordance with Figures 2 and 3, and shall consist of 15 test jigs (duplex receptacle terminals) having the following characteristics:

a) One terminal baseplate, as shown in Figure 4, shall be made out of 0.76 ±0.03 mm (0.030 ±0.001 in) 70/30 ASTM sheet brass, Rockwell B 82-86 hardness.

b) Screws shall be made of AISI* 1010 carbon steel and located at 21.4 mm (0.84 in) centers. See Figure 5 for screw description.

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Note: *Carbon steel in compliance with ASTM Standard A29 is recommended.*

c) The other terminal baseplate (neutral side) shall be the same as described in Item (a) but, in addition, shall have immersion tin plating of less than 0.003 mm (0.0001 in) thickness.

d) The two binding head screws, size No. 8-32, used on the white terminal baseplate shall be zinc-plated a minimum of 0.003 mm (0.0001 in) thick and have a chromate conversion coating.

e) The other two binding head screws, size No. 8-32, in the yellow side (line) of the jig shall be zinc-plated a minimum of 0.003 mm (0.0001 in) thick and brass-finished.

f) Screws shall be free-running when finger torque is applied until the screwhead engages with the wire.

3.6.3 Preparation of specimens

Thirty-one specimens of insulated solid 3.31 mm^2 (12 AWG) aluminum wire of length 610 to 685 mm (24 to 27 in) shall be prepared for the test.

3.6.4 Procedure

3.6.4.1 The test conductor shall be connected to form a loop under the screwhead. The end of the test conductor to be connected to the device binding screws shall be formed in a plane to have a bend as shown in Figure 3, with the inside diameter of the bend equal to approximately 0.5 mm (0.02 in) more than the nominal diameter of the device terminal screw. The end of the conductor shall not project from under the head of the screw more than 1/2 the diameter of the test conductor.

3.6.4.2 Terminal screws shall be tightened to a torque of 0.68 N•m (6.0 lbf-in) and held for 30 seconds. Jigs shall be connected together at terminal screws A and B by means of a 610 to 685 mm (24 to 27 in) piece of aluminum conductor. Terminal screws C and D of each jig shall be connected by a 610 to 685 mm (24 to 27 in) piece of the conductor. One thermocouple (Type J, 30 AWG iron constantan) shall be cemented or soldered in accordance with Figure 4, attached at the midpoint (on the breakoff tab) of each terminal baseplate between the screws. These jigs shall then be connected to a 40 A, 60 Hz constant current supply and subjected to 50 cycles of operation, with each cycle consisting of 3.5 hours ON and 0.5 hours OFF. Care shall be taken not to disturb the connecting wires after applying the torque.

3.6.4.3 Temperature measurement shall be taken in accordance with the method described in 3.6.4.4 and 3.6.4.5.

3.6.4.4 Temperature measurements at each connection shall be made, starting with the 25th cycle, and at every 25 cycles thereafter for a total of 5 measurements. Measurements shall then be taken every 40 cycles for a total of 3 measurements, and then every 80 cycles for a total of 3 measurements. This will yield 11 measurements in total for each connection.

Note: *The cycle of measurement may vary from that specified to the extent of allowing it to occur during regular working hours.*

3.6.4.5 Connection stability shall be determined by the following criteria:

a) At any point in the test there shall be no temperature rise in excess of 100°C over the ambient temperature.

b) The stability factor (ΔT) shall be determined for each of the 11 data points for each of the connections monitored (the stability factor is defined as the maximum temperature rise of any one data point above the average temperature rise of all 11 data points for a particular connection). The data points are those described in 3.6.4.4.

For each point monitored, the ΔT shall not be greater than 10°C.

3.6.4.6 Where a temperature exceeds 175 °C (1 thermocouple measurement) within the first 50 cycles of test, the result shall not be counted in the overall performance rating. The device shall be removed and replaced by two new test jigs. These shall be inserted into the circuit in such a manner as not to disturb the wire connections or the other test jigs.

3.6.5 Results and calculations

The temperatures measured by all 30 thermocouples shall be recorded at the end of 500 cycles.

3.6.6 Report

The report shall include, as a minimum, temperature measurement on all thermocouples.

3.7 Length of lay

3.7.1 Scope

This test establishes a method for determining the LENGTH OF LAY of any component of a conductor or assembly.

3.7.2 Apparatus

The apparatus shall consist of a length-measuring device accurate to 1 mm (0.04 in).

3.7.3 Preparation of specimens

3.7.3.1 Uncovered components (conductors or assemblies)

A specimen of sufficient length, determined by multiplying the number of complete revolutions to be measured (minimum of 2) plus 2 by the maximum lay length permitted for the component to be measured shall be cut from the sample and straightened. The specimen shall be tightly secured at both ends to a work surface to ensure that the components cannot untwist.

3.7.3.2 Covered components (insulated conductors, jacketed and/or taped assemblies)

A specimen of sufficient length, determined by multiplying the number of complete revolutions to be measured (minimum of 2) plus 2 by the maximum lay length permitted for the component to be measured shall be cut from the sample cable or cord and straightened. The specimen shall be tightly secured at both ends to a work surface to ensure that the components cannot untwist. A longitudinal window shall be cut in the covering(s) in the center portion of the specimen to expose the component to be measured, leaving the remaining covering intact at both ends. The length of the window shall be approximately 25 mm (1 in) longer than twice the specified maximum lay length. The width of the window shall be 180° or less.

Alternatively, the width of the window may be the entire circumference of the specimen. In this case, the window shall be cut prior to securing the specimen to the work surface. The two ends of the specimen shall be secured to the work surface. The radial orientation of the ends of the specimen relative to each other, after securement, shall be the same as prior to specimen preparation.

Example: If the specified maximum lay length is 57 mm (2.25 in), the window shall have the following approximate length:

$$(2 \times 57) + 25 = 139 \text{ mm}$$

or

$$(2 \times 2.25) + 1 = 5.5 \text{ in}$$

3.7.4 Procedure

The distance (D) required for at least two complete revolutions of the component shall be measured along the longitudinal axis of the specimen.

3.7.5 Results and calculations

The lay length shall be calculated as follows:

$$L = D/N$$

where

L = lay length, mm (in)

D = distance, mm (in)

N = number of complete revolutions measured

3.7.6 Report

The report shall include, as a minimum, the LENGTH OF LAY of the component(s).

4 Insulation, overall covering, and jacket materials tests

4.1 Thickness

4.1.1 Scope

The tests in this clause establish methods for determining the minimum thickness at any point, and the average thickness of conductor insulation, extruded overall covering, and jacket materials.

4.1.2 Apparatus

The apparatus shall consist of the following, whichever are applicable:

a) a pin-gauge dial micrometer capable of exerting a force of 0.25 ±0.02 N (0.056 ±0.004 lbf), having a nominal pin diameter of 1 mm (0.04 in) and an anvil having nominal dimensions of 1 mm by 8 mm (0.043 in by 0.312 in), and with a resolution and accuracy of 0.01 mm (0.001 in);

b) a micrometer microscope with a resolution and accuracy of 0.01 mm (0.001 in), except that in the case of referee measurements taken following non-compliance in accordance with 4.1.4.1.3, 4.1.4.2.3 or 4.1.4.2.4, the resolution and accuracy shall be 0.001 mm (0.0001 in);

c) a dial micrometer having flat surfaces on both the anvil and the end of the spindle that exerts a force of 0.10 to 0.83 N (0.022 to 0.187 lbf), both the spindle and anvil having nominal dimensions of:

1) 2 mm by 9.5 mm (0.078 in by 0.375 in), with a resolution and accuracy of 0.01 mm (0.001 in); or

2) 6.4 mm (0.25 in) in diameter with a resolution and accuracy of 0.01 mm (0.001 in);

d) a laser micrometer with a resolution and accuracy of 0.01 mm (0.001 in);

e) for mineral insulated cable, a file for flattening and smoothing the face of specimens; and

f) for mineral insulated cable, a steel gauge wire of a specified diameter.

4.1.3 Preparation of specimens

4.1.3.1 Minimum thickness at any point

4.1.3.1.1 A specimen having a maximum length of 8 mm (0.31 in), but in no case longer than the width of the anvil, shall be cut perpendicular to the longitudinal axis of the cable and removed. Any separators or other components shall be removed from the insulation or jacket under examination. If the jacket or insulation cannot be removed without damage, measurements shall be made using the micrometer microscope method described in 4.1.4.1.2.

4.1.3.1.2 In the case of mineral insulated cable, the face of one end of a specimen 8 mm (0.31 in) in length shall be filed to provide a surface that is flat and smooth. The mineral insulation shall then be removed to a depth of 3 mm (0.12 in) below the end of the sheath without disturbing the original position of the conductor(s).

Note: *The specimen may be cut into segments to fit into the gauge.*

4.1.3.2 Average thickness

4.1.3.2.1 Pin gauge and micrometer microscope methods

A specimen shall be cut and prepared in accordance with 4.1.3.1.

4.1.3.2.2 Difference method

A specimen of any convenient length shall be cut.

4.1.4 Procedure

4.1.4.1 Minimum thickness at any point

4.1.4.1.1 Pin gauge method

The specimen shall be placed on the pin, the movable members of the gauge permitted to come gently to rest on the specimen, and the thickness shall be read. In rotating the specimen, the movable member shall not be in contact with it. The procedure shall be repeated until the minimum thickness is found and recorded.

4.1.4.1.2 Micrometer microscope method

The point of minimum thickness shall be located and the thickness measured.

4.1.4.1.3 Mineral insulated cable

A steel gauge wire of the specified diameter shall be inserted gently between the conductors and sheath, and between adjacent conductors.

4.1.4.1.4 Non-compliance procedures

4.1.4.1.4.1 In case of non-compliance with the specified minimum insulation thickness at any point, a micrometer microscope or other optical instrument according to 4.1.2(b) shall be used to view the clean-cut end of one of the two specimens and to locate the point of minimum thickness.

4.1.4.1.4.2 In case of non-compliance with the specified minimum jacket thickness at any point, a micrometer microscope or other optical instrument according to 4.1.2(b) shall be used to locate and measure the maximum and minimum thicknesses on each of the slices.

4.1.4.2 Average thickness

4.1.4.2.1 Averaging method

The minimum and maximum thickness shall be determined using the procedures described in 4.1.4.1.1 or 4.1.4.1.2. For insulation, measurements shall be made within the irregularities resulting from conductor stranding. For extruded-to-fill jackets, all measurements shall be made within the irregularities resulting from the conductors or other components. If the pin described in 4.1.4.1.1 does not fit within the irregularities, this method is not applicable.

4.1.4.2.2 Difference method

4.1.4.2.2.1 For insulation only, the average thickness shall be determined by determining the diameter over the insulation and the diameter over the uninsulated conductor. The minimum and maximum diameter over the insulation shall be measured at three points spaced no less than 50 mm (2 in) apart along the axis of the specimen and recorded. The average conductor diameter shall be determined in accordance with 3.1. The average thickness of insulation shall be calculated in accordance with 4.1.5.2.2.

4.1.4.2.2.2 For flexible cords only, the average thickness of jacket may be determined by measuring the diameter over the jacket and the diameter over core, including separator, under the jacket. The minimum and maximum diameter over the jacket and the core shall be measured at three points spaced no less than 50 mm (2 in) apart along the axis of the specimen and recorded. The average thickness of jacket shall be calculated in accordance with 4.1.5.2.2.

4.1.4.2.3 Non-compliance procedures – average thickness of insulation of thermoplastic – and thermoset-insulated wires and cable, flexible cord and fixture wire

4.1.4.2.3.1 In case of non-compliance with the specified average insulation thickness requirements, a micrometer microscope or other optical instrument according to 4.1.2(b) shall be used.

4.1.4.2.3.2 Five sections 100 mm (4 in) long shall be cut from the non-compliant sample with one of the five points at the center of each section. Without damaging or stressing the insulation, the conductor and any separator shall be removed and the five tubes of insulation cut in two at their centers. Each cut shall be clean and perpendicular to the longitudinal axis of the tube. This yields ten specimens for measurement, however measurements shall be made on only five specimens – one specimen from each tube.

4.1.4.2.3.3 The clean-cut end of each of the five specimens shall be viewed through the instrument and the maximum and minimum thicknesses determined. In the case of stranded conductors, it is appropriate for the average insulation thickness to be 0.08 mm (3 mils) less than the specified average insulation thickness.

4.1.4.2.4 Non-compliance procedures – average thickness of jacket on flexible cord, fixture wire and elevator cable

In case of non-compliance with the specified average jacket thickness requirements, referee measurements shall be made by means of an optical device according to 4.1.2(b).

4.1.5 Results and calculations

Results shall be recorded.

4.1.5.1 Minimum thickness at any point

4.1.5.1.1 The minimum thickness shall be as measured in accordance with 4.1.4.1 and recorded. When individual strands are less than 1.09 mm (0.043 in), and the measurement is made using the micrometer microscope method, 0.08 mm (0.003 in) shall be added to the measured value. The addition of the 0.08 mm (0.003 in) to the measured value does not apply to compact or compressed stranded conductors, or where a separator is used over the stranded conductor, or where measuring the thickness of a tape insulation.

4.1.5.1.2 For insulation thickness measurements following non-compliance, the recorded value shall be rounded to the nearest 0.01 mm (0.001 in) and compared with the specified minimum insulation thickness at any point. The results obtained with the optical instrument shall be considered conclusive.

4.1.5.1.3 For jacket thickness measurements following non-compliance, the maximum and minimum thicknesses of each slice shall be recorded to the nearest 0.001 mm (0.0001 in). The smallest of the four measurements shall be rounded to the nearest 0.001 inch (0.01 mm) and compared with the specified minimum jacket thickness. The results obtained with the optical instrument shall be considered conclusive.

4.1.5.2 Average thickness

4.1.5.2.1 Averaging method

The average of the measurements obtained in 4.1.4.2.1 shall constitute the average thickness of the insulation or jacket.

4.1.5.2.2 Difference method

The six overall diameter readings obtained in 4.1.4.2.2 shall be averaged. The average insulation thickness shall be calculated as the difference between the average overall diameter and the diameter over the uninsulated conductor, including the separator, if present, divided by two. The average jacket thickness shall be calculated as the difference between the average diameter over the jacket and the diameter over the core, including the separator, divided by two.

4.1.5.2.3 Measurements in case of non-compliance

4.1.5.2.3.1 For insulation thickness, the maximum and minimum thicknesses of each specimen obtained in accordance with 4.1.4.2.3 shall be recorded to the nearest 0.001 mm (0.0001 in). The average of the ten measurements shall be calculated and rounded to the nearest 0.001 mm (0.0001 in) and compared with the specified average thickness. The results obtained with the optical instrument shall be considered conclusive.

4.1.5.2.3.2 For jacket thickness, the maximum and minimum thicknesses of each slice shall be recorded to the nearest 0.001 mm (0.0001 in). The average of the four measurements shall be calculated, then rounded to the nearest 0.001 mm (0.0001 in) and compared with the specified average jacket thickness. The results obtained with the optical instrument shall be considered conclusive.

4.1.6 Report

The report shall include, as a minimum, the following:

a) minimum thickness at any point; and

b) average thickness.

4.2 Physical properties (ultimate elongation and tensile strength)

4.2.1 Scope

These tests establish methods for determining ultimate elongation and tensile strength of insulation and jacket materials under specified conditions as described in 4.2.8.

4.2.2 Materials and reactants

Fluids as specified in the product standard shall be used.

4.2.3 Apparatus

The apparatus shall consist of the following:

a) a power-driven machine provided with a device that indicates the maximum load reached. The machine shall be capable of separating the grips at speeds of 500 ±25 mm/min (20 ±1 in/min), and also at 50 ±5 mm/min (2 ±0.2 in/min). The applied load as indicated shall be accurate to 2 percent or less of the value read;

b) an extensometer or scale for determining the elongation with a resolution of 2 mm (0.1 in) or better;

c) dies B, C, D, E or F as described in ASTM D412 or NMX-J-178-ANCE. Dies C and D shall be used with 25 mm (1 in) gauge marks. Dies B, E, and F shall be used with 50 mm (2 in) gauge marks. Dies capable of cutting a 6.3 mm or 3.2 mm (0.250 or 0.125 in) wide specimen having parallel sides are permitted. The tolerance on the width between the cutting edges in the parallel portion of the die shall be -0.00, +0.05 mm (-0.000, +0.002 in);

Note: *Tolerances on the remaining portions of the die are not critical.*

d) a caliper with a resolution and accuracy of 0.01 mm (0.001 in);

e) a dial micrometer having a 6.3 to 6.4 mm (0.248 to 0.252 in) diameter flat presser foot exerting a total force of 0.83 ±0.03 N (3.0 ±0.1 ozf) on a rectangular anvil measuring approximately 9 x 2 mm (0.35 x 0.08 in). The face of the anvil on the minor dimension shall be slightly convex. Alternatively, these measurements shall be made with a dead-weight dial micrometer having a presser foot 6.4 ±0.2 mm (0.248 ±0.010 in) in diameter and exerting a total of 85 ±3 gf or 0.83 ±0.03 N (3.0 ±0.1 ozf) on the specimen – the load being applied by means of a weight. The presser foot shall be at least 2 mm (0.08 in) onto the edge of the specimen for each measurement. Micrometers shall have a resolution and accuracy of 0.01 mm (0.001 in);

f) a micrometer with a resolution and accuracy of 0.001 mm (0.0001 in);

g) a heated bath for oil capable of maintaining the specified temperature within ±1°C;

h) weather (sunlight) resistance apparatus as follows:

1) Xenon-arc: Xenon-arc radiation and water-spray exposure equipment shall comply with ASTM G151 and Cycle 1 of the Common Exposure Conditions Table in ASTM G155 or NMX-J-553-ANCE. The specimens shall be mounted in the specimen holders of the equipment. The xenon-arc apparatus shall be provided with a Daylight Filter. The spectral power distribution (SPD) shall conform to the requirements of the Relative Ultraviolet Spectral Power Distribution Specification for Xenon Arc with Daylight Filters Table ~~1~~ of ASTM G155 for a xenon lamp with a Daylight Filter. Operation of the lamp assembly shall maintain a level of spectral irradiance at the specimens of at least 0.35 W/(m^2•nm) monitored at a wavelength of 340 nm.

2) Carbon-arc: The apparatus shall comply with ASTM G151 and ASTM G153 or NMX-J-553-ANCE. The apparatus shall include twin arcs struck between two sets of vertical carbon electrodes that are 13 mm or 1/2 inch in diameter and are individually enclosed in clear globes of heat-resistant optical glass (9200-PX Pyrex glass or its equivalent) that is opaque at wavelengths shorter than 275 nm (1 % transmission at 275 nm as the nominal cutoff point) and whose transmission improves to 91 % at 370 nm. The spectral power distribution of the emission from the globes shall comply with Table 1 of ASTM G153 or NMX-J-553-ANCE;

i) a forced air-circulating oven. The apparatus for the air-oven aging of specimens shall be as indicated in NMX-J-417-ANCE or ASTM D5423 (Type II ovens) and ASTM D5374 and shall circulate the air within the aging chamber at high velocity. Fresh air is to be admitted, continuously, to the chamber to maintain normal oxygen content in the air surrounding the specimens. The exhaust ports of the oven shall be adjusted to achieve 100 to 200 complete fresh-air changes per hour. For purposes of calculating the number of fresh air changes the volume of the oven shall be based on the interior dimensions of the oven. The blower, fan, or other means for circulating the air shall be located entirely outside the aging chamber. The oven shall be capable of maintaining the temperature specified in Table 3;

j) a power-driven splitting or skiving machine consisting of an adjustable upper pressure roller, a band knife or a rotary bell knife, and a power-driven feed roller that passes a sample across the knife blade thereby separating or slicing the sample into layers, with no resulting heating of the sample material from which die-cut specimens are to be prepared. The machine shall be used for the following:

1) to produce a strip of insulation from a 13.3 mm^2 (6 AWG) or larger conductor or a strip of jacketing material; and

2) to remove irregularities from samples of insulation, jacket, or the like;

k) a power-driven buffing machine (grinding wheel). The abrasive wheel shall be nominal No. 36 grit (particle size of 0.486 mm (0.019 in). The wheel shall run true and shall not vibrate. The diameter of the wheel is not specified; however, 0.12 – 0.16 m (4.75 – 6.25 in) has been found appropriate. The rotary velocity of the wheel shall be 2500 – 3500 r/min. The diameter and rotary velocity of the wheel shall be selected to give the wheel a peripheral speed (rpm x π x wheel diameter) of 15 to 25 m/s (3000 to 5000 ft/min). The machine shall have a slow feed that applies light pressure and removes very little material at one cut, thereby not overheating the specimen or the wheel;

CAUTION: The maximum wheel diameter and the maximum wheel rpm specified in this item are not to be used together, as this combination will result in a peripheral speed above 25 m/s (5000 ft/min). This applies even for wheels that are marked as being intended for a peripheral speed above 25 m/s (5000 ft/min).

l) a suitable block or draw plane;

m) a balance accurate to 0.1% of mass measured;

n) a length-measuring device accurate to 0.1% of length measured;

o) a hand- or power-driven machine with steel grips may be used for stretching a conductor for the purpose of removing the conductor from the insulation; and

p) a temperature-measuring device with an accuracy of ±1°C.

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

4.2.4 Preparation of specimens

4.2.4.1 Sample selection and number of specimens

4.2.4.1.1 Samples shall be taken from a wire, cable or cord, finished or during manufacture, at any time following curing of the compound, where applicable.

4.2.4.1.2 A minimum of six specimens per sample shall be tested ″as received″ and after accelerated aging or liquid immersion. If the specimen breaks outside of the gauge marks or the grips of the mechanical extensometer at a value below that specified as the acceptable minimum, the test results shall be disregarded and the test shall be repeated with another specimen.

4.2.4.2 Forms of specimen

4.2.4.2.1 General

Each specimen shall be in one of the following forms:

a) If insulation, it shall be tubular or die-cut, prepared in accordance with 4.2.4.2.2 or 4.2.4.2.3, if the wire or cable is smaller than 13.3 mm^2 (6 AWG) and has an insulation thickness of 2.5 mm (0.10 in) or less. In all other cases, it shall be die-cut and prepared in accordance with 4.2.4.2.3.

Note: *For tubular specimens, if stranded conductors cannot be removed without damage to the insulation, the insulation may be slit longitudinally and the conductors removed.*

b) If a jacket, it shall be die-cut, prepared in accordance with 4.2.4.2.3. Alternatively, for jackets where the nominal thickness is less than 0.76 mm (0.03 in) or where the overall diameter is not greater than 5.1 mm (0.2 in), the jacket shall be tested in one of the following ways:

1) in its finished tubular form;

2) die-cut without performing the buffing operation when this would reduce the thickness to less than 0.38 mm (0.015 in); or

3) carefully slit longitudinally and tested in its finished form when the specimen cannot be removed in a tubular form without damage and cannot be die-cut due to its physical size.

Where die-cut specimens are required, they shall be prepared before further conditioning as described in 4.2.4.2.3 and 4.2.5.1.3.

4.2.4.2.2 Tubular specimens

A tubular specimen shall be prepared from a sufficient length of wire, cable, or cord, finished or during manufacture, less any coverings. The conductor shall be removed. Methods for removing the conductor are described in Annex A.

4.2.4.2.3 Die-cut specimens

A die-cut specimen shall be prepared from a sufficient length of sample, less any coverings, as follows:

a) The sample shall be slit longitudinally and removed from the underlying component. The separator or strand shield, if any, shall be removed.

b) The internal and external irregularities shall be removed using the apparatus described in 4.2.3, items j), k), or l), whichever is best suited for the material, to provide a smooth specimen of uniform thickness. The thickness shall not be reduced by more than 50% except for specimens with an as-received thickness of 5 mm (0.2 in) or more. Adhering insulation shall be removed from a jacket sample. Adhering jacket shall be removed from an insulation sample.

Note: *For rigid or hard specimens, which cannot be flattened in preparation for skiving or buffing, the specimens may be immersed in warm water at a temperature set below 60°C for several minutes to make the material pliable. After water immersion and removal from the water, all surface moisture should be blotted from the surface of the specimens by means of a clean, absorbent cloth that is free of lint.*

c) After allowing the sample to rest for at least 30 minutes, the specimen shall be cut from the smoothed section using one of the dies specified in 4.2.3(c). The use of a press for operating the cutting die is recommended. The sample shall be placed on a smooth surface of wood or another material that will not damage the cutting edges of the die. The cross-sectional area of the center constricted portion of a die-cut specimen shall be no greater than 16 mm^2 (0.025 in^2).

4.2.5 Procedure

4.2.5.1 Determination of cross-sectional area

4.2.5.1.1 Tubular specimens

The cross-sectional area shall be calculated from the following formula:

$$A = \frac{\pi}{4}\left(D^2 - d^2\right)$$

where

A = cross-sectional area, mm^2 (in^2)

D = the lowest average of maximum and minimum diameters over the sample measured at a position midway between the ends of the sample and at positions approximately 25 mm (1 in) on each side of the midposition, mm (in)

d = the highest average of maximum and minimum diameters over the underlying component (including any separator) measured at points approximately 10 mm (0.39 in) from each end of the specimen, mm. In the case of a conductor consisting of very fine strands, it can be difficult to take the measurement as described. In such a case, an annular section of insulation shall be carefully removed as shown in Figure 6; the average conductor diameter may be measured at that location, mm (in)

Note: *For jackets tested in their finished tubular form in accordance with Item b) i) of 4.2.4.2.1: d = the average of wall thickness measurements (measured using an optical micrometer) multiplied by 2, subtracted from D.*

4.2.5.1.2 Parallel, flat or irregularly shaped specimens

The cross-sectional area shall be calculated from the following formula:

$$A = \frac{1000W}{LD}\ mm^2 \text{ or } \frac{W}{LD}\ in^2$$

where

A = cross-sectional area, mm^2 (in^2)

W = mass of the specimen with the conductor(s) removed, g, minimum 5 g (0.011 lb)

L = length of the specimen, mm (in)

D = density of the compound, g/cm^3 (lb/in^3)

Note: *An acceptable method of determining density is described in Annex B.*

4.2.5.1.3 Die-cut specimens

The cross-sectional area shall be determined using the width of the cutting die and the minimum thickness of the smoothed section, to the nearest 0.01 mm (0.001 in), using the dial micrometer as described in 4.2.3(e). The area shall be calculated from the following formula:

$$A = t \times w$$

where

A = cross-sectional area, mm^2 (in^2)

t = minimum thickness of the smoothed section, mm (in)

w = width of the cutting die, mm (in)

4.2.5.2 Ultimate elongation and tensile strength

The elongation and tensile strength tests shall be conducted simultaneously at ROOM TEMPERATURE. The specimen shall be conditioned at ROOM TEMPERATURE for at least 30 minutes prior to testing. Video, laser, or mechanical extensometers or a scale method shall be used to determine elongation. When other than a mechanical extensometer is used, two gauge marks, 25 mm ±2.5 mm (1 in ±0.10 in) apart and equidistant from the center of the specimen, shall be placed on the specimen. These gauge marks shall be at right angles to the direction of pull in the testing machine and as narrow as possible, to facilitate measurement. The specimen shall be completely at rest while being marked. The specimen shall be clamped in position, with the gauge marks between the grips so that the section between the gauge marks is straight but not under tension. The distance between a gauge mark and the adjacent grip shall not exceed 13 mm (0.5 in). The grips shall be separated at a uniform rate until the specimen ruptures. The rate of separation shall be 8.5 mm/s (20 in/min) unless specified otherwise in the product standard. During the separation of the jaws, the distance between the gauge marks shall be measured continuously so that the distance at the instant of rupture can be recorded to within 2 mm (0.1 in). The maximum load before break, W, shall be recorded to the nearest 0.5 N (0.1 lbf). If the specimen breaks outside of the gauge marks or the grips of the mechanical extensometer at a value below that specified as the acceptable minimum, the test results shall be disregarded and the test shall be repeated with another specimen.

4.2.6 Results and calculations

4.2.6.1 General

The average ultimate elongation and tensile strength shall be based on the first five acceptable tests as defined in 4.2.4.1.

4.2.6.2 Ultimate elongation

The percentage elongation shall be calculated from the following formula:

$$\frac{L_2 - L_1}{L_1} \times 100$$

where

L_2 = spacing between gauge marks or grips of mechanical extensometer at rupture, mm (in)

L_1 = initial spacing between gauge marks or grips of mechanical extensometer, mm (in)

4.2.6.3 Tensile strength

The tensile strength shall be calculated from the following formula:

$$TS = W/A$$

where

TS = tensile strength, MPa (lbf/in^2)

W = maximum load before break, N (lbf)

A = cross-sectional area, mm^2 (in^2)

4.2.7 Report

The report shall include, as a minimum, the following:

a) type of exposure;

b) average values for aged and unaged specimens; and

c) average retention values.

4.2.8 Conditioning of specimens

4.2.8.1 As-received (unaged) specimens

The apparatus and procedure outlined in 4.2.3 – 4.2.6 shall apply to determinations of tensile strength and elongation of insulation, jacket, and similar coverings when tested in the as-received condition.

4.2.8.2 Short-term air-oven aging

4.2.8.2.1 Prior to air-oven aging, measurements necessary for the calculation of cross-sectional area shall be made. The specimens shall be suspended within the appropriate test chamber described in 4.2.3, so that they will not come in contact with one another or with the sides of the chamber. Specimens having widely different properties or composition shall be aged in separate test chambers. The specimens shall be heated at the specified temperature for the specified period of time. Oven temperatures shall be recorded throughout the period of aging. Following air oven aging, the specimens shall be removed from the oven and allowed to rest for 16 to 96 hours at ROOM TEMPERATURE.

4.2.8.2.2 Ultimate elongation and tensile strength shall be determined using the apparatus and procedure outlined in 4.2.3 – 4.2.6. Gauge marks shall be applied after the conditioning.

4.2.8.3 Oil resistance

4.2.8.3.1 Prior to the oil resistance test, the gauge marks shall be applied and measurements necessary for the calculation of cross-sectional area shall be made. The immersion vessel shall have a minimum volume of 100 ml (6 in^3). The vessel shall be filled with a specified oil and then placed in a bath or oven as described in 4.2.3. Specimens shall be suspended in the vessel and maintained at the specified temperature and time. Care shall be taken to minimize contact with the walls of the vessel or other specimens. Oil shall not be allowed to get inside a tubular specimen of insulation. In the case of a jacket, both surfaces (inside and out) shall be exposed to the oil.

4.2.8.3.2 Following immersion, the specimens shall be blotted to remove excess oil, and allowed to rest for 16 to 96 hours at ROOM TEMPERATURE.

4.2.8.3.3 Ultimate elongation and tensile strength shall be determined using the apparatus and procedure outlined in 4.2.3 – 4.2.6. Gauge marks shall be applied before the conditioning.

4.2.8.4 Gasoline resistance

4.2.8.4.1 The immersion vessel shall have a minimum volume of 100 ml (6 in^3). The bottom 25 mm (1 in) of the vessel shall be filled with tap water, and the remainder of the vessel filled with equal volumes of iso-octane and toluene maintained at 23 ±1°C.

Note: *See ASTM D471 (Fuel C) for the iso-octane and toluene blend.*

4.2.8.4.2 Specimens shall be suspended in the vessel and maintained at the specified temperature and time. Specimens shall be suspended in the vessel with care taken to minimize contact with the walls of the vessel or other specimens. Fluid shall not be allowed to get inside a tubular specimen of insulation. In the case of a jacket, both surfaces (inside and out) shall be exposed to the fluid.

4.2.8.4.3 Following immersion, the specimens shall be blotted to remove excess fluid, and allowed to rest for 16 to 96 hours at ROOM TEMPERATURE.

4.2.8.4.4 Ultimate elongation and tensile strength shall be determined using the apparatus and procedure outlined in 4.2.3 – 4.2.6. Gauge marks shall be applied after the conditioning.

4.2.8.5 Weather (sunlight) resistance

4.2.8.5.1 Xenon-arc exposure

Samples of finished cable shall be exposed in the xenon-arc apparatus for the specified number of hours, in accordance with the procedure described in NMX-J-553-ANCE or Cycle 1 exposure in ASTM G155, except that the pH of the water shall be 4.5 – 8.0. Each cycle shall consist of 102 minutes of light and 18 minutes of light and water spray. Samples shall be mounted in accordance with the xenon-arc apparatus manufacturer's instructions.

4.2.8.5.2 Carbon-arc exposure

Samples of finished cable shall be exposed in the weathering apparatus for the specified number of hours, in accordance with the procedure described in ASTM G153 or NMX-J-553-ANCE, except that the pH of the water shall be 4.5 – 8.0. Each cycle shall consist of 17 minutes of light and 3 minutes of light and water spray. The carbon arcs shall operate continuously and carry a current of 15 to 17 A each at a drop in rms potential of 120 to 145 V. Samples shall be hung vertically in the drum of the apparatus.

4.2.8.5.3 Specimen preparation and testing

Following either exposure, the samples shall be removed from the test apparatus and retained in still air under conditions of ambient ROOM TEMPERATURE and atmospheric pressure for not less than 16 and not more than 96 hours. Ultimate elongation and tensile strength shall be determined using the apparatus and procedure described in 4.2.3 – 4.2.6. The surfaces exposed to the light source shall not be buffed, skived, or planed away. Gauge marks shall be applied after the conditioning. For comparative purposes, specimens from unaged cable shall be prepared in an identical manner.

4.3 Dry temperature rating of new materials (long-term aging test)

4.3.1 Scope

This test verifies the dry temperature rating of new materials, and establishes short-term air oven aging parameters and requirements.

Note 1: *The long-term aging test evaluates a material for its dry temperature rating only. Other properties are evaluated based on requirements in the applicable wire and cable standard.*

Note 2: *For the product standard, after sufficient experience with a new material has been compiled, the material will be submitted for inclusion in the standard in a timely manner.*

4.3.2 Apparatus

The apparatus shall be as specified in 4.2.3.

4.3.3 Preparation of specimens

4.3.3.1 Specimens shall be prepared as described in 4.2.4.

4.3.3.2 The total number of specimens in the oven shall enable removal of specimens in sets of six at a time, in intervals of 90, 120, and 150 days and, at the manufacturer's request, in additional intervals of 180 and 210 days.

4.3.4 Procedure

4.3.4.1 The specimens shall be aged as described in 4.2.8.2 at the temperature determined in 4.3.4.2.

4.3.4.2 The oven temperature, T_{test}, shall be 102% of the desired temperature rating expressed on the Kelvin scale. This temperature shall be calculated, in °C, using the following formula (T_{test} shall be rounded to the nearest whole number):

$$T_{test}\ (°C) = 1.02 \times (273.15 + T_{rating}\ (°C)) – 273.15$$

Note: *The test temperatures applied for the most common temperature ratings are given in Table 4.*

4.3.4.3 Sets of six specimens shall be removed at the intervals specified in 4.3.3.2.

4.3.4.4 Test specimens in each set shall be tested individually for ultimate elongation and tensile strength as described in 4.2.3 – 4.2.6. The ultimate elongation and tensile values for each set of specimens shall be averaged for each aging time interval. If the results of one or more of the six specimens differ significantly, the results from only one specimen may be discarded.

4.3.5 Results and calculations

4.3.5.1 The ultimate elongation and tensile strength shall be calculated in accordance with 4.2.6.

4.3.5.2 The ultimate elongation or tensile strength at 300 days shall be determined by the following formula:

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

where

$U_{(t)}$ = ultimate elongation, % or tensile strength, MPa (lbf/in^2)

U_{90} = regression constant (ultimate elongation or tensile strength computed at 90 days)

R = decay constant as determined in 4.3.5.4

t = time, days

See Annex C for a sample calculation.

4.3.5.3 The variables in the formula, transformed as $Y = \ln[U_{(t)}]$, $B = \ln[U_{90}]$, and $T = (t – 90)$, convert the formula into linear form $Y = B + RT$.

4.3.5.4 Using the 90 days and longer-term data, the constants B and R shall be determined by least squares linear regression. The projected ultimate elongation or tensile strength at 300 days shall then be calculated using the formula in 4.3.5.2.

4.3.5.5 The ultimate elongation calculated for 300 days shall not be less than 50%. The tensile strength calculated for 300 days shall not be less than 2 MPa (300 lbf/in^2) for insulation intended for use under an overall covering, jacket, or armor and not less than 4 MPa (600 lbf/in^2) for overall coverings, jackets, and for unjacketed insulation.

4.3.5.6 Following the determination of the temperature rating, the parameters and requirements for the short-term air-oven aging test as described in 4.2.8.2 shall be established in accordance with Annex D.

4.3.6 Report

The report shall include, as a minimum the following:

a) verification of the dry temperature rating; and

b) short-term air oven aging parameters and requirements.

4.4 Carbon black content

4.4.1 Scope

This test establishes the methods for determining carbon black content in insulations or jackets.

4.4.2 Apparatus, preparation of specimens, procedures, and results and calculations

For insulations or jackets that do not generate corrosive fumes on pyrolysis, the carbon black content shall be determined in accordance with one of the following methods:

a) Method 1 (In Mexico): NMX-J-437-ANCE or ASTM D4218;

b) Method 2 (In Canada and United States): ASTM D6370 or ASTM E1131

4.4.3 Report

The report shall include, as a minimum, the following:

a) test method used; and

b) carbon black content.

5 Components tests

5.1 Coverage of fibrous braids

5.1.1 Scope

This test establishes the method for determining the degree of coverage of fibrous braids.

5.1.2 Apparatus

The apparatus shall consist of the following:

a) a dial micrometer having flat surfaces on both the anvil and the end of the spindle, that exerts a force of 0.10 to 0.83 N (0.022 to 0.187 lbf), and with a resolution and accuracy of 0.01 mm (0.001 in);

b) a protractor or other appropriate means capable of measuring the lay angle of the braid within 1 degree; and

c) a measuring device capable of measuring ±1 mm (0.04 in).

5.1.3 Preparation of specimens

The specimen shall be a minimum of 1.5 m (5 ft) cut from finished wire, cable, or cord, finished or during manufacture.

5.1.4 Procedure

See F.1 of Annex F.

5.1.5 Results and calculations

See s F.2 and F.3 of Annex F.

5.1.6 Report

The report shall include, as a minimum, percent coverage.

5.2 Coverage of shielding (wraps and braids)

5.2.1 Scope

This test establishes the method for determining the degree of coverage of wraps and braids intended as wire, cable or cord shielding.

5.2.2 Apparatus

The apparatus shall consist of the following:

a) a dial micrometer having flat surfaces on both the anvil and the end of the spindle that exerts a force of 0.10 to 0.83 N (0.022 to 0.187 lbf), and with a resolution and accuracy of 0.01 mm (0.001 in); and

b) a measuring device capable of measuring ±1 mm (0.04 in).

5.2.3 Preparation of specimens

The specimen shall be of any convenient length, cut from wire, cable or cord, finished or during manufacture.

5.2.4 Procedure

See G.1 of Annex G.

5.2.5 Results and calculations

See G.1 of Annex G.

5.2.6 Report

The report shall include, as a minimum, percent coverage.

5.3 Saturation

5.3.1 Scope

This test establishes the method for determining the degree of saturation of a fibrous covering.

5.3.2 Apparatus

The apparatus shall consist of the following:

a) a desiccator containing anhydrous calcium chloride;

b) specified mandrels. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size;

c) a quick-damping balance accurate to 10 mg; and

d) an agitated constant-temperature bath of tap water maintained at a temperature of 21 ±1°C, either fitted with a cover to keep out dust or placed within a tight enclosure during the test.

Note: *The water should be replaced when it becomes dirty or shows the presence of a surface film of dust or wax.*

5.3.3 Preparation of specimens

5.3.3.1 Prior to cutting a test specimen, the wire sample shall attain ROOM TEMPERATURE. Handling and flexing of samples to be tested shall be reduced to the absolute minimum required for conducting the test.

5.3.3.2 A specimen 610 ±6 mm (24 ±0.25 in) in length shall be cut from the wire or cable sample and shall be bent around a mandrel of the specified diameter. For a 33.6 mm^2 (2 AWG) or smaller wire and for a multiple-conductor cable or assembly for which the factor F in the product standard is 2 or 3, the maximum number of complete turns that fit on the mandrel shall be made around the mandrel with the wire tight on the mandrel, adjacent turns 3 to 6 mm (0.125 to 0.25 in) apart, and with a 50 to 60 mm (2 to 2.5 in) straight length at each end of the specimen extending away from the mandrel. For wire sizes larger than 33.6 mm^2 (2 AWG) and for a multiple-conductor cable or assembly for which the factor F is 4.5, 6, 9, or 10, a half turn shall be made around the mandrel.

5.3.4 Procedure

5.3.4.1 The specimen shall be removed from the mandrel without disturbing its form and shall be placed in the desiccator over anhydrous calcium chloride at ROOM TEMPERATURE for at least 18 hours. It shall then be removed from the desiccator and weighed to the nearest 10 mg. The weight shall be recorded as W.

5.3.4.2 The specimen shall then be immersed in the tap-water bath, with 25 ±3 mm (1 ±0.125 in) of each end of the coil (or the 180° bend) projecting above the surface of the water. After 24 hours of immersion, the specimen shall be removed from the bath, shaken vigorously for 5 s to remove adherent moisture and weighed again 2 minutes after removal from the bath. This weight shall be recorded as W_1. All fibrous coverings other than tape shall then be removed from the full length of the specimen. The conductor(s), insulation, and any tape shall then be weighed. In the case of an assembly for use in armored cable, any overall fibrous covering and any fibrous covering on the individual wires shall be taken together in one test, and a second test shall be made on only the fibrous covering on the individual wires. This weight shall be recorded as W_2.

5.3.5 Results and calculations

The moisture absorbed by the specimen shall not be adjusted for the portion of the specimen projecting above the water. The percentage of absorption shall be calculated (to 0.1 percent) by means of the following formula:

$$\frac{100(W_1 - W)}{W - W_2}$$

5.3.6 Report

The report shall include, as a minimum, percentage of absorption.

6 Electrical tests for finished wire and cable

6.1 Continuity

6.1.1 Scope

This test establishes the methods for determining the continuity of conductors.

6.1.2 Apparatus

6.1.2.1 Method 1 (general)

The apparatus shall consist of the following:

a) equipment that provides an ac or dc voltage equal to or less than 120 V; and

b) a means of indicating an unbroken circuit (e.g., an incandescent lamp, a bell, or a buzzer).

6.1.2.2 Method 2 (eddy current)

The apparatus shall consist of equipment that applies current at one or several frequencies in the range of 1 to 125 kHz to an induction coil for the purpose of inducing eddy currents in the conductor moving through the coil at production speed. The equipment shall detect the variation in impedance of the test coil caused by each break in the conductor and provide a visual indication to the operator.

6.1.3 Preparation of specimens

No specific preparation is required.

6.1.4 Procedure

6.1.4.1 Method 1 (general)

Each of the individual conductors of the wire or cable shall be connected in series with the indicator and an ac or dc source of voltage equal to or less than 120 V.

6.1.4.2 Method 2 (eddy current)

The longitudinal axis of the conductor shall be coincident with the electrical center of the test coil. The wire or cable shall have little or no vibration as it passes through the test coil and shall clear the coil by a distance that is not greater than 13 mm (0.5 in). Variations in the speed of the wire through the test coil shall be limited to plus 50% and minus whatever percentage (50% maximum) keeps the signal amplitude from falling below the level at which a break can be detected. Each time there is a change in the wire or cable construction being tested, separate calibration, balance, and adjustments for wire speed, sensitivity, maximum signal-to-noise ratio, and maximum rejection of signals indicating gradual variations in diameter and other slow changes shall be made for each size, type of stranding, and conductor material. Calibration without any wire in the test coil shall be made at least daily to check whether the equipment is functioning.

Note: *The temperature along the length of the wire being tested may vary from the temperature at which the equipment was calibrated, balanced, and so forth for the size, type of stranding, and conductor material, provided that the variations are gradual and are without hot or cold spots that cause false signals.*

6.1.5 Results and calculations

Operation of the equipment indicator shall be evidence of continuity of the conductor under test.

6.1.6 Report

No report is required.

6.2 Dielectric voltage-withstand

6.2.1 Scope

This test establishes the methods for determining the dielectric voltage-withstand of a wire or cable.

6.2.2 Apparatus

The apparatus shall consist of the following:

a) an isolation transformer capable of supplying a test potential of 48 to 62 Hz, whose output potential is continuously variable from near zero to at least the specified rms test potential;

b) a voltmeter having an accuracy of ±5%, on the high voltage side of the transformer. If analog, it shall have a response time that does not introduce a lagging error greater than 1% of full scale at the specified rate of increase in voltage;

c) a fault current indicator;

d) a forced-air oven as described in 4.2.3(i), having insulated bushings for connection of the test voltage while the oven is closed;

e) a temperature-measuring device with an accuracy of ±1°C;

f) a tank filled with tap water; and

g) a means of grounding, maximum impedance of 15 Ω.

6.2.3 Preparation of specimens

6.2.3.1 Method 1 (in water)

6.2.3.1.1 Both ends of the individual conductors shall be made bare.

6.2.3.1.2 In preparing the wire for test, each end of the specimen shall be brought out well above the water level in the tank, where applicable, and the covering removed from the surface of the insulation for a short distance if necessary to prevent surface leakage. The temperature of the water in which the specimen is immersed need not be controlled unless specified in the product standard.

6.2.3.1.3 Unless specifically required by the product standard, a shielded or metal-covered single-conductor specimen need not be immersed in water, the test voltage being applied between the conductor and the shield or metal covering.

6.2.3.1.4 Unless specifically required by the product standard, a multiconductor cable need not be immersed in water, the test voltage being applied between each conductor and the electrode, consisting of all other conductors connected together and to all shields and metal coverings, as applicable.

6.2.3.1.5 In all cases, the ends of the conductor of the specimen shall be spaced from the grounded electrode a sufficient distance to prevent corona or flashover at the ends during application of the test voltage.

6.2.3.2 Method 2 (in air)

6.2.3.2.1 Both ends of the individual conductors shall be made bare.

6.2.3.2.2 For a single-conductor cable, a grounding electrode, when not present as a component, shall be applied. A snug-fitting close-weave copper braid, a metallic tape, or graphite have been found to be acceptable.

6.2.3.3 Method 3 (in air at elevated temperature)

6.2.3.3.1 Both ends of the individual conductors shall be made bare.

6.2.3.3.2 For a single-conductor cable, a grounding electrode, when not present as a component, shall be applied. A snug-fitting close-weave copper braid, a metallic tape, or graphite have been found to be acceptable.

6.2.4 Procedure

6.2.4.1 Method 1 (in water)

The wire or cable shall be immersed in water, except for the ends, for the specified period, prior to application of the test voltage. For a single-conductor cable, or an assembly of single-conductor cables without an overall covering, the test voltage shall be applied between the insulated conductor(s) and the grounded water electrode. The test voltage shall be reached within a period of 10 to 60 s and increased at a rate not exceeding 500 V/s. For multiple-conductor cables with an overall jacket, the test voltage shall be applied between each insulated conductor and all other conductors, all other metallic components where present, and the grounded water electrode. In all cases, the ends of the conductor under test shall be separated from the grounded electrode a sufficient distance to prevent corona or flashover at the ends during application of the test voltage.

6.2.4.2 Method 2 (in air)

For a single-conductor cable, the test voltage shall be applied between the insulated conductor in the wire or cable and the grounded electrode. For multiple-conductor cables, the test voltage shall be applied between each insulated conductor and all other conductors, all other metallic components where present, and the grounded electrode. The test voltage shall be reached within a period of 10 to 60 s and increased at a rate not exceeding 500 V/s. In all cases, the ends of the conductor under test shall be separated from the grounded electrode a sufficient distance to prevent corona or flashover at the ends during application of the test voltage.

6.2.4.3 Method 3 (in air at elevated temperature)

The specimen shall be placed in the oven for the specified time and at the specified temperature. The test shall be performed as described in 6.2.4.2, while maintained at the specified temperature.

6.2.5 Results and calculations

Triggering of the fault indicator shall be evidence of failure.

6.2.6 Report

The report shall include, as a minimum, the following:

a) test voltage;

b) test duration;

c) test temperature; and

d) test result.

6.3 Dielectric breakdown

6.3.1 Scope

This test specifies the method for determining the voltage at which electrical breakdown of a wire or cable occurs.

6.3.2 Apparatus

The apparatus shall consist of the following:

a) an isolation transformer capable of supplying a test potential of 48 to 62 Hz, whose output potential is continuously variable from near zero to the breakdown voltage;

b) a voltmeter having an accuracy of ±5%, on the high voltage side of the transformer. If analog, it shall have a response time that does not introduce a lagging error greater than 1% of full scale at the specified rate of increase in voltage;

c) a fault current indicator;

d) a tank filled with tap water; and

e) a means of grounding, with a maximum impedance of 15 Ω.

6.3.3 Preparation of specimens

6.3.3.1 Both ends of the conductor shall be made bare.

6.3.3.2 In preparing the wire for test, each end of the specimen shall be brought out well above the water level in the tank to prevent surface leakage. The temperature of the water in which the specimen is immersed need not be controlled unless specified in the product standard.

6.3.4 Procedure

The wire or cable shall be immersed in water, except for the ends, for the specified time period. The test voltage shall be applied between the insulated conductor and the grounded water electrode, and shall be increased at a rate not exceeding 500 V/s until breakdown occurs. The ends of the conductor under test shall be separated from the grounded electrode a sufficient distance to prevent corona or flashover at the ends during application of the test voltage.

6.3.5 Results and calculations

Triggering of the fault indicator shall be evidence of failure.

6.3.6 Report

The report shall include, as a minimum, breakdown voltage.

6.4 Insulation resistance

6.4.1 Scope

This test specifies the method for determining the resistance of conductor insulation.

6.4.2 Apparatus

The apparatus shall consist of the following:

a) a megohmmeter or megohm bridge of applicable range, capable of presenting readings that are accurate to 10% or less of the value indicated by the meter, and applying a dc potential of 100 to 500 V to the insulation for 60 seconds prior to each reading;

b) a sinusoidal or nearly sinusoidal ac source capable of supplying the required test potential at 48 to 62 Hz;

c) a tank filled with tap water, having a temperature controller capable of maintaining the water at the required temperature ±1°C; if metal, the tank shall be grounded or, if nonmetallic, it shall contain a grounded electrode;

d) a temperature-measuring device with an accuracy of ±1°C; and

e) a forced-circulation air oven in accordance with 4.2.3(i), having insulated bushings for connecting the specimen to the IR-measuring apparatus while the oven is closed.

6.4.3 Preparation of specimens

Specimens shall be prepared in accordance with 6.2.3 as applicable.

6.4.4 Procedure

6.4.4.1 Short-term insulation resistance

6.4.4.1.1 Method 1 (15°C in water)

6.4.4.1.1.1 When determining insulation resistance at a temperature of 15°C, the test shall be performed with water at any temperature from 10 to 35°C. The specimen shall be immersed in the water for the specified time. The water temperature variation shall remain within ±1°C for at least 30 minutes immediately prior to the test.

6.4.4.1.1.2 The megohmmeter or megohm bridge shall be connected to the specimen and the measurement made in accordance with the instrument manufacturer's instructions. The insulation resistance of the specimen shall be read after a 60 second application of a dc voltage of 100 to 500 V between the conductor and ground.

6.4.4.1.1.3 The megohmmeter or megohm bridge reading, length of specimen, and the water temperature shall be recorded.

6.4.4.1.1.4 A retest at 15 ±1°C shall be conducted for a specimen that does not show complying test results when the water temperature is at a different temperature.

6.4.4.1.1.5 Where specimens are connected together for the insulation-resistance test and complying results are not obtained, the individual specimens shall be retested to determine which ones have insulation resistances that comply.

6.4.4.1.2 Method 2 (15°C in air)

6.4.4.1.2.1 When determining insulation resistance at a temperature of 15°C, the test shall be performed at any air temperature from 10 to 35°C. The specimen shall be conditioned in the test environment for a minimum of 6 hours prior to testing. The air temperature variation shall remain within ±1°C for at least 30 minutes immediately prior to the test.

6.4.4.1.2.2 The megohmmeter or megohm bridge shall be connected to the specimen and the measurement made in accordance with the instrument manufacturer's instructions. The insulation resistance of the specimen shall be read after a 60 second application of a dc voltage of 100 to 500 V between the conductor and ground.

6.4.4.1.2.3 The megohmmeter or megohm bridge reading, length of specimen, and the air temperature shall be recorded.

6.4.4.1.2.4 A retest at 15 ±1°C shall be conducted for a specimen that does not show complying test results when the air temperature is at a different temperature.

6.4.4.1.2.5 Where specimens are connected together for the insulation-resistance test and complying results are not obtained, the individual specimens shall be retested to determine which ones have insulation resistances that comply.

6.4.4.2 Long-term insulation resistance

6.4.4.2.1 Method 1 (in water)

6.4.4.2.1.1 When determining insulation resistance at other than 15°C (e.g., 50°C, 75°C, 90°C), the test shall be performed with the tap water at the specified temperature ±1°C, which shall be maintained together with the specimen for the time and at the specified electrical potential. The potential shall be applied to the insulation at all times other than while readings of insulation resistance are being taken. The test shall be performed on 2 or more specimens each having the center 15 m (50 ft) immersed in the tap water, and sufficient additional length available at each end of the specimen outside the water for connection to the voltage source.

6.4.4.2.1.2 The megohmmeter or megohm bridge shall be connected to the specimen and the measurement made in accordance with the instrument manufacturer's instructions. The insulation resistance of the specimen shall be read after a 60 seconds application of a dc voltage of 100 to 500 V between the conductor and ground. The readings shall be taken at 24 hours, 7 days, and every 7 days thereafter for the duration of the test.

6.4.4.2.1.3 The megohmmeter or megohm bridge readings, number and length of specimens, and the water temperature shall be recorded.

6.4.4.2.2 Method 2 (in air at elevated temperature)

6.4.4.2.2.1 When determining insulation resistance, the test shall be performed at the specified temperature ±1°C, which shall be maintained together with the specimen for the time and at the specified electrical potential. The potential shall be applied to the insulation at all times other than while readings of insulation resistance are being taken. The test shall be performed on 2 or more specimens 15 m (50 ft) in length, with sufficient additional length available at each end of the specimen for connection to the voltage source.

6.4.4.2.2.2 The megohmmeter or megohm bridge shall be connected to the specimen and the measurement made in accordance with the instrument manufacturer's instructions. The insulation resistance of the specimen shall be read after a 60 second application of a dc voltage of 100 to 500 V between the conductor and ground. The readings shall be taken at 24 hours, 7 days, and every 7 days thereafter for the duration of the test.

6.4.5 Results and calculations

The insulation resistance (IR) of each specimen shall be calculated as follows:

$$IR = LR_SF$$

where

IR = calculated insulation resistance, GΩ•m

L = length of test specimen, m

R_S = measured insulation resistance of the test specimen, GΩ

F = temperature correction factor where applicable (see Annex E)

or

$$IR = (L/1000)R_SF$$

where

IR = calculated insulation resistance, MΩ•1000 ft

L = length of test specimen, ft;

R_S = measured insulation resistance of the test specimen, MΩ;

F = temperature correction factor where applicable (see Annex E)

The insulation resistance (IR) shall be the averaged results of the specimens tested.

Note: *Temperature correction factor "F" is not applicable to 6.4.4.2.*

6.4.6 Report

The report shall include, as a minimum, the following:

a) test temperature; and

b) insulation resistance results (temperature corrected as applicable).

6.5 Capacitance and relative permittivity

6.5.1 Scope

This test determines the method for measuring the change in capacitance and relative permittivity of wire or cable insulation.

6.5.2 Apparatus

The apparatus shall consist of the following:

a) a capacitance bridge capable of operating at a sinusoidal or nearly sinusoidal voltage at a frequency of 1000 Hz at 10 V or less, or 60 Hz at 3.15 kV/ mm (80 V/mil) of insulation thickness;

b) a water tank capable of maintaining the water at the required temperature; and

c) a temperature-measuring device with an accuracy of ±1°C.

6.5.3 Preparation of specimens

Any coverings over the insulation shall be removed. Both ends of a 4.6 – 5 m (15 – 16 ft) specimen shall be made bare.

6.5.4 Procedure

6.5.4.1 The center 3.05 m (10 ft) sections of three specimens shall be immersed in tap water. The remaining length of each end of the specimen shall be kept dry and outside the water for connection to the voltage source. The immersion period shall be 14 days. The water temperature and the depth of immersion of the specimen shall be kept the same whenever readings are taken.

6.5.4.2 The capacitance of the insulation shall be measured and recorded using a voltage at a frequency of 1000 Hz or 60 Hz, by means of a capacitance bridge. When measured at 1000 Hz, the potential impressed upon the insulation shall not exceed 10 V. When measured at 60 Hz, the potential impressed upon the insulation shall result in an average stress of 3.15 kV/mm of insulation or 80 V/mil of insulation.

6.5.5 Results and calculations

The capacitance of the insulation shall be determined as the average from three specimens, after immersion in water for durations of 1 day, 7 days, and 14 days, at the specified temperature. Each result shall be measured to the nearest picofarad. Increases in capacitance from 1 day to 14 days and from 7 days to 14 days shall be expressed as percentages of the 1 day and 7 days values, respectively.

The relative permittivity (dielectric constant) of the insulation shall be determined after 1 day by means of the following formula:

$$\epsilon_r = 41{,}390/L \times C \log_{10} \frac{D}{d}$$

where

ε_r = relative permittivity

L = length of specimen immersed in water, m

C = capacitance in microfarads of the immersed 3050 mm (120 in) portion of the specimen

D = measured diameter over the insulation, mm (in)

d = measured diameter under the insulation, mm (in)

6.5.6 Report

The report shall include, as a minimum, the following:

a) percent change in capacitance from 1 day to 14 days and 7 days to 14 days;

b) frequency and voltage applied;

c) relative permittivity; and

d) water temperature.

6.6 Stability factor

6.6.1 Scope

This test establishes the method for determining the stability factor of insulated conductors.

6.6.2 Apparatus

The apparatus shall consist of the following:

a) a power factor bridge capable of operating at a sinusoidal or nearly sinusoidal voltage at a frequency of 60 Hz at 3.15 kV/mm (80 V/mil) and 1.58 kV/mm (40 V/mil) of insulation thickness;

b) a water tank capable of maintaining the water at the required temperature;

c) a forced-circulation air oven in accordance with 4.2.3(i); and

d) a temperature-measuring device with an accuracy of ±1°C.

6.6.3 Preparation of specimens

Three 4.6 – 5 m (15 – 16 ft) specimens shall be taken from an insulated conductor. Specimens of insulated conductors shall not have a conductor separator and shall be selected before assembly. For thermoset-insulated conductors, specimens shall be selected not less than 48 hours after extrusion, then conditioned at 70.0 ±2.0°C (158.0 ±2.6°F) in air for 24 hours, and cooled at ROOM TEMPERATURE for 1 hour.

6.6.4 Procedure

6.6.4.1 The center 3 m (10 ft) section of each specimen shall be immersed continuously in tap water for 14 days at the specified temperature.

6.6.4.2 The 1 m (3 ft) end portions of each specimen shall be kept dry above the water. A tight-fitting cover for the tank shall be placed directly above the surface of the water. The water level shall be kept constant.

6.6.4.3 The percentage power factor of each specimen shall be measured with 60 Hz current at average stresses of 3.15 and 1.58 kV/mm (80 and 40 V/mil) after 1 day and 14 days total immersion, and each result shall be recorded to the nearest 0.1%.

6.6.5 Results and calculations

6.6.5.1 The stability factor for each specimen shall be the numerical difference between the percentage power factors measured at 3.15 and 1.58 kV/mm (80 and 40 V/mil). The stability factor shall be determined after 1 day, and after 14 days, to the nearest 0.1.

6.6.5.2 The stability-factor difference shall then be determined for each specimen by subtracting the stability factor determined after 1 day from the stability factor determined after 14 days. The stability-factor difference shall be to the nearest 0.1.

6.6.6 Report

The report shall include as a minimum, the following:

a) test voltage;

b) stability factors; and

c) stability factor differences.

6.7 Spark

6.7.1 Scope

This procedure establishes the method for detecting electrical faults in insulations and jackets.

6.7.2 Apparatus

The apparatus shall consist of the following:

a) a transformer having one lead of its high voltage winding grounded and capable of supplying the necessary ac (rms) test voltage within ±5% during the test, while the wire or cable passes through the electrode. The limits of the frequency of the test voltage shall be 50 Hz to 4.0 kHz. A voltage source shall not be connected to more than one electrode;

b) a transformer having one lead of its high voltage winding and the core of the transformer solidly connected to earth ground and capable of supplying the necessary dc voltage within ±5% during the test, while the wire or cable passes through the electrode. The current output shall not exceed 5 mA. After a fault, the dc test voltage shall recover to the specified level in 5 ms or less, unless 610 mm (2 ft) or less of the product travels through the electrode in the time it takes for the full voltage recovery. Any ripple existent shall not exceed 1%. A voltage source shall not be connected to more than one electrode;

c) an electrode that makes contact with the surface of the test specimen. A pipe, coiled spring, or the like shall not be used. Electrodes shall conform to the following:

1) When a link or bead-chain type of electrode is used, the bottom of the metal electrode enclosure shall be V- or U-shaped. The chains shall have a length appreciably greater than the depth of the enclosure, and the width of the trough shall be approximately 40 mm (1.6 in) greater than the diameter of the largest size of wire that will be tested. The beads shall have a diameter of 2 to 5 mm (0.1 to 0.2 in). The longitudinal spacing of the chains shall be not more than 13 mm (0.5 in). The

transverse spacing of the chains shall be not more than 10 mm (0.4 in), except that the spacing shall not be more than 13 mm (0.5 in) if the transverse rows of chain are staggered. See Figure 7.

2) A brush-type or roller-type electrode shall only be used for wide, flat constructions. The electrode shall be as least as wide as the specimen being tested. The brush bristles of brush-type electrodes shall have a length appreciably greater than the distance between the mounting means and shall be closely spaced. The rollers of roller-type electrodes shall be smooth, free of corrosion, and in intimate contact with the specimen.

3) The electrode shall be provided with a grounded metallic screen or the equivalent as a guard against contact by persons.

4) The length of the electrode shall be sufficient to allow application of the voltage for a minimum of 9 full cycles, at the running speed and operating frequency. Electrode length shall be calculated as follows:

$$\text{Electrode length (mm)} = \frac{\text{Maximum running speed (m/min)} \times 150}{\text{Frequency (Hz)}}$$

or

$$\text{Electrode length (in)} = \frac{\text{Maximum running speed (ft/min)} \times 1.80}{\text{Frequency (Hz)}}$$

d) a voltmeter having an accuracy of ±5%, to indicate the actual test voltage being applied to the specimen at any time during the test. The voltmeter shall be visible to the operator when the spark test operation is being performed; and

e) a device for signaling a fault in the specimen and, in addition, a means for recording or marking the location of specimen faults or for stopping the process upon occurrence of a fault. The response time of the device shall result in detecting and/or registering faults spaced no further than 610 mm (2 ft) apart for any product speed.

6.7.3 Preparation of specimens

6.7.3.1 If the conductor coming from the pay-off reel is bare, the conductor shall be earth-grounded prior to the insulating process.

6.7.3.2 If the conductor coming from the pay-off reel is insulated, an earth-ground connection shall be made at either the pay-off or take-up reel. For 5.26 mm^2 (10 AWG) and smaller-sized single-conductor cables, an earth-ground connection shall be made at both the pay-off and the take-up reels unless the conductors have been tested for continuity and found to be of one integral length.

6.7.3.3 For other cable constructions, the outermost conductive components shall be earth-grounded.

6.7.3.4 Each earth-ground connection shall be bonded directly to the earth ground of the spark tester.

6.7.4 Procedure

6.7.4.1 AC test

6.7.4.1.1 The specified voltage shall be applied between the electrode and ground, and the specimen shall be moved through the electrode.

6.7.4.1.2 The maximum speed of the wire shall be determined by the following formula:

$$\text{Maximum speed (m/min)} = (1/150) \times \text{Frequency (Hz)} \times \text{Electrode length (mm)}$$

or

$$\text{Maximum speed (ft/min)} = (5/9) \times \text{Frequency (Hz)} \times \text{Electrode length (in)}$$

6.7.4.2 DC test

6.7.4.2.1 The specified voltage shall be applied between the electrode and ground, and the specimen shall be moved through the electrode.

6.7.4.2.2 The surface of the specimen shall be in contact with the electrode for a distance of 125 ±25 mm (5 ±1 in).

6.7.5 Results and calculations

Any electrical breakdown of the insulation or jacket shall be detected.

6.7.6 Report

The report shall include, as a minimum, the following:

a) test voltage; and

b) number of faults.

6.8 Standard arcing test

6.8.1 Scope

This procedure establishes the method for determining the resistance to arcing when exposed to a specified test flame.

6.8.2 Apparatus

The apparatus shall consist of the following:

a) a voltage source of 120 V ac, having a capacity that enables short-circuiting of the circuit to cause a 15 A fuse or circuit breaker to open;

b) a 15 A fuse or circuit breaker;

c) an indicator connected across the supply to indicate when voltage is being applied to the specimen;

d) a non-conductive table or support;

e) a fume hood or flame test cabinet;

f) a laboratory burner conforming to IEC 60695-11-3 that is suitable for the calorific value of the gas and having an inside diameter of 9.5 ±0.3 mm (0.375 in ±0.01 in) and a length of 100 ±10 mm (4 ±0.4 in) above the primary-air inlets or an equivalent burner that meets the calibration or confirmation practice of IEC 60695-11-3; and

g) a gas supply obtained with one of the following fuel gases (all measured at a normal pressure of 101 kPa):

1) methane, at 98% minimum purity, having a heat content of 37 ±1 MJ/m^3 at 25°C; or

2) natural gas, with a certified heat content of 37 ±1 MJ/m^3 at 25°C.

Note 1: *Alternate fuels, such as propane, at a 96% minimum purity, having a heat content of 94 ±2 MJ/m^3 at 25°C or butane, at 99% minimum purity, having a heat content of 120 ±3 MJ/m^3 at 25°C, may be used if a stable flame is obtained and the heat evolution profile complies with ASTM D5207 or with IEC 60695-11-3.*

Note 2: *The burner used is identified in ISO 10093 as ignition source P/PF2.*

6.8.3 Preparation of specimens

The specimen for test shall be of any suitable length. One end shall be cut off square, care being taken that the conductor ends are flush with the cut end of the specimen. The specimen shall be laid across the table or support, the square cut end protruding approximately 100 mm (4 in) beyond the table edge. The other end shall be prepared so that it can be connected to the voltage source.

6.8.4 Procedure

The test shall be carried out within the fume hood or flame test cabinet. A voltage of 120 V ac shall be connected between the conductors of two-conductor specimen and between the circuit conductors joined together and the grounding conductor of a three-conductor specimen. A steady flame with an overall height of 1-1/2 inches or 38 mm with the temperature at its tip 816°C (1500°F) or higher as measured using a chromel-alumel (nickel-chromium and nickel-manganese-aluminum) thermocouple shall be used. The tip shall be applied to a point on the specimen 13 mm (0.5 in) from the square end for a 2 minute period, or until an arc is struck, whichever is the shorter time.

6.8.5 Results and calculations

The presence of an arc shall be determined.

6.8.6 Report

The report shall include, as a minimum, the following:

a) time to arcing, if any, in seconds; and

b) indication of circuit opening, if any.

6.9 Flex arcing test

6.9.1 Scope

This test establishes the method for determining the resistance to arcing when exposed to flexing.

6.9.2 Apparatus

The apparatus shall consist of the following:

a) a means of flexing the specimen using a flexing cycle consisting of bending the specimen to a position 90 ±5 degrees from the vertical, back through 180 ±5 degrees from that position, and then back to the vertical;

b) a power supply capable of providing 120 ±2 V ac and the current specified;

c) a 120 ±2 V variable electrical resistive load;

d) a bushing with bracket;

e) weights;

f) a 24 ±5 V ac, maximum 200 mA circuit to detect conductor breakage and stop the flexing apparatus; and

g) a bleached cheesecloth running 22.1 – 36.8 m^2/kg (12 to 20 yd^2/lb) and having a count of approximately 24 – 28 by 28 – 32.

6.9.3 Preparation of specimens

6.9.3.1 Specimens 1 m (3 ft) long shall be tested. Specimens shall be flexed until all of the strands in one circuit conductor break. Flat cables shall be flexed edgewise at the bushing, not flatwise. Flexing shall be achieved by

a) clamping the specimen in a flexing machine so that approximately 60 cm (2 ft) of the cord is free to hang from the clamping device (e.g., appropriate strain-relief-type bushing); the weight shall be applied 215 mm (8.5 in) below the clamping device; and

b) applying one of the following weights to the cord, as the specimen hangs from the clamping device on the flexing machine:

Size of conductor mm² (AWG)	Weight, g (lb) ±2%
0.824 (18)	900 (2)
1.04 (17)	1130 (2.5)
1.31 (16)	1360 (3)
1.65 (15)	1585 (3.5)
2.08 (14)	1810 (4)
3.31 (12)	2270 (5)

6.9.3.2 After one circuit conductor breaks, the flexing machine shall stop automatically, and the specimen shall be examined for deterioration of the insulation. If there is evidence of splitting or cracks in the insulation, or of conductor strands protruding through the insulation, such specimens shall be discarded, and the value of the weight reduced as necessary to obtain sufficient specimens that do not exhibit this deterioration.

6.9.4 Procedure

6.9.4.1 Each specimen shall be wrapped closely with four single layers of cheesecloth, approximately 5 cm (2 in) wide, centered over the location of the break in the circuit conductor, and the combination of the specimen and the cheesecloth shall then be clamped by a bushing which is then secured in a sheet metal bracket mounted on a nonconductive base (see Figure 8).

6.9.4.2 The cord shall be positioned in the bushing so that the break in the circuit conductor is located approximately 0.6 cm (0.25 in) from the front face of the bushing. The bushing shall be secured in the bracket so that its axis is in a horizontal position.

6.9.4.3 Both ends of the broken circuit conductor shall be connected to a 120 ±2 V ac circuit in series with a resistive load as indicated in Figure 9.

6.9.4.4 The variable resistor shall be adjusted so that the appropriate current from the following table is flowing through the circuit conductor under test:

Size of conductor, mm² (AWG)	Current flowing in cord, A
0.824 (18)	10 ±0.5
1.04 (17)	13 ±0.5
1.31 (16)	15 ±0.5
1.65 (15)	17 ±0.5
2.08 (14)	20 ±0.5
3.31 (12)	30 ±0.5

6.9.4.5 With the power applied, the specimen shall be gripped approximately 20 cm (8 in) from the break in the circuit conductor. Move the specimen so that the circuit is opened and closed at a rate of 15 to 20 cycles per minute. An opening and closing of the circuit shall be considered one cycle.

6.9.4.6 The circuit shall be opened and closed for 20 cycles. If 20 cycles cannot be completed on a specimen, because the circuit can no longer be opened and closed, that specimen shall be discarded and the procedure repeated on a new specimen.

6.9.4.7 If prior to completion of the 20th cycle there is perforation of the insulation due to arcing, as evidenced by burning or charring of the cheesecloth, the test shall be stopped.

6.9.5 Results and calculations

Observation shall be made of the presence of perforation of the insulation, or the completion of 20 cycles.

6.9.6 Report

The report shall include, as a minimum, the following:

a) number of cycles to perforation, if any; and

b) indication of completion of 20 cycles.

6.10 Jacket resistance

6.10.1 Scope

This test establishes the method for measuring the electrical resistance of a jacket material.

6.10.2 Apparatus

The apparatus shall consist of the following:

a) a megohmmeter or megohm bridge as described in 6.4.2 of applicable range, capable of presenting readings that are accurate to 10% or less of the value indicated by the meter, and applying a dc potential of 500 V to the jacket for 60 seconds prior to each reading;

b) a clean, lint-free absorbent cloth;

c) a hygrometer or other appropriate means of measuring relative humidity; and

d) metal foil strips 13 mm (0.5 in) wide and of sufficient length to encircle the specimen at least once.

6.10.3 Preparation of specimens

A specimen having length of at least 100 mm (4 in) shall be cut from a finished wire or cable and tested at 50 ±20% relative humidity and at ROOM TEMPERATURE. The outer surface of the entire length of the specimen shall be wiped with a soft, clean, lint-free, absorbent cloth. After wiping, there shall be no contact with the center 50 mm (2 in) portion of the specimen. Two strips of metal foil shall then be wrapped snugly around the specimen center, with the strips separated by a distance of 13 ±1 mm (0.5 ±0.040 in). The jacket between the strips shall not be contacted during application of the foil or during the remainder of the test. The foil strips shall be secured and terminated to allow connection to the megohmmeter or megohm bridge.

6.10.4 Procedure

Each of the foil strips shall be connected to a megohmmeter or megohm bridge. The reading shall be taken immediately after 500 V dc has been applied to the specimen for 60 seconds.

6.10.5 Results and calculations

The measured resistance shall be recorded.

6.10.6 Report

The report shall include, as a minimum, measured resistance value.

6.11 AC leakage current test through insulation

6.11.1 Scope

This test establishes the method for measuring the ac leakage current through insulation.

6.11.2 Apparatus

The apparatus shall consist of the following:

a) a 120 V AC power supply, 48 to 62 Hz;

b) a resistor of known value ±1% accuracy;

c) a voltmeter having an accuracy of ±5% or better; and

d) metal foil.

Note: *It is convenient to have a known resistor of* **1000** Ω *and the voltmeter to read in millivolts because, in such case, the meter readings are numerically equal to the current flow in microamperes per* **3 m** *(10 ft)***.**

6.11.3 Preparation of specimens

6.11.3.1 Part 1

A specimen 3 m (10 ft) in length shall be cut from finished wire or cable and formed into a coil of 2 complete turns and placed on a non-conductive surface. One end of the specimen shall be cut flush and perpendicular to its axis, and at the other end, all conductors shall be prepared for electrical connection.

6.11.3.2 Part 2

A specimen 3 m (10 ft) in length shall be cut from finished wire or cable. The entire length shall be straightened and tightly wrapped with metal foil and placed on a non-conductive surface. One end of the specimen shall be cut flush and perpendicular to its axis, and at the other end, the grounding conductor shall be cut off flush with the jacket and the circuit conductors shall be prepared for electrical connection.

6.11.4 Procedure

6.11.4.1 Part 1

The circuit conductors and the grounding conductor of the specimen described in 6.11.3.1 shall be connected to a 120 V ac power supply with the resistor in series. See Figure 10. The voltmeter shall be connected across the resistor. The circuit conductors shall be energized separately and the voltmeter reading recorded for each.

6.11.4.2 Part 2

The circuit conductors of the specimen described in 6.11.3.2 and the metal foil shall be connected to a 120 V ac power supply with the resistor in series. See Figure 11. The voltmeter shall be connected across the resistor. The circuit conductors shall be energized separately and the voltmeter reading recorded for each.

6.11.5 Results and calculations

The leakage current from each circuit conductor of both specimens shall be calculated by dividing the voltmeter reading by the known resistor value.

6.11.6 Report

The report shall include, as a minimum, the following:

a) voltmeter readings from each circuit conductor of each specimen tested;

b) value of known resistor used; and

c) calculated leakage current values for circuit conductors from both specimens.

6.12 AC leakage current test through jacket

6.12.1 General

This test establishes the method for measuring the ac leakage current through jacket.

6.12.2 Apparatus

The apparatus shall consist of the following:

a) A circuit breaker;

b) An isolation transformer capable of supplying a test potential of 48 to 60 Hz, whose output potential is continuously variable from near zero to at least the specified rms test potential;

c) A voltmeter having an accuracy of ±5%, on the high voltage side of the transformer. If analog, it shall have a response time that does not introduce a lagging error greater than 1% of full scale at the specified rate of increase in voltage;

d) Current meter or other means of indicating an rms current of 10 mA flowing in the test circuit; and

e) Metal foil.

6.12.3 Preparation of specimens

A specimen having a length of at least 600 mm (2 ft) shall be cut from a finished wire or cable and tested at 50 ± 20% relative humidity and at ROOM TEMPERATURE and placed on a non-conductive surface. The center 150 mm (6 in) of the outside of the specimen shall be wrapped tightly with the metal foil.

6.12.4 Procedure

An rms potential of 1500V shall be applied between all of the conductors and any shield(s) connected together and the metal foil connected to ground. The applied rms potential shall be increased from near zero at an essentially uniform rate that results in 1500V being applied in 30 seconds. The potential shall be held constant at 1500V for 60 seconds and shall then be reduced to near zero at the rate mentioned above.

6.12.5 Results and calculations

The maximum rms current through the jacket shall be recorded while the test potential is being increased, held or decreased.

6.12.6 Test Report

The report shall include maximum rms current as a minimum:

6.13 Resistance of armor

6.13.1 Scope

This test establishes the method for determining the resistance of the finished armor, including the bonding conductor, of armored and metal-clad cable.

6.13.2 Apparatus

Equipment shall include the following:

a) a V-shaped wooden trough having a cross-sectional area sufficient to contain the specimen and provided with stud-type connectors secured in a metal plate fastened across each end of the trough. The connectors shall be sufficiently large to be secured to the armor of the specimen, and the vertical centerlines of the connectors shall be spaced a distance of 3 m (10 ft.) apart (see Figure 12); and

b) a resistance bridge having a range of 0.001 – 11 Ω and accurate within 2% of the resistance to be read.

6.13.3 Preparation of specimens

A cable specimen approximately 3.5 m (11.5 ft.) in length and with the armor in place shall be placed in the trough, and shall be allowed to lie freely without any tension. The specimen, without kinks or bends, shall be clamped securely in the connectors. In the case of armor having a color coating, no effort shall be made to remove or scrape through the coating before or during the resistance measurement.

6.13.4 Procedure

Connection from the bridge to the specimen shall be made through leads of very low resistance connected to the trough end plates. The resistance of the armor shall then be read directly in ohms.

6.13.5 Results and calculations

The resistance of the armor shall be recorded.

6.13.6 Report

The report shall include, as a minimum, the following:

a) cable description; and

b) resistance reading.

7 Mechanical tests for finished wire and cable

7.1 Fall-in of extruded materials

7.1.1 Scope

This test establishes the method for determining the penetration of extruded material into a stranded conductor.

7.1.2 Apparatus

The apparatus shall consist of a wire brush.

7.1.3 Preparation of specimens

A 75 mm (3 in) length of the insulation shall be stripped from a sample length of the finished stranded conductor, and the outer surface of the conductor shall be cleaned with a wire brush to remove the visible extruded material. The outermost strands shall then be peeled back.

7.1.4 Procedure

Where the outermost strands are peeled back, the conductor shall be examined for the presence of extruded material among the strands, with NORMAL VISION.

7.1.5 Results and calculations

The presence of extruded material among the strands shall be determined.

7.1.6 Report

The report shall include, as a minimum, report of the presence of extruded material, if any.

7.2 Heat shock

7.2.1 Scope

This test establishes the method for determining the ability of wire or cable to withstand thermo-mechanical stress.

7.2.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C;

c) cylindrical mandrels of specified diameters. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size; and

d) a micrometer or micrometer caliper with a resolution and accuracy of 0.01 mm (0.001 in).

7.2.3 Preparation of specimens

The specimen shall be cut to a length sufficient to allow winding around the mandrel for the specified number of turns.

7.2.4 Procedure

7.2.4.1 Each specimen shall be tightly wound around a mandrel having the specified diameter for the specified number of turns. Successive windings shall be in contact with one another, and both ends of the specimen shall be held securely in place.

7.2.4.2 The assembly of the mandrel and specimen shall be placed in the oven for the time and at the specified temperature.

7.2.4.3 After conditioning, the assembly shall be removed from the oven and cooled to ROOM TEMPERATURE, the mandrel removed, and the specimen examined on the outside surface with NORMAL VISION.

7.2.4.4 If circumferential depressions are observed, the specimen shall be split twice longitudinally 180° apart, and the inside surface of the extruded layer shall be examined to determine if internal cracks are present.

7.2.5 Results and calculations

The presence of cracks shall be determined.

7.2.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) indication of cracks.

7.3 Heat shock resistance

7.3.1 Scope

This test establishes the method for determining the ability of wire or cable to withstand thermo-mechanical stress followed by unwinding.

7.3.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C;

c) cylindrical mandrels of specified diameters. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size; and

d) a micrometer or micrometer caliper with a resolution and accuracy of 0.01 mm (0.001 in).

7.3.3 Preparation of specimens

The specimen shall be cut to a length sufficient to allow winding around the mandrel for the specified number of turns.

7.3.4 Procedure

7.3.4.1 Each specimen shall be tightly wound around a mandrel having the specified diameter for the specified number of turns. Successive windings shall be in contact with one another, and both ends of the specimen shall be held securely in place.

7.3.4.2 The assembly of the mandrel and specimen shall be placed in the oven for the time and at the specified temperature.

7.3.4.3 After conditioning, the assembly shall be removed from the oven and cooled to ROOM TEMPERATURE. A dielectric test, when specified, shall be conducted in accordance with 6.2, Method 1. The specimen shall then be unwound from the mandrel and examined on the outside surface with NORMAL VISION.

7.3.4.4 If circumferential depressions are observed, the specimen shall be split twice longitudinally 180° apart, and the inside surface of the extruded layer shall be examined to determine if internal cracks are present.

7.3.5 Results and calculations

The presence of cracks shall be determined.

7.3.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) indication of cracks.

7.4 Shrinkback

7.4.1 Scope

This test establishes the method for determining resistance to longitudinal shrinkage of conductor insulation in water.

7.4.2 Apparatus

The apparatus shall consist of the following:

a) a tank filled with tap water, having a temperature controller capable of maintaining the water at the required temperature ±3°C;

b) a temperature-measuring device with an accuracy of ±1°C; and

c) a micrometer caliper or optical micrometer microscope with a resolution and accuracy of 0.01 mm (0.001 in).

7.4.3 Preparation of specimens

A 5 m (16 ft) length of solid conductor shall be formed into a loose coil of approximately 300 mm (12 in) in diameter. Care shall be taken not to have any kinks or sharp bends throughout the coil.

7.4.4 Procedure

7.4.4.1 The coil shall be immersed in water at 90 ±3°C with 100 to 110 mm (4 to 4.4 in) of each end of the wire supported out of the water. Care shall be taken to minimize contact with the walls of the tank. The ends shall be trimmed flush within 1 minute following immersion.

7.4.4.2 After 24 hours of immersion, the length of conductor exposed at each end shall be measured while the coiled insulated conductor is still immersed in the tank. Measurement of exposed conductor length shall be from the start of the cut caused by the cutting tool to the insulation.

7.4.4.3 If after 24 hours, the exposed conductor length at either end exceeds 3 mm (0.12 in), the test shall be continued for an additional 6 days, and the exposed conductor length at each end of the specimen measured.

7.4.5 Results and calculations

The lengths of exposed conductor at each end of the coil shall be recorded.

7.4.6 Report

The report shall include, as a minimum, lengths of exposed conductor on each end.

7.5 Shrinkback in air

7.5.1 Scope

This test establishes the method for determining resistance to longitudinal shrinkage of conductor insulation in air.

7.5.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i); and

b) a micrometer caliper or optical micrometer microscope with a resolution and accuracy of 0.01 mm (0.001 in).

7.5.3 Preparation of specimens

Immediately before testing, 200 mm (8 in) specimens shall be cut from the center of a 1.5 m (60 in) length of insulated conductor and then reduced to 150 mm (6 in) by trimming each end of the specimen. For a coaxial cable with a skin over the insulation, the skin shall not be removed.

7.5.4 Procedure

Specimen(s) 150 mm (6 in) in length shall be placed on a felt bed or on a layer of preheated talc or glass beads in a circulating-air oven as described in 7.5.2(a) for 1 hour at the specified temperature. At the end of the conditioning period, the specimen shall be allowed to cool to ROOM TEMPERATURE. The shrinkback shall be measured at both ends of the conductor.

7.5.5 Results and calculations

The total length of exposed conductor shall be determined by summing the measurements of shrinkback.

7.5.6 Report

The report shall include, as a minimum, the sum of the lengths of exposed conductor.

7.6 Cold bend

7.6.1 Scope

This test establishes the method for determining the resistance to cracking of wire or cable components during bending at low temperature.

7.6.2 Apparatus

The apparatus shall consist of the following:

a) a low-temperature chamber capable of maintaining the specified temperature within ±1°C;

b) a temperature-measuring device with an accuracy of ±1°C;

c) a micrometer or micrometer caliper with a resolution and accuracy of 0.01 mm (0.001 in);

d) cylindrical mandrels of diameters specified in the product standard. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size; and

e) thermally insulated gloves.

7.6.3 Preparation of specimens

The specimen shall be cut to a length sufficient to perform the test and shall be straightened.

7.6.4 Procedure

7.6.4.1 The specimen and the mandrel shall be placed in the cold chamber at the temperature and for the specified duration. While still in the chamber, the specimen shall be bent around the mandrel. Bending shall commence as quickly as possible and at a rate such that the time taken to complete the specified number of turns shall be within 30 seconds. Flat cable shall be wound on its flat side.

7.6.4.2 Where there is insufficient space in the cold chamber for the mandrel, or for bending the specimen, bending of the specimen shall be allowed to take place outside of the cold chamber. Bending of the specimen shall commence as quickly as possible. In the instance where the mandrel is too large to be placed in the chamber, it shall be maintained at ROOM TEMPERATURE. In any case, bending shall be completed within 30 seconds from the time the chamber is opened.

7.6.4.3 If the tension on the specimen is not specified, it shall be just sufficient to cause the specimen to conform to the periphery of the mandrel. Unless rotation of the mandrel is performed remotely, the specimen and mandrel shall be handled using thermally insulated gloves.

7.6.4.4 The specimen, whether on or off of the mandrel, shall be allowed to return to ROOM TEMPERATURE and then straightened. The inside and outside surfaces of the components shall be examined with NORMAL VISION for cracking.

7.6.5 Results and calculations

The presence of cracks, if any, shall be noted.

7.6.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) indication of cracking, if any.

7.7 Cold impact

7.7.1 Scope

This test establishes the method for determining the resistance to cracking of wire or cable components when subjected to an impact at low temperature.

7.7.2 Apparatus

The apparatus shall consist of the following:

a) a low-temperature chamber capable of maintaining the specified temperature within ±1°C;

b) a temperature-measuring device with an accuracy of ±1°C;

c) an impact apparatus with a means to guide and permit the impact mass to fall freely without constraints for a minimum of 915 mm (36 in). The apparatus shall be capable of maintaining the face of the impact mass perpendicular to the specimen at impact. The impact apparatus shall be provided with a locking mechanism that permits release from the specified height (see Figure 16);

d) a metallic impact mass of 1.36 -0, +0.03 kg (3 -0, +0.06 lb), with a flat steel impact face of minimum thickness of 13 mm (0.5 in) and a diameter of 25 -0.5, +0 mm (1 -0.02, +0 in), with rounded edges; and

e) wood anvils of nominal cross-section of 90 x 40 mm (3.5 x 1.5 in) and a minimum length of 200 mm (8 in) cut from spruce, pine, or encino (Holm Oak). If a failure occurs, a referee test may be conducted using spruce.

7.7.3 Preparation of specimens

Ten specimens shall be cut to a length of 130 ±6 mm (5 ±0.25 in). The specimens shall be straightened and placed in the cold chamber, along with the wood anvils at the specified temperature for a minimum duration of 4 hours.

7.7.4 Procedure

7.7.4.1 The impact mass shall be secured with its face at a height of 915 -0, +18 mm (36 -0, +0.7 in) above the upper surface of the specimen.

7.7.4.2 After conditioning, one wood anvil shall be fastened to a solid support that will not absorb the impact.

7.7.4.3 One conditioned specimen shall be centered in the impact area, and in the direction of the grain of the wood anvil. For specimens that are not circular, the flatter side shall be impacted. Specimens shall not be placed within 25 mm (1 in) of any imperfections or knots present in the wood anvil.

7.7.4.4 The impact mass shall be released to impact on the specimen. If the test is performed outside the low-temperature chamber, this shall be completed within 15 seconds after removal of the specimen from the chamber. The weight shall only strike the specimen once.

7.7.4.5 The impact mass shall be raised and secured for another test. The procedure described in 7.7.4.3 and 7.7.4.4 shall be repeated on the remainder of the 10 specimens. The entire procedure described in 7.7.4.2 – 7.6.4.4 shall be completed within 3 minutes.

7.7.4.6 An anvil shall not be used to test more than one series of 10 specimens.

7.7.4.7 The specimens shall be allowed to rest for a minimum of 1 hour at ROOM TEMPERATURE and then examined for cracks, ruptures, or other damage to all surfaces of the nonmetallic components of the cable. The examination shall be made with NORMAL VISION.

7.7.5 Results and calculations

The number of specimens exhibiting cracks, ruptures, or other damage, if any, shall be recorded.

7.7.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) number of specimens showing cracks, ruptures or other damage.

7.8 Deformation

7.8.1 Scope

This test establishes the method for determining the resistance to deformation of wire or cable insulation or jacket at elevated temperatures.

7.8.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C;

c) a dial micrometer having flat surfaces on both the anvil and the end of the spindle with a diameter of 6.4 ±0.2 mm (0.25 ±0.01 in), and that exerts a force of 0.83 ±0.03 N (0.187 ±0.0067 lbf) and with a resolution and accuracy of 0.01 mm (0.001 in) for measured thickness of greater than 0.25 mm (0.010 in), and with a resolution and accuracy of 0.001 mm (0.0001 in) for measured thickness of 0.25 mm (0.010 in) or less. Alternatively, for the initial thickness measurement of a specimen in strip form, use of a dial micrometer as described in 4.2.3(e) shall be permitted; and

d) a weight as specified in the product standard. The end of the weight intended to bear upon the specimen shall have a flat foot with a diameter of 9.5 mm (0.375 in), edges slightly rounded, and be mounted in a frame so as to provide free vertical movement (see Figure 13).

7.8.3 Preparation of specimens

Specimens shall be taken from wire, cable or cord, finished or during manufacture. The specimens shall be nominal 25 mm (1 in) in length and, where required, shall be either in the as-received form with coverings, if any, removed or left in place as required, or in a smoothed strip form with a maximum width of 14 mm (0.56 in) and having uniform thickness of less than or equal to 1.5 mm (0.06 in). When a specimen with a width of less than 9.5 mm (0.375 in) is used and the results do not comply with the requirements, the test results are to be discarded and the test shall be repeated with a wider specimen. Smoothed strip shall be prepared using the apparatus described in 4.2.3(j), (k), or (l). When testing the specimen in the as-received form, the diameter of the bare conductor shall be measured in accordance with 3.1, on an adjacent section of the conductor, taken at not more than 150 mm (6 in) from the end of the specimen.

7.8.4 Procedure

7.8.4.1 The test specimen shall be marked at the position where the foot of the weight is to bear on the specimen. At this marked position, the initial thickness of an as-received specimen shall be determined as described in 4.1.4.2.2, using a dial micrometer as described in 7.8.2, except that only one measurement shall be taken at the marked position. The initial thickness of a smoothed specimen shall be measured directly using a dial micrometer as described in 7.8.2. Thicknesses of smoothed specimens or of insulation on as-received specimens greater than 0.25 mm (0.010 in) shall be measured to an accuracy of 0.01 mm (0.001 in). Thicknesses of 0.25 mm (0.010 in) or less shall be measured to an accuracy of 0.001 mm (0.0001 in).

7.8.4.2 The test apparatus and the specimen shall be conditioned in the air oven at the specified temperature for 1 hour unless otherwise specified. At the end of this time, while still in the oven, the specimen shall be placed under the foot of the weight at the marked position. The specimen shall remain under test under these conditions for 1 hour unless otherwise specified.

7.8.4.3 At the end of this time, the specimen shall be carefully removed from under the foot of the weight. Within 15 seconds of removal, the thickness at the marked position shall be measured using the method described in 7.8.4.1.

7.8.4.4 In the event that a specimen with stranded conductors or with members that can easily be collapsed, such as fibers or air-gap coaxial cable, when tested in the as-received form does not meet the testing requirements of the product standard, the core may be removed and replaced by a solid conductor which fits snugly, and the test repeated.

7.8.4.5 Evidence of splitting, cracking through, and exposed conductor shall be noted.

7.8.5 Results and calculations

The percent deformation shall be calculated from the following formula:

$$\frac{(T_1 - T_2)}{T_1} \times 100$$

where

T_1 = thickness before test, mm (in)

T_2 = thickness after test, mm (in)

7.8.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration;

c) percent deformation;

d) splitting and conductor exposure, for insulated conductor specimen; and

e) splitting and cracking through, for smoothed strip specimen.

7.9 Hot creep elongation and hot creep set

7.9.1 Scope

This test establishes the method for determining the hot creep elongation and hot creep set after exposure to elevated temperature.

7.9.2 Apparatus

The apparatus shall consist of the following:

a) the apparatus as described in 4.2.3(c), (e), (f), (j), (k), (l), (m), (n), and (p);

b) a circulating air oven in accordance with 4.2.3(i), for temperature variation and temperature fluctuation only;

c) a test fixture as shown in Figure 14, having the following characteristics:

i) upper gripping assembly capable of suspending the specimen vertically; and

ii) unrestrained lower gripping assembly capable of supporting a weight; and

d) a scale for measuring elongation, calibrated with divisions of 1 mm (0.1 in).

7.9.3 Preparation of specimens

7.9.3.1 Three specimens shall be prepared from a sample of insulation taken from finished wire or cable, or from the wire or cable during manufacture. Any jacket or covering shall be removed. One specimen shall be tested and the other two specimens shall be held in reserve.

7.9.3.2 For conductor sizes up to and including 8.37 mm^2 (8 AWG), a tubular specimen shall be prepared in accordance with 4.2.4.2.2. The specimen shall not be cut longitudinally.

7.9.3.3 For conductor sizes larger than 33.6 mm^2 (2 AWG), a die-cut specimen with a uniform cross-sectional area not greater than 16 mm^2 (0.025 in^2) between the benchmarks shall be prepared from the insulation. A die-cut specimen shall be prepared in accordance with 4.2.4.2.3.

7.9.3.4 For conductor sizes 13.3 to 33.6 mm^2 (6 to 2 AWG), a tubular or die-cut specimen shall be allowed.

7.9.4 Procedure

7.9.4.1 General

7.9.4.1.1 The cross-sectional area of the specimen shall be determined in accordance with 4.2.5.1.

7.9.4.1.2 The total weight (W_t) shall be calculated as follows:

$$W_t = \text{cross-sectional area } (mm^2) \times 20.4\ (gf/mm^2)$$

or

$$W_t = \text{cross-sectional area } (in^2) \times 29.0\ (lbf/in^2)$$

where

W_t = total weight, including gripping assembly and weights added to the lower gripping assembly, gf (lbf)

7.9.4.1.3 An as-received specimen shall be marked with benchmarks 25 ±2.5 mm (1 ±0.10 in) apart. These benchmarks shall be at right angles to the direction of pull in the testing machine and as narrow as possible, to facilitate measurement. The specimen shall be completely at rest while being marked.

7.9.4.2 Hot creep elongation

7.9.4.2.1 Weight (W_t) as determined in 7.9.4.1.2 shall be added to the lower gripping assembly.

7.9.4.2.2 One end of the specimen shall be attached to the upper gripping assembly of the test fixture. The lower gripping assembly shall then be attached to the other end of the specimen. The distance between the gripping assemblies shall not be greater than 100 mm (4 in).

7.9.4.2.3 The test fixture with the attached specimen shall be placed in the circulating-air oven preheated to 150 ±2°C.

7.9.4.2.4 After 15 minutes, while still in the oven and with the weight still attached, the distance between the benchmarks shall be measured with the scale. This distance (D_e) shall be recorded to the nearest 1 mm (0.1 in).

7.9.4.3 Hot creep set

7.9.4.3.1 The hot creep set test shall be performed on the same specimen as the hot creep elongation test in 7.9.4.2. The test shall be made immediately following the hot creep elongation test.

7.9.4.3.2 Without removing the specimen from the oven, the lower gripping assembly shall be removed from the specimen. The oven door shall be closed immediately to minimize cooling of the specimen. The specimen shall remain in the oven for 5 minutes.

7.9.4.3.3 The specimen shall be removed from the oven and test fixture and left at ROOM TEMPERATURE for at least 1 hour.

7.9.4.3.4 The distance (D_s) between benchmarks shall be measured to the nearest 1 mm (0.1 in) and recorded using the scale.

7.9.5 Results and calculations

7.9.5.1 The hot creep elongation shall be calculated as follows:

$$C = \frac{100 \times (D_e - G)}{G}$$

where

C = hot creep elongation, %

D_e = distance between the benchmarks obtained in 7.9.4.2.4

G = original distance between the benchmarks

7.9.5.2 The hot creep set shall be calculated as follows (the result can be positive or negative):

$$S = \frac{100 \times (D_s - G)}{G}$$

where

S = hot creep set, %

D_S = distance between the benchmarks obtained in 7.9.4.3.4

G = original distance between the benchmarks

7.9.5.3 If the specimen does not comply with either the specified hot creep elongation or hot creep set requirements, each test shall be repeated on the two reserved specimens. The hot creep elongation and hot creep set values shall be determined from the averages of the three specimens.

7.9.6 Report

The report shall include, as a minimum, the following:

a) hot creep elongation, %; and

b) hot creep set, %.

7.10 Abrasion resistance

7.10.1 Scope

This test establishes the method for determining resistance to abrasion.

7.10.2 Apparatus

The apparatus shall consist of the following:

a) a horizontally reciprocating mechanism (simple harmonic motion) having a travel length of 160 ±8 mm (6.25 ±0.31 in) that cycles at 28 ±1 cycles/min (See Figure 15 – equipment design and dimensions are typical, but not required). One cycle consists of one complete back-and-forth motion;

b) a weight as specified by the product standard;

c) an abrading medium consisting of medium grade (80 grit) emery cloth;

d) a non-rotating cylindrical surface, minimum 90 degree arc with a radius of 89 ±0.9 mm (3.5 ±0.035 in); and

e) a counting device to record the number of cycles.

7.10.3 Preparation of specimens

Six straight specimens shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture. Each specimen shall be 1 m (40 in) in nominal length, and tested without any conditioning.

7.10.4 Procedure

7.10.4.1 The test apparatus and the specimens shall be in thermal equilibrium with the surrounding air at ROOM TEMPERATURE throughout the test.

7.10.4.2 One end of each specimen shall be attached to the reciprocating mechanism while it is at one end of its travel. The other end of each specimen shall be attached to a weight as defined in the product standard. Each specimen shall be laid over the quarter cylinder. The outer surface of the cylinder shall have an unused sheet of emery cloth, as described in 7.10.2, attached. The longitudinal axis of the cylinder shall be horizontal, and perpendicular to the test specimens in each of the vertical planes.

7.10.4.3 The reciprocating mechanism shall be started. Each cycle shall consist of one complete back-and-forth motion with a stroke of 160 ±8 mm (6.25 ±0.31 in). The reciprocating mechanism shall be stopped every 50 cycles and the emery cloth shall be shifted slightly to one side so that in subsequent cycles each specimen is abraded by a fresh surface of emery cloth.

7.10.4.4 Each specimen shall be abraded for the specified number of cycles.

7.10.4.5 Each specimen shall be examined for exposure of the conductive material.

7.10.5 Results and calculations

Exposure of the conductor on any of the 6 specimens shall be determined.

7.10.6 Report

The report shall include, as a minimum, exposure of conductor, if any.

7.11 Crush resistance

7.11.1 Scope

This test specifies the method for determining resistance to crushing.

7.11.2 Apparatus

The apparatus shall consist of the following:

a) a power-driven compression machine provided with a device to measure and indicate the compression force at rupture accurate to 2% or less of the value read. The machine shall be capable of operating at a power-actuated jaw speed of 10 ±1 mm/min (0.5 ±0.05 in/min);

b) two flat steel plates 50 mm (2 in) wide;

c) a 19 mm (0.75 in) diameter solid steel drill rod of the same length as the plate; and

d) a power supply 30 V dc or less, with a means of indicating contact between the conductor and the steel plate or drill rod.

7.11.3 Preparation of specimens

7.11.3.1 The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall be a minimum of 2500 mm (100 in) in length. One end of the conductor shall be made bare.

7.11.3.2 The bare end of the specimen shall be connected to one side of the power supply. Both plates shall be connected to the other side of the power supply.

7.11.4 Procedure

7.11.4.1 Method 1 (two steel plates)

7.11.4.1.1 Each steel plate shall be mounted horizontally in the compression machine. The longitudinal axes of the plates shall be in the same vertical plane. The specimen, apparatus, and surrounding air shall be in thermal equilibrium at ROOM TEMPERATURE.

7.11.4.1.2 The first test point on the specimen shall be centered on the lower plate and parallel to the 50 mm (2 in) dimension. The upper steel plate shall be lowered until contact is made with the surface of the specimen. The downward motion of the plate shall then be continued at the specified rate until the indicator signals contact.

7.11.4.1.3 The force indicated by the compression machine at the moment of contact shall be recorded. The procedure shall be repeated at nine additional test points evenly spaced along the specimen length. These points shall be at least 250 mm (10 in) apart, and at least 125 mm (5 in) from either end of the specimen.

7.11.4.2 Method 2 (drill rod and plate)

The test shall be performed as described in 7.11.4.1, except that a solid steel rod as described in 7.11.2 shall be bolted or otherwise secured along the centerline of either plate, perpendicular to the 50 mm (2 in) dimension.

7.11.5 Results and calculations

The average of the ten results shall be calculated.

7.11.6 Report

The report shall include, as a minimum, individual and average compression forces at contact.

7.12 Crush resistance (accelerated compression rate)

7.12.1 Scope

This test specifies the method for determining resistance to crushing at an accelerated rate of compression.

7.12.2 Apparatus

The apparatus shall consist of the following:

a) two 50 mm (2 in) wide, flat, horizontal steel plates in a compression machine whose jaws close at the rate of 5.0 ±0.5 mm/min (0.20 ±0.02 in/min). The edges of the plate shall not be sharp;

b) two flat steel plates 50 mm (2 in) wide; and

c) a power supply of 30 V dc or less, with a means of indicating contact between the conductor and the steel plate or drill rod.

7.12.3 Preparation of specimens

The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The insulated conductors shall be removed from a sample length of the finished cable having solid conductors and individually straightened with the fingers. Specimens shall be nominally 180 mm (7 in) long cut from the straight insulated conductors. Both ends of the conductor shall be made bare.

7.12.4 Procedure

7.12.4.1 Each steel plate shall be mounted horizontally in the compression machine. The longitudinal axes of the plates shall be in the same vertical plane. The specimen, apparatus, and surrounding air shall be in thermal equilibrium at ROOM TEMPERATURE.

7.12.4.2 The length of the specimen shall be parallel to the 50 mm (2 in) dimension of the plates, 25 mm (1 in) of the specimen shall extend outside of the plates at one end of the specimen, and 100 mm (4 in) of the specimen shall extend outside the plates at the other end of the specimen. The bare end of the specimen shall be connected to one side of the power supply. Both plates shall be connected to the other side of the power supply.

7.12.4.3 The upper steel plate shall be lowered until contact is made with the surface of the specimen. The downward motion of the plate shall then be continued at the specified rate until the indicator signals contact. The force indicated by the compression machine at the moment of contact shall be recorded.

7.12.4.4 The compression machine shall be reversed and the plates separated. The specimen shall be turned end for end, rotated 90 degrees, reinserted (from the end opposite the one originally inserted) between the plates, and the test as described in 7.12.4.3 repeated.

7.12.4.5 The test described in 7.12.4.1 – 7.12.4.4 shall be repeated for an additional 4 specimens.

7.12.5 Results and calculations

The average of all ten of the crushing forces obtained for the five specimens shall be calculated.

7.12.6 Report

The report shall include, as a minimum, individual and average compression forces at contact.

7.13 Impact resistance

7.13.1 Scope

This test specifies the method for determining the impact resistance of insulation and/or covering when impacted by a free-falling mass.

7.13.2 Apparatus

The apparatus shall consist of the following:

a) an impact apparatus with a means to guide and permit the impact mass to fall freely without constraints for a minimum of 610 mm (24 in) (see Figure 16). The apparatus shall be capable of maintaining the face of the impact mass perpendicular to the specimen at impact. The impact apparatus shall be provided with a locking mechanism that permits release from the specified height;

b) a steel impact mass of 0.454 -0, +0.009 kg (1 -0, +0.02 lb), 38 -1, +0 mm (1.5 -0.03, +0 in) in diameter, and nominally 51 mm (2 in) in length, with rounded edges;

c) an impact anvil consisting of a solid rectangular block of steel nominally 200 mm (8 in) long, 150 mm (6 in) wide and 105 mm (4.125 in) high, secured to a rigid support; and

d) a power supply 120 V ac, capable of indicating contact between the conductor and the impact mass or anvil. The circuit shall trigger and maintain the signal on any momentary contact.

7.13.3 Preparation of specimens

The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall be a minimum of 2500 mm (100 in) in length. One end of the conductor shall be made bare.

7.13.4 Procedure

7.13.4.1 The specimen, the anvil, the weight, and the remainder of the test equipment shall be in thermal equilibrium at ROOM TEMPERATURE.

7.13.4.2 The bare end of the specimen shall be connected to the live (hot) side of the power supply. The impact apparatus and the anvil shall be connected to the neutral side of the power supply. The impact apparatus and the anvil shall also be connected to earth ground.

7.13.4.3 The test shall be conducted at ten points that are evenly spaced along the specimen length, at least 250 mm (10 in) apart, and at least 125 mm (5 in) from either end of the specimen.

7.13.4.4 The weight shall be raised and secured such that the impact face of the weight will be 610 -0, +12 mm (24 -0, +0.5 in) above the upper surface of the specimen. The specimen shall be placed across the width of the anvil. The impact point of the specimen shall be centered on the impact area of the anvil.

7.13.4.5 The weight shall then be released, falling freely in the guide. The weight shall strike the specimen once, then immediately be raised to and secured at the 610 mm (24 in) height to prevent repetitive strikes on the specimen.

7.13.4.6 The test shall be repeated on the remaining nine test points of the specimen as described in 7.13.4.4 and 7.13.4.5.

7.13.4.7 The specimen shall be visually examined at the points of impact for exposure of the conductor.

7.13.5 Results and calculations

Contact(s) as evidenced by triggering of the indicator, or visibility of the conductor, shall be recorded.

7.13.6 Report

The report shall include, as a minimum, number of contacts.

7.14 Dielectric breakdown after glancing impact

7.14.1 Scope

This test specifies the method for determining the retention of electrical breakdown voltage of conductor insulation and/or covering after a glancing impact.

7.14.2 Apparatus

The apparatus shall consist of the following:

a) an isolation transformer capable of supplying a test potential of 48 to 62 Hz, whose output potential is continuously variable from near zero to the breakdown voltage;

b) a voltmeter having an accuracy of ±5% on the high voltage side of the transformer. If analog, it shall have a response time that does not introduce a lagging error greater than 1% of full scale at the specified rate of increase in voltage;

c) a fault current indicator;

d) a tank filled with tap water at ROOM TEMPERATURE;

e) a means of grounding with a maximum impedance of 15 Ω; and

f) an apparatus for applying a glancing impact to a wire specimen as shown in Figure 17, having the following characteristics:

1) an oak wood anvil nominally 50 mm x 100 mm (2 in x 4 in) in cross-section and 250 mm (10 in) in length, rigidly supported 45 ±2 degrees from the horizontal;

2) a means of fastening the ends of the test specimen to the anvil;

3) an impact mass 0.454 -0, +0.009 kg (1 -0, +0.02 lb), consisting of a solid steel cylinder, 19 -1, +0 mm (0.75 -0.03, +0 in) in diameter having all surfaces smooth and one end rounded to a radius of 9.5 -0.5, +0 mm (0.375 -0.015, +0 in); and

4) a hollow tube to contain and guide the impact mass, having a 21 -0, +0.5 mm (0.82 -0, +0.02 in) inner diameter, mounted over the anvil in a vertical position.

7.14.3 Preparation of specimens

The test specimen shall be taken from a sample of solid 2.08 mm^2 (14 AWG) finished wire or cable, or from the wire or cable during manufacture without any conditioning. The sample shall be cut into twelve specimens nominally 380 mm (15 in) in length. One end of the conductor in each of the specimens shall be made bare and each specimen shall be straightened. The specimen and apparatus shall be at ROOM TEMPERATURE.

7.14.4 Procedure

7.14.4.1 The specimen, the anvil, the weight, and the remainder of the test equipment shall be in thermal equilibrium at ROOM TEMPERATURE.

7.14.4.2 The specimen shall be fastened along the long axis of the anvil and centered on the impact area. The impact mass shall be positioned in the guide tube, with the hemispherical end downward and 460 -0, +9 mm (18 -0, +0.4 in) above the midpoint of the specimen. The impact mass shall be released and allowed to fall freely and strike the specimen only once. The specimen shall be removed from the apparatus.

7.14.4.3 The impact process shall be repeated on five additional specimens. After each set of six glancing impacts, the anvil shall be examined for damage. If damage is evident, the anvil shall be replaced.

7.14.4.4 A specimen shall be immersed in water, except for the ends. The ends of the specimen shall be separated from the grounded water electrode a distance sufficient to prevent corona or flashover at the ends during application of the test voltage. The test voltage shall be applied between the insulated conductor and the grounded water electrode, and increased at a uniform rate of 10 to 60 V/s until breakdown occurs. The breakdown voltage shall be recorded.

7.14.4.5 The procedure described in 7.14.4.4 shall be performed on all specimens.

7.14.5 Results and calculations

7.14.5.1 Triggering of the fault indicator shall be evidence of dielectric breakdown. The high and low values shall be discarded, and the average breakdown voltage for the remaining four specimens that were subjected to the glancing impact described in 7.14.4.2 shall be calculated.

7.14.5.2 The average breakdown voltage for the six specimens that were not subjected to the glancing impact shall be calculated.

7.14.5.3 The ratio of the average breakdown voltage of specimens subjected to glancing impact to the average breakdown voltage of non-impacted specimens shall be calculated.

7.14.6 Report

The report shall include, as a minimum, the following:

a) average breakdown voltage for specimens not subjected to the glancing impact;

b) average breakdown voltage for specimens subjected to the glancing impact;

c) ratio of the average breakdown voltage of specimens subjected to glancing impact to the average breakdown voltage of non-impacted specimens; and

d) discarded breakdown voltage values, if any.

7.15 Flexibility at ROOM TEMPERATURE after aging

7.15.1 Scope

This test establishes the method for determining the flexibility of wire or cable at ROOM TEMPERATURE after aging.

7.15.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C; and

c) cylindrical mandrels of specified diameters. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size.

7.15.3 Preparation of specimen

The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The length of the specimen shall be sufficient to allow winding around the mandrel for the specified number of turns.

7.15.4 Procedure

7.15.4.1 The specimen shall be aged in the oven for the specified time and temperature, then immediately removed from the oven.

7.15.4.2 The specimen shall be wound around a mandrel at a uniform rate of approximately 4 seconds per turn at ROOM TEMPERATURE, within 16 to 96 hours after removal from the oven.

7.15.4.3 Specimens of conductor sizes 85.0 mm^2 (3/0 AWG) or smaller shall be tightly wound 4 adjacent turns around the mandrel. Specimens of conductor sizes larger than 85.0 mm^2 (3/0 AWG) shall be wound around the mandrel in a 180 degree U-bend.

7.15.4.4 All internal and external surfaces of all insulation and jacket components of the specimen shall be examined for cracks or splits under NORMAL VISION.

7.15.5 Results and calculations

The presence of cracks and splits shall be noted.

7.15.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) indication of cracks.

7.16 Flexibility of separator tape under a jacket

7.16.1 Scope

This test establishes the integrity of a separator tape under a jacket, after flexing at ROOM TEMPERATURE.

7.16.2 Apparatus

The apparatus shall consist of the following:

a) a micrometer or micrometer caliper with a resolution and accuracy of 0.01 mm (0.001 in);

b) a cylindrical mandrel of specified diameter. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size; and

c) a temperature-measuring device with an accuracy of ±1°C

7.16.3 Preparation of specimens

The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall be cut to a length sufficient to allow winding around the mandrel for the specified number of turns, and the specimen shall be straightened.

7.16.4 Procedure

7.16.4.1 The specimen shall be wound around a mandrel for the specified number of turns. The specimen shall be wound at a uniform rate such that the operation is completed within 1 minute. Specimens of flat cable shall be wound on the flat side. Specimens of cable with longitudinally-applied separator tape shall be wound with the separator tape overlap facing outwards from the mandrel.

7.16.4.2 With the specimen still on the mandrel, the jacket shall be opened sufficiently to allow examination of the separator tape(s) and overlap(s) under NORMAL VISION.

7.16.5 Results and calculations

The presence of any cracks or splits in the separator tape(s) or openings of the overlap(s) shall be noted.

7.16.6 Report

The report shall include, as a minimum, indication of any cracks or splits in the separator tape(s) or openings of the overlap(s).

7.17 Flexibility of armored cable and metal-sheathed cable

7.17.1 Scope

This test determines the ability of a cable to withstand specified flexing without damage to the cable armor or any underlying components.

In the United States and Mexico, this test applies to Armored Cable and Metal-Clad Cable.

In Canada, this test applies to Armored Cable and Metal-Sheathed Cable.

7.17.2 Apparatus

The apparatus shall consist of the following:

a) a stepped cone as shown in Figure 18, with each step being a right-circular cylinder approximately 50 mm (2 inches) high, having steps of the specified diameters for the sizes of cable being tested; or

b) mandrels of the specified diameters for the sizes of cable being tested.

7.17.3 Preparation of specimens

Straight specimens of cable shall be taken from a reel or during manufacture. Any covering over the armor shall be removed.

7.17.4 Procedure

7.17.4.1 (Method 1 – interlocking armored cables)

A specimen shall be wrapped the specified number of turns around a mandrel of the specified diameter with sufficient tension applied to the specimen to cause it to conform closely to the periphery of the mandrel. While the specimen is in this position, observation shall be made to determine whether or not the edges of adjacent convolutions of the armor are separated to expose the conductor assembly.

7.17.4.2 (Method 2 – metal sheathed cables)

Specimens shall be wound around the mandrel (flatwise in the case of flat-twin cable) 180 degrees as specified without any more tension than is necessary to keep the armor in contact with the mandrel throughout the turn, then straightened and bent 180 degrees in the opposite direction. This bending cycle shall be repeated, where applicable, until the specimen has been subjected to the specified number of 180 degree bends. Bending shall be done slowly and at a uniform rate of speed.

7.17.4.3 (Method 3 – continuously corrugated welded sheath)

In the case of welded armor, one specimen shall be bent with the weld line located at the inner edge of the bend, a second specimen shall be bent with the weld line at the outer edge of the bend, and a third specimen shall be bent with the weld line midway between the inner and outer edges of the bend.

7.17.5 Results and calculations

7.17.5.1 The specimen while wound on the mandrel shall be examined for evidence of damage to the conductor assembly and separation of the convolutions of the armor sufficient to expose any of the underlying components of the specimen. In the case of metal sheathed cables, the armor and the covering under the armor and conductor assembly shall be examined for damage.

7.17.5.2 Smooth or corrugated armor shall be examined for any weld openings, cracks, splits, tears or other openings.

7.17.5.3 Adjacent convolutions of interlocked armor shall be examined to determine if any part of the cable inside the armor is visible.

7.17.6 Test Report

The report shall include, as a minimum, the following:

a) Cable size and number of conductors;

b) Diameter of mandrel used during the test; and

c) Results of cable examination indicating compliance.

7.18 Swelling and blistering when immersed in liquid

7.18.1 Scope

This test establishes the method for determining resistance to swelling or blistering of a cable.

7.18.2 Apparatus

The apparatus shall consist of the following:

a) a dial micrometer having flat surfaces on both the anvil and the end of the spindle, that exerts a force of 0.10 to 0.83 N (0.022 to 0.187 lbf) and with a resolution and accuracy of 0.01 mm (0.001 in);

b) a tank capable of accommodating a coil of cable while maintaining the liquid to the specified temperature ±1°C;

c) specified materials and reactants; and

d) a temperature-measuring device with an accuracy of ±1°C.

7.18.3 Preparation of specimens

A nominal 10 m (32 ft) test specimen shall be taken from a sample of finished cable with a circular cross-section. The specimen shall be marked at five test points using a means that is durable in the specified liquid that does not damage the cable. The marks shall be 2 m (6.6 feet) apart at points 1, 3, 5, 7, and 9 m (7 ft apart at points 2, 9, 16, 23, and 30 ft) along the length of the specimen.

7.18.4 Procedure

7.18.4.1 The minimum and maximum diameters of the specimen shall be measured to the nearest 0.01 mm (0.001 in) at each of the five marked points. Each measurement shall be recorded.

7.18.4.2 The specimen shall be loosely coiled, and then immersed in the tank, maintaining the liquid at the specified temperature, with both ends of the coiled specimen extending at least 300 mm (12 in) above the liquid.

7.18.4.3 The coiled specimen shall remain immersed continuously for 14 d, then removed from the liquid, and uncoiled at ROOM TEMPERATURE. All liquid shall be blotted immediately from the surface of the specimen by means of a clean, absorbent, lint-free cloth.

7.18.4.4 The specimen shall be inspected for evidence of blistering under NORMAL VISION. The maximum and minimum diameters of the specimen shall be measured immediately at each of the five marked points. Each measurement shall be recorded.

7.18.5 Results and calculations

The increase in diameter due to swelling shall be calculated as follows:

$$I = 100\ (D - d)/d$$

where

I = percent increase due to swelling

D = average diameter of the ten measurements taken after immersion

d = average diameter of the ten measurements taken before immersion

Note: *Dimensions can be in mm or inches, provided that they are consistent throughout the calculations.*

7.18.6 Report

The report shall include, as a minimum, the following:

a) immersion liquid and temperature of liquid;

b) evidence of blistering, if any; and

c) increase in diameter, if applicable.

7.19 Durability of ink printing

7.19.1 Scope

This test establishes the method for determining the durability of ink printing.

7.19.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C;

c) a kraft felt with a thickness of 1.2 ±0.25 mm (0.05 ±0.01 in) not having more than 30% wool content and the remainder of the composition being rayon; and

d) a weight block with a machined face of 25 mm (1 in) by 50 mm (2 in) and a uniform height to ensure even weight distribution throughout the area of the lower face. Clamps or other means shall be provided for securing the craft felt in place. Without the felt in place, the weight block and clamps shall be 450 ±5 g (1 ±0.01 lb).

7.19.3 Preparation of specimen

Two specimens shall be taken from finished wire or cable, or from the wire or cable during manufacture. The specimens shall be 300 mm (12 in) in length with the printing centered. The specimens shall be handled minimally and shall not be wiped, scraped, or otherwise cleaned in any way.

7.19.4 Procedure

7.19.4.1 One specimen shall be conditioned in a forced-circulation air oven at the specified temperature and for the specified period of time. The other specimen shall be maintained at ROOM TEMPERATURE for a minimum of 24 hours.

7.19.4.2 Upon removal from the oven, the conditioned specimen shall be allowed to rest for a minimum of 60 minutes prior to testing. Following the rest period, the specimen shall be placed and secured on a solid, flat, horizontal surface with the printing up and at the center of the length of the specimen.

7.19.4.3 With the specimen secured in place, the felted surface of the weight block shall be placed horizontally on the printed area of the specimen with the 50 mm (2 in) dimension of the felted surface parallel to the length of the specimen. With the weight block resting freely on the specimen, the weight block shall be slid lengthwise by hand along the printed area of the specimen for a total of three cycles, each cycle consisting of one complete back-and-forth motion covering the center 250 mm (10 in) of the specimen. Three cycles shall be completed at an even pace within a total of 5 to 10 seconds.

7.19.4.4 The procedure described in 7.19.4.3 shall be repeated on the remaining specimen.

7.19.4.5 The felt may be used for several tests, but shall be replaced as soon as the fiber is flattened or becomes soiled. When not in use, the weight shall not be stored resting on the felt surface.

7.19.5 Results and calculations

The legibility of both specimens shall be examined with NORMAL VISION and noted.

7.19.6 Report

The report shall include, as a minimum, indication of legibility of ink printing, temperature, and duration of conditioning.

7.20 Color coating

7.20.1 Scope

This procedure establishes a method for determining the ability of surface ink or paint coatings to maintain adhesion without deleterious effects to the insulation.

7.20.2 Apparatus

The apparatus shall consist of the following:

a) the apparatus as described in 4.2.3, excluding items (g) and (h);

b) the apparatus as described in 7.15.2; and

c) the apparatus as described in 7.6.2.

7.20.3 Preparation of specimens

7.20.3.1 General

Specimens for preparation as specified in 7.20.3.2 – 7.20.3.4 shall be taken from samples of finished wire or cable, or from wire or cable during manufacture.

7.20.3.2 Part 1

Specimens shall be prepared as described in 4.2.4.

7.20.3.3 Part 2

Specimens shall be prepared as described in 7.15.3.

7.20.3.4 Part 3

Two specimens of any convenient length, and of contrasting colors, one having the surface color coating and the other uncoated, shall be twisted together for six or more turns having a LENGTH OF LAY not exceeding 20 times the measured overall diameter of one specimen.

7.20.4 Procedure

7.20.4.1 Part 1

Specimens shall be tested in accordance with 4.2.3 – 4.2.6 after conditioning as described in 4.2.8.1 – 4.2.8.2.

7.20.4.2 Part 2

Specimens shall be tested in accordance with the procedure described in 7.15.4, except that the specimen shall be examined for flaking of coating only.

7.20.4.3 Part 3

The specimens shall be suspended in the air oven and conditioned at the specified temperature and for the specified period of time. The specimens shall then be removed from the oven and allowed to cool at ROOM TEMPERATURE for 1 hour, after which they shall be untwisted and examined. The length and width of color coating transferred to the uncoated specimen shall be measured.

7.20.5 Results and calculations

7.20.5.1 Part 1

The average ultimate elongation and tensile strength shall be calculated in accordance with 4.2.6.

7.20.5.2 Part 2

The presence of flaking of the coating shall be recorded.

7.20.5.3 Part 3

The length and width of color coating transferred to the uncoated specimen shall be recorded.

7.20.6 Report

The report shall include, as a minimum, the following:

a) type of exposure;

b) average values for aged and unaged specimens;

c) average retention values;

d) presence of flaking of coating, if any; and

e) migration of coating, if any.

7.21 Mechanical strength

7.21.1 Scope

This test establishes the method for determining the ability of a cord to withstand mechanical stress.

7.21.2 Apparatus

The apparatus shall consist of the following:

a) a tensile testing machine in accordance with 4.2.3(a);

b) a weight of the specified value; and

c) two clamps capable of tightly holding the specimen while under tension without damaging the specimen (see Figure 19). Wire mesh grips shall be allowed as an alternative clamping means.

7.21.3 Preparation of specimens

A specimen shall be cut from a sample of finished cord. The length of the specimen shall be sufficient to allow a minimum spacing of 600 mm (2 ft) between clamps.

7.21.4 Procedure

7.21.4.1 The specimen shall be clamped and the required load shall be applied gradually to the specimen.

7.21.4.2 If the load is applied using a tensile test machine, the tension shall be increased by separating the clamps at a rate of 25 ±3 mm/min (1 ±0.1 in/min) until the specified load is reached. The load shall be maintained for the specified duration, after which time it shall be removed. A referee test may be conducted by applying the load described in 7.21.4.3.

7.21.4.3 If the load is applied by the lifting of a weight, the weight shall be centered directly under the lifting point and shall be prevented from rotating. The load shall be maintained for the specified duration, after which the load shall be removed.

7.21.4.4 The specimen shall be observed to determine if any conductor breaks during the test in the area between the clamps.

7.21.4.5 For the method described in 7.21.4.2, the specimen shall be removed from the clamps and examined for conductor breakage.

Note: *Breakage of individual strands does not constitute conductor breakage unless all strands are broken.*

7.21.4.6 For the method described in 7.21.4.3, conductor breakage is as evidenced by the specimen's inability to support the full load applied for the specified duration.

7.21.5 Results and calculations

The specimen shall be evaluated for conductor breakage.

7.21.6 Report

The report shall include, as a minimum, indication of the specimen's ability to support the specified weight for the specified period of time.

7.22 Strength and elongation of cable in tension

7.22.1 Scope

This test determines the ability of a completed cable to withstand longitudinal mechanical stress.

7.22.2 Apparatus

The apparatus shall include the following:

a) a tensile testing machine set at a jaw separation rate of 0.4 mm/s (0.02 in/s), or a weight of the value specified for the strength of the specimen and a means for slowly lifting it; and

b) two clamps (e.g., as shown in Figure 19) capable of tightly holding the specimen while under tension, without allowing any strengthening cords to slip and without damaging the cable to the extent of reducing its performance in the test. Wire mesh grips may be used as an alternative means of clamping the cable.

7.22.3 Preparation of specimens

The specimen shall be of the length and in the condition outlined in Table 5 and shall be clamped in the jaws of the tensile testing machine. When a specimen is to be tested for elongation, gauge marks shall be placed on the specimen 1000 mm (39.4 in) apart unless otherwise specified.

7.22.4 Procedure

The required load shall be applied gradually to the specimen. If applied by the lifting of a weight, the specimen shall be centered directly under the lifting point and shall be prevented from rotating. The load shall be maintained for the specified period, after which it shall be removed.

7.22.5 Results and calculations

7.22.5.1 Following application of the load, the specimen shall be removed from the clamps and examined for damage both inside and outside. Only the straight section between the jaw faces shall be considered.

7.22.5.2 When required, the elongation shall be measured as follows:

a) armored cable: the elongation shall be the sum of the apparent recessions of the conductor assembly into the armour at both ends of the specimen, measured using a scale graduated in millimeters; or

b) other than armored cable: the elongation shall be the increase in distance between the gauge marks during application of the load.

7.22.6 Report

The report shall include the following as a minimum:

a) For tension testing, the presence of openings in the armor convolutions and damage to the jacket;

b) For elongation testing, the length of permanent elongation measured; and

c) The weight applied and duration of test.

7.23 Bend test on nylon covered conductors

7.23.1 Scope

This test establishes the method for evaluating the resistance of a covering to stress caused by bending.

7.23.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i);

b) a temperature-measuring device with an accuracy of ±1°C;

c) a mandrel of appropriate diameter. When a specified mandrel is not available, a mandrel with a smaller diameter may be used. However, in the event of non-compliant results, the wire or cable shall be re-tested using the specified mandrel size; and

d) a dial micrometer having flat surfaces on both the anvil and the end of the spindle, that exerts a force of 0.10 to 0.83 N (0.022 to 0.187 lbf), or laser micrometer, both of which have a resolution and accuracy of 0.01 mm (0.001 in).

7.23.3 Preparation of specimen

A specimen with a covering, having a minimum length of 300 mm (12 in), shall be cut from a sample of finished wire or cable, or from wire or cable during manufacture, and straightened.

7.23.4 Procedure

7.23.4.1 The mandrel diameter shall be determined by measuring the diameter of the specimen. The mandrel diameter shall be equal to that of the specimen, +0, –10%. In the case of a parallel construction, the minor dimension shall be used in determining the mandrel diameter.

7.23.4.2 The specimen shall be suspended vertically in an oven at the specified temperature for the specified period of time. Following conditioning, the specimen shall be removed from the oven. Within 16 to 96 hours at ROOM TEMPERATURE, the specimen shall be wound 6 turns around a mandrel, each turn in contact with the adjacent turn.

7.23.4.3 In the case of a parallel construction, the specimen shall be wound on its flat side around the mandrel.

7.23.4.4 The specimen shall be examined for cracks with NORMAL VISION, both in the wound and unwound condition.

7.23.5 Results and calculations

The presence of any cracks shall be determined.

7.23.6 Report

The report shall include, as a minimum, presence of any cracks.

7.24 Tightness of insulation

7.24.1 Scope

This test establishes the method for determining the tightness of insulation.

7.24.2 Apparatus

The apparatus shall consist of the following:

a) a gripping device (vise) to mount test specimen vertically;

b) a specified weight; and

c) a scale calibrated with divisions of 1 mm (0.03 in).

7.24.3 Preparation of specimen

7.24.3.1 Single conductor

A specimen of an insulated conductor taken from a sample of finished wire or cable, or from wire or cable during manufacture, shall be gently straightened and cut to a length of 275 mm (11 in). The specimen shall have 50 mm (2 in) of insulation and any separator removed from one end. A reference mark shall be placed on the conductor where it enters the insulation. The other end of the specimen shall have the insulation slit longitudinally for a length of 75 mm (3 in). The conductor shall be cut and removed, and then the empty insulation with any separator shall be taped back together.

7.24.3.2 Parallel multiconductor

A specimen of a parallel multiconductor taken from a sample of finished wire or cable, or from wire or cable during manufacture, shall be gently straightened and cut to a length of 405 mm (16 in). A 50 mm (2 in) length of insulation and any separator shall be removed from the circuit conductors at both ends of the specimen. One bare circuit conductor shall be cut off even with the insulation at one end of the specimen, and the other bare circuit conductor shall be cut off even with the insulation at the other end of the specimen (see Figure 20). In the case of cables with more than three conductors, two adjacent circuit conductors shall be chosen. All other conductors shall be cut off even with the insulation at both ends of the specimen. Reference marks shall be placed on the conductors at both ends where they enter the insulation.

7.24.4 Procedure

7.24.4.1 Single conductor

The specified weight shall be attached to the specimen by tying the taped insulation to the weight. The bare conductor at the other end of the specimen shall be secured in the gripping assembly and the weight gently lowered and released so that it is supported by the specimen for the specified time period. The distance between the end of the insulation and the reference mark shall be measured with the weight in place.

7.24.4.2 Parallel multiconductor

The specified weight shall be attached to the bare circuit conductor at one end, and the weight and attached specimen shall then be supported from the bared end of the other circuit conductor for the specified time period. The distance between the end of the insulation and the reference mark shall be measured on both conductors with the weight in place.

7.24.5 Results and calculations

The additional length of bare conductor exposed during the test shall be noted.

7.24.6 Report

The report shall include, as a minimum, length of additional exposed conductor.

7.25 Tightness of armor

7.25.1 Scope

This test establishes the method for determining the ability of armor of a completed cable to adequately maintain a grip after pulling of the conductor assembly.

7.25.2 Apparatus

7.25.2.1 The apparatus shall consist of the following:

a) a pipe 3 m (9.8 feet) long and having an inside diameter slightly greater than the outside diameter of the armour of the specimen;

b) a pipe cap with a clearance hole, the diameter of which is slightly greater than the inside diameter of the armour; and

c) a specified weight.

7.25.2.2 The pipe shall be used to keep the test specimen approximately straight and shall be supported in a vertical position with the pipe cap attached to the lower end. The pipe cap provides a shoulder against which the armor of the specimen rests. The edges of the clearance hole in the cap shall be rounded.

7.25.3 Preparation of specimens

7.25.3.1 A specimen shall be taken from a reel or during manufacture and cut to a length of 3.5 m (11.5 ft.), and the armour removed from at least 0.5 m (19.7 in) at one end.

7.25.3.2 The ends of the armour shall be cut square and any burrs of metal removed. The specimen shall then be drawn into the pipe with the exposed conductor assembly projecting through the hole in the cap at the lower end of the pipe.

7.25.4 Procedure

The specified weight shall be attached to the conductor assembly projecting through the hole in the cap and shall be allowed to hang freely for 1 minute. Care shall be taken that the conductor assembly does not rub on the sides of the hole.

7.25.5 Results and calculations

The upper end of the specimen shall be examined to determine the distance the conductor assembly has receded into the armour.

7.25.6 Report

The test report shall include the following as a minimum:

a) Number and size of conductors; and

b) Distance conductor assembly receded into the armour.

7.26 Flexing of shielded cables

7.26.1 Scope

This test establishes the method for evaluating the conductors of shielded cables for resistance to breakage from repeated flexing.

7.26.2 Apparatus

The apparatus shall consist of the following:

a) a flexing apparatus (see Figure 21);

b) a cycle counter capable of counting a minimum of 15 000 cycles; and

c) an alternating current source capable of providing specified current and detecting conductor breakage and stopping the flexing apparatus.

7.26.3 Preparation of specimen

Six specimens, each 5 m (15 ft) in length, shall be cut from a sample of finished shielded cable. The ends of the circuit conductors shall be made bare.

7.26.4 Procedure

7.26.4.1 The circuit conductors in the specimens shall be connected in series with the current source and each other.

7.26.4.2 The test shall be conducted at ROOM TEMPERATURE. The specimens shall be mounted on the pulleys. The pulleys shall be mounted so that the specimens are horizontal as they pass between them. The weight, pulleys, and current used in the test shall be as specified in the product standard. The clamps at the ends of the specimens shall be positioned as shown in Figure 21.

7.26.4.3 With the specimens in place and rated current flowing in the circuit conductors, the two central pulleys shall be moved in tandem in a horizontal reciprocating motion. The motion shall be constant at the rate of 0.4 m/s (1.3 ft/s) or 12 cycles per minute, each cycle consisting of one complete back-and-forth motion through a stroke of approximately 1 m (3 ft).

7.26.4.4 The motion shall be continued until the specified number of cycles has been completed, or until a circuit conductor opens and the test has stopped automatically.

7.26.5 Results and calculations

The number of cycles at the time the test was stopped shall be noted.

7.26.6 Report

The report shall include, as a minimum, number of cycles completed for each specimen.

7.27 Mandrel pinch of ″-R″ cords

7.27.1 Scope

This test specifies the method for determining resistance to pinching of insulation and/or covering.

7.27.2 Apparatus

The apparatus shall consist of the following:

a) a power-driven compression machine provided with a device to measure and indicate the compression force at rupture accurate to 2% or less of the value read. The machine shall be capable of operating at a power-actuated jaw speed of 5 ±1.3 mm/min (0.20 ±0.05 in/min);

b) one flat steel plate 50 mm (2 in) wide;

c) a mandrel with a right-angle corner with a corner radius of 1.19 mm (0.046 in) (see Figures 22 and 23); and

d) a low-voltage ac power supply with a means of indicating contact between the circuit conductors, and between the circuit conductors and the grounding conductor, steel plate, or mandrel.

7.27.3 Preparation of specimens

7.27.3.1 The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall be a minimum of 300 mm (12 in) in length. One end of the conductor shall be made bare.

7.27.3.2 The plate, mandrel, and any grounding conductor shall be connected to earth ground. The circuit conductors shall be connected to the power supply.

7.27.4 Procedure

7.27.4.1 The steel plate shall be mounted horizontally in the compression machine. The mandrel shall be bolted or otherwise secured along the centerline of the plate, as indicated in Figure 23. The specimen, apparatus, and surrounding air shall be in thermal equilibrium at ROOM TEMPERATURE.

7.27.4.2 The specimen shall be centered on the steel plate at a right angle to the longitudinal axis of the mandrel. See Figure 23. The mandrel shall be lowered until contact is made with the surface of the specimen. The downward motion of the mandrel shall then be continued at the rate of 5 ±1.3 mm/min (0.20 ±0.05 in/min) until one of the indicators signals contact.

7.27.4.3 The force indicated by the compression machine at the moment of contact shall be recorded. The procedure shall be repeated four additional times.

7.27.5 Results and calculations

The results shall consist of the forces indicated by the compression machine at each moment of contact.

7.27.6 Report

The report shall include, as a minimum, the results in 7.27.5.

7.28 Mandrel crush of ″-R″ cords

7.28.1 Scope

This test specifies the method for determining resistance to crushing of insulation and/or covering.

7.28.2 Apparatus

The apparatus shall consist of the following:

a) a 90.7 kg (200 lb) mass contained by an appropriately supported structure;

b) one flat steel plate 50 mm (2 in) wide;

c) a mandrel with a right-angle corner with a corner radius of 1.19 mm (0.046 in) (see Figures 22 and 23);

d) a low-voltage ac power supply with a means of indicating contact between the circuit conductors, and between the circuit conductors and the grounding conductor, steel plate, or mandrel; and

e) a suitable timing device.

7.28.3 Preparation of specimens

7.28.3.1 The test specimen shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall be a minimum of 300 mm (12 in) in length. One end of the conductor shall be made bare.

7.28.3.2 The plate, mandrel, and any grounding conductor shall be connected to earth ground. The circuit conductors shall be connected to the power supply.

7.28.4 Procedure

7.28.4.1 The specimen, apparatus, and surrounding air shall be in thermal equilibrium at ROOM TEMPERATURE. The steel plate shall be mounted horizontally. The mandrel shall be position along the centerline of the plate, as indicated in Figure 23.

7.28.4.2 The specimen shall be centered on the steel plate at a right angle to the longitudinal axis of the mandrel. (See Figure 23.) The mandrel shall be lowered until contact is made with the surface of the specimen. The mass shall then be lowered onto the top of the mandrel. The specimen shall be left under test under these conditions for the lesser of seven hours, or until contact is made.

7.28.4.3 Record whether any electrical contact occurs during the test. The procedure shall be repeated four additional times.

7.28.5 Results and calculations

The results shall consist of whether electrical contact occurred during the test.

7.28.6 Report

The report shall include, as a minimum, the results in 7.28.4.

7.29 Flexing of ″-R″ cords

7.29.1 Scope

This test specifies the method for determining resistance to flexing of insulation and/or covering.

7.29.2 Apparatus

The apparatus shall consist of the following:

a) a means of flexing the specimen using a flexing cycle consisting of bending the specimen to a position 90 degrees from the vertical, back through 180 degrees from that position, and then back to the vertical (see Figures 24 – 26);

b) a power supply capable of providing 300 ±2 V ac and the current specified (see Figures 24 – 26);

c) a 300 ±2 V variable electrical resistive load;

d) an L-bracket measuring 38.1 mm (1.5 inches) deep and 38.1 mm high with a slot having dimensions as shown in Figure 25;

e) a cord attachment bracket shown in Figure 26;

f) six 110 g (0.25 lb) weights;

g) a circuit to detect conductor breakage and stop the flexing apparatus;

h) six smoothly rounded bushings having a 25.4 mm (1 in) diameter opening; and

i) a time-delayed fuse, as indicated in Table 6.

7.29.3 Preparation of specimens

The test specimens shall be taken from a sample of finished wire or cable, or from the wire or cable during manufacture without any conditioning. The specimen shall of a sufficient length. Both ends of the conductors shall be made bare.

7.29.4 Procedure

7.29.4.1 Each supply cord specimen shall be mounted through a slot in the L-bracket of the test fixture shown in Figure 25. The cord shall exit vertically through the top surface of the bracket base and shall be routed across a curved surface for attachment, see Figure 26.

7.29.4.2 Each specimen shall be passed through a horizontal bushing. The free end of each specimen shall be attached to an unsupported weight.

7.29.4.3 The grounding conductors shall be connected to earth ground. The circuit conductors shall be connected to the power supply, as indicated in Figure 24.

7.29.4.4 The conductors shall be loaded to the maximum rated current based on conductor size and cord type. A voltage of 300 V shall be applied between the conductors. Current shall not be passed through the grounding conductor, which shall be connected to ground. The circuit shall be protected by a time-delay fuse. One or more series current relays shall be provided to shut down the machine if a conductor opens.

7.29.4.5 The six specimens shall be flexed at a rate of approximately 20 cycles per minute for 3,100 cycles or until open circuit or short circuit occurs. One cycle consists of 90-degree rotation of the test assembly in one direction, 180-degree rotation in the opposite direction, and then return to the starting point.

Note: *The flex shall be in the direction of smallest cord cross-section.*

7.29.5 Results and calculations

The following conditions shall be recorded for each specimen:

a) development of an open circuit;

b) development of a short circuit;

c) breakage of more than 10 percent of the strands of any circuit or grounding conductor;

d) broken strands piercing the insulation and becoming accessible;

e) cracking or degradation of the cord insulation; or

f) exposure of the shield on shielded constructions.

7.29.6 Report

The report shall include, as a minimum, the results in 7.29.5.

7.30 Armored cable bushing insertion

7.30.1 Scope

This test establishes the method to determine that the construction of an armored cable suitably accepts the proper insertion of a cable bushing.

7.30.2 Apparatus

The apparatus for this test shall include the following:

a) a sample of armored cable taken from a reel or from manufacture; and

b) cable bushing of a size appropriate for the cable to be tested.

7.30.3 Preparation of specimens

Approximately 50 mm (2 in) of armor shall be removed from one end of the cable. If it is intended that the fibrous covering be removed before a bushing is inserted, such covering shall be removed manually from the conductor assembly.

7.30.4 Procedure

The bushing shall be inserted between the conductors and the armor.

7.30.5 Results

It shall be observed whether or not the bushing can be readily inserted such that the flange on it comes into contact with the cut end of the armor, and that it remains in that position after pressure has been removed.

7.30.6 Report

The report shall include as a minimum, the following:

a) description of cable;

b) trade size of bushing; and

c) whether the bushing remains in position after insertion pressure is removed.

8 Environmental tests for finished wire and cable

8.1 Copper corrosion

8.1.1 Scope

This test establishes the method for determining the chemical compatibility of copper, copper alloy, or copper-clad aluminum conductors in contact with insulation material.

8.1.2 Apparatus

The apparatus shall consist of the following:

a) a forced-circulation air oven in accordance with 4.2.3(i); and

b) a temperature-measuring device with an accuracy of ±1°C.

8.1.3 Preparation of specimens

Two specimens of insulated conductor shall be cut to lengths not less than 300 mm (12 in) that allow for at least one specimen to be placed in the oven vertically.

8.1.4 Procedure

8.1.4.1 One specimen shall be conditioned at ROOM TEMPERATURE. The second specimen shall be conditioned in the oven at the specified temperature for the specified period of time. Oven temperatures shall be recorded throughout the period of conditioning. The specimen shall then be removed from the oven and allowed to cool to ROOM TEMPERATURE.

8.1.4.2 The insulation shall be stripped from the conductors of both specimens and the surface of the conductors examined with NORMAL VISION.

8.1.5 Results and calculations

Any evidence of corrosion of the copper (normal oxidation or discoloration not caused by the insulation or any separator shall be disregarded) shall be noted.

8.1.6 Report

The report shall include, as a minimum, the following:

a) test temperature;

b) test duration; and

c) evidence of corrosion on conditioned and unconditioned specimens.

8.2 Ozone resistance

8.2.1 Scope

This test method is used to determine the resistance of insulated wire or cable to degradation when exposed to specified concentration of ozone in air or oxygen.

8.2.2 Materials and reactants

Materials and reactants shall consist of

a) Ambient air or compressed air supply with adequate filtration of particulate matter. The moisture content of the air source shall be minimized; and

b) a cooling water system for operating temperature below 49°C.

8.2.3 Apparatus

The apparatus* shall consist of the following:

a) an ozone generator for generating a controlled amount of ozone, by means of either an ultraviolet light source, corona discharge or a combination of both. The ozone generator shall be equipped with a variable power controller to adjust the ozone generator output. The ozone generating source shall be isolated from the internal chamber but within the integral external structure;

b) an ozone test chamber with the following:

1) a chamber interior of stainless steel, with all seams sealed and the chamber door provided with a gasket to assure leakproof operation so as not to affect the ozone concentration during the duration of the test;

2) an automatic control system that regulates and maintains the set point ozone concentration and corrects for external barometric pressure, temperature and relative humidity;

3) a means for circulating ozonized air under controlled conditions of humidity and temperature through the chamber. The source of air may be ambient or from a compressed air supply. Adequate filtration of particulate matter from the source shall be minimized, either through filtration, a desiccant or by other means;

4) the door sealed to prevent loss of partial pressure that would affect the ozone concentration for the duration of the test. If equipped with an observation window, it shall be of tempered glass;

5) a volume of not less than 0.14 m^3 (5 ft^3);

6) installed in an environment free from dust, smoke or other volatiles which may affect the performance of the automatic measurement and control system;

7) a cooling water system provided for operating temperatures below 49°C; and

8) the chamber exhaust properly routed to the atmosphere; and

c) an ozone measurement and control system.

The ozone concentration shall be determined using standard gas laws based upon the absorption of ultra-violet light in conjunction with the partial pressure of ozone in a controlled air-ozone mixture.

Note: *There are other techniques used to measure gaseous ozone such as the wet chemical method which is based on the absorption of ozone in a potassium iodide solution and titration of the released iodine with sodium thiosulfate. However, the UV absorption method has been found to be more accurate and precise and as such, is now commonly used and has been used against which others are calibrated.*

*There is currently only one known source of ozone test apparatus at this time – Ozone Research Equipment Co., a division of CCSi, Inc. 1145 Highbrook Avenue, #500, Akron, OH 44301. The OREC 0500-0900 Series Ozone test chambers and Model 03DM-100 ozone monitor have been found suitable. Equivalent apparatus are also acceptable.

8.2.4 Preparation of specimens

8.2.4.1 Two specimens shall be selected from a point beyond 1.5 m (4.9 feet) from the end of the reel or coil to be tested. If protective coverings have been applied, they shall be removed when non-adherent. Where tapes or sheaths are applied prior to curing, are left in place during curing, and are consequently adherent to the test specimen in the completed cable, such coverings shall not be removed. Specimens shall be examined to ensure they are free from mechanical defects, such as cuts, dents, tears, and loose threads.

8.2.4.2 The specimens shall be bent as follows:

a) One specimen, at a temperature not less than 20°C, shall be bent in the direction of its existing curvature, without twisting, one turn around a brass, aluminum, or suitably treated wooden mandrel having a diameter as shown in Table 7.

b) The second specimen shall be bent in a similar manner, but in the direction opposite to the existing curvature.

c) Each of the bent specimens shall be tied with tape at the point where the ends cross. If the specimen is too rigid to permit crossing of the ends, it may be bent in the form of a “U” and tied so that at least a 180 degree bend of the appropriate diameter is obtained.

d) The specimen shall conform closely to the periphery of the mandrel.

e) The surface of each specimen shall be wiped with a clean cloth to remove dirt or moisture.

f) The bent specimen on its mandrel shall be placed in a desiccator for a minimum of 30 to 45 minutes to remove the surface moisture, and then left in the desiccator until it is placed in the ozone test chamber.

8.2.5 Procedure

8.2.5.1 All equipment shall be calibrated in accordance with the equipment manufacturer's instructions.

8.2.5.2 Prior to bending of the specimen the atmosphere in the exposure chamber shall be conditioned as follows:

a) The exhaust system above the chamber shall be turned on.

b) The system parameter verification check shall be performed prior to start up.

c) The temperature of the air in the test chamber shall be adjusted to the specified oven temperature.

d) The desired ozone concentration shall be set on the control panel.

8.2.5.3 After the ozone chamber has been in equilibrium operation for at least 45 minutes at the specified ozone concentration and temperature, the test specimen on the mandrel shall be placed in the test chamber. Care shall be taken not to handle the material under test. The specimen shall be supported with the axis of the mandrel horizontal and midway between the top and bottom of the chamber, with the free ends of the specimen pointing down but not touching the bottom of the chamber.

8.2.5.4 After exposure for 3 hours to ozone at the specified concentration and temperature, the test specimen shall be removed from the chamber. Any covering on the specimen shall be removed.

8.2.6 Results and calculations

The insulation or jacket, whichever applicable, shall be examined by NORMAL VISION for cracks in the bent portion only.

8.2.7 Test report

The report shall include the following as a minimum:

a) Temperature in the ozone chamber, °C;

b) Exposure time, hours;

c) Ozone concentration, % by volume or ppm;

d) Any evidence of cracks; and

e) Mandrel diameter.

8.3 Copper sulfate test for zinc coatings on formed and unformed steel strip (preece test)

8.3.1 Scope

This test establishes the method for determining the performance of zinc coatings for formed and unformed steel strip for finished armored cable.

8.3.2 Apparatus

The apparatus for the test shall consist of the following:

a) a vessel of glass or other chemically nonreactive material having a width of at least twice the widest dimension of the specimen;

b) a glass thermometer;

c) a timing device that indicates elapsed seconds;

d) a standard solution of copper sulfate;

e) paper towels or cheesecloth;

f) a solvent such as trichloroethylene or chloroform; and

g) a source of running tap water.

8.3.3 Materials and reactants

The requirements for the standard solution and wash water shall be as follows:

8.3.3.1 Preparation of solution

8.3.3.1.1 Copper sulfate solution shall be made by dissolving approximately 36 parts by weight of commercial reagent grade copper sulfate ($CuSO_4$) crystals in 100 parts by weight of distilled water.

Note: *Chemically pure (cp) copper sulfate crystals are preferable to commercial grade, although not necessary, for the Preece test.*

8.3.3.1.2 If heat is used to complete the solution of copper sulfate crystals, the solution shall be allowed to cool. The solution shall then be agitated with an excess of powdered cupric hydroxide [$Cu(OH)_2$], approximately 0.8 g/L of solution.

8.3.3.1.3 The neutralized solution shall be allowed to stand for 24 hours and then filtered or decanted.

Note 1: *An excess of cupric hydroxide is present when the sediment of this reagent accumulates at the bottom of the vessel.*

Note 2: *Cupric oxide (CuO) of approximately 0.7 g/L of solution may be substituted for cupric hydroxide provided that the solution is allowed to stand not less than 48 hours after this addition and before filtering or decanting.*

8.3.3.1.4 The test solution shall have a relative density of 1.186 at 18°C. To adjust a solution of inappropriate relative density, distilled water shall be added if the relative density is high, and a copper sulfate solution of a higher relative density shall be added if the relative density is low.

8.3.3.2 Quantity of solution

The quantity of copper sulfate solution required for each test depends on the superficial area of the test specimen and the mass of coating. The quantity shall not be less than 40 ml/g of zinc coating on the specimen and shall be sufficient to cover the specimen so that the top surface of the solution is at least 10 mm (0.4 in) above the top of the section of the specimen under test.

Note: *The theoretical minimum amount of copper sulfate solution required to dissolve 1 g of zinc is 13.3 ml. The quantity specified is three times this minimum to ensure an adequate rate of solution.*

8.3.3.3 Wash water

Tap water shall be used for rinsing. If no running water is available, the rinse water shall be changed often enough, preferably after each dip, to ensure that it is reasonably free from copper sulfate. The temperature of the rinse water shall be 18 ±3°C.

8.3.4 Preparation of specimens

8.3.4.1 The required quantity of specimens 150 mm (6 in) in length (axial measurement) shall be cut from partially uncoiled armor, free from abrasions from which the conductor assembly has been removed. The required quantity of additional straight specimens 150 mm (6 in) in length shall be cut from a sample length of the zinc-coated steel strip before forming.

8.3.4.2 All grease, etc., shall be removed by washing the specimen in trichloroethylene or chloroform. The specimen shall then be rinsed in water and dried with paper towels, and the zinc surface clean before immersion in the copper sulfate solution. Care shall be taken to avoid contact of the cleaned surface with foreign objects, particularly the hands.

8.3.4.3 At one end of a sample length of finished cable, the armor shall be unwound from the outside to expose to view, both edges and the inner surface of the formed strip, and to facilitate working cheesecloth between the turns onto the inner surface to dry that surface during the test. In order to reduce the damage to the zinc coating, the strip shall not be straightened as it is unwound but shall remain in the helical form with a diameter not larger than approximately three times the cable diameter.

8.3.4.4 The specimens shall be cleaned with an organic solvent. Each specimen shall be examined for evidence of damage to the zinc coating occurring during specimen preparation, not during forming, and only specimens that are not damaged shall be selected for use in the test. One specimen of the unformed strip and one specimen of the armor shall be tested.

8.3.4.5 The two selected specimens shall be rinsed in water, and all of their surfaces dried with clean cheesecloth, removing as much of the water as possible in the drying operation as water slows the reaction between the zinc and the solution, thereby adversely affecting the test results.

8.3.4.6 The surface of the zinc shall be dry and clean before a specimen is immersed in the copper sulfate solution. The specimens shall not be touched by the hands or in any way that can contaminate or damage the surfaces.

8.3.5 Procedure

8.3.5.1 The vessel described in 8.3.2(a) shall be filled with the solution described in 8.3.3.1 – 8.3.3.2 to a depth sufficient to immerse not less than half the axial length of the specimen. The temperature of the solution shall be 18 ±1°C. The specimen shall then be placed in a vertical position in the center of the vessel containing the standard solution. The specimen shall remain in the solution for 60 seconds, during which time it shall not be moved and the solution shall not be stirred.

8.3.5.2 After 60 seconds, the specimen shall be removed from the vessel, immediately rinsed in a stream of running water, and rubbed dry with a clean, wet, lint-free cloth until any loosely adhering deposits of copper are removed. The turns of the specimen of partially uncoiled armor shall not be further separated during this process, and hands and other damaging and contaminating objects and substances shall not be allowed to touch any surfaces that were immersed.

> **Note:** *A clean soft-bristle test-tube or bottle brush in good condition and of applicable size may be used to rub (only) the interior surfaces of the specimen of partially uncoiled armor.*

8.3.5.3 The procedures in 8.3.5.1 – 8.3.5.2 shall be repeated until the specified total number of immersions has been made. Following completion of testing on each specimen, a fresh portion of the standard solution employed for each additional specimen.

> **Note:** *A fixed deposit of copper generally occurs first at the weakest points in the zinc coating and increases in area upon successive dips until the entire zinc coating disappears.*

8.3.6 Results and calculations

8.3.6.1 The condition of the portion of the specimen that was immersed shall be examined for a bright deposit of closely adhering metallic copper on all or any part of that portion. Each edge and broad surface shall be considered separately. The portion of the specimen within 13 mm (0.5 in) of its immersed end shall be disregarded.

8.3.6.2 In the case of interlocked armor, if there is a deposit, an estimate shall be made of the ratio of the copper-covered surface to the total surface immersed, expressed as a percentage. The estimate shall be based on examination with NORMAL VISION. The surface within 10 mm (0.4 in) of the cut end shall be disregarded.

8.3.7 Report

The report shall include, as a minimum, the following:

a) presence of bright deposits, if any, on edges or on broad surfaces after each immersion; and

b) for interlocked armor, estimated ratio of copper-covered surface to total surface immersed, after each immersion.

9 Burning characteristics tests

9.1 FT2/FH/Horizontal flame

9.1.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the horizontal propagation of flame and the dropping of flaming particles.

9.1.2 Materials and reactants

Materials and reactants shall consist of the following:

a) methane, at 98% minimum purity, having a heat content of 37 ±1 MJ/m^3 (1000 ±30 Btu/ft^3) at 25°C and 101 kPa (14.7 psi); or natural gas, with a heat content of 37 ±1 MJ/m^3 (1000 ±30 Btu/ft^3) at 25°C and 101 kPa (14.7 psi); and

Note: *Alternative gases, such as propane, at a 95% minimum purity, having a heat content of* 94 ±2 MJ/m^3 *(2540 ±50 Btu/ft^3) at* 25°C *and* 101 kPa *(14.7 psi) or butane, at 99% minimum purity, having a heat content of* 120 ±3 MJ/m^3 *(3240 ±80 Btu/ft^3) at* 25°C *and* 101 kPa *(14.7 psi), may be used if a stable flame is obtained and the heat evolution profile complies with ASTM D5207 or NMX-J-192-ANCE or IEC 60695-11-3.*

CAUTION: Propane and butane gases are denser than air and can settle and become an explosion hazard. Consult the gas supplier for special precautions to be taken.

b) surgical cotton, dry and untreated.

9.1.3 Apparatus

The apparatus shall consist of the following:

a) a draft-free chamber having a means for access and viewing that can be sealed. Each linear interior dimension of the chamber shall be at least 610 mm (24 in). The interior volume of the chamber shall be at least 4 m^3 (140 ft^3), including the volume of an exhaust transition, if any. At least 2 m^3 (70 ft^3) of this volume shall be above the point of impingement of the flame on the specimen, as space for the heat and smoke to accumulate so as not to influence the test;

b) an angle block (see Figure 27) to place the burner at a 20 ±1 degree angle from the vertical position. The angle block shall be capable of moving the flame into position on the specimen. It shall also be capable of directing the flame away from the specimen beyond vertical, or withdrawing the flame a minimum distance of 150 mm (6 in) from the specimen;

c) laboratory stands or other supports used to secure the specimen. These shall not create updrafts or impede the air supply to the flame. Regardless of the method employed, the specimen supports shall be 200 to 230 mm (7 to 9 in) apart;

d) a laboratory burner conforming to ASTM D 5025 or NMX-J-192-ANCE or IEC 60695-11-3, suitable for the calorific value of the gas and having an inside diameter of 9.5 ±0.3 mm (0.375 ±0.01 in) and a length of 100 ±10 mm (4.0 ±0.4 in) above the primary-air inlets. The burner shall be calibrated in accordance with ASTM D 5207 or NMX-J-192-ANCE or IEC 60695-11-3 each time a cylinder of gas, when used, is changed or refilled, or any of the apparatus is changed;

Note: *It is recommended that the burner flame be calibrated at least every 30 days and each time that a cylinder of gas is changed or if any of the apparatus is changed. It is also recommended that where the gas used is other than the grade of methane specified for referee purposes, the burner flame be calibrated each day immediately before testing is begun.*

e) a length-measuring device accurate to 5% of char length requirement;

f) a flame height gauge capable of measuring the specified flame heights; and

g) a timing device capable of measuring the specified times in seconds, having a resolution of 1 second and an accuracy of ±0.5 second.

9.1.4 Preparation of specimens

A specimen shall be taken from a sample of wire, cable, or cord, finished or during manufacture, 250 to 300 mm (10 to 12 in) long, and shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours, then straightened and secured horizontally to the specimen supports. In the case of flat parallel constructions, the specimen shall be secured with its major axis in the vertical position.

9.1.5 Procedure

9.1.5.1 The height of the test flame, with the burner vertical, shall be adjusted to 125 ±10 mm (5.0 ±0.4 in), with an inner blue cone 40 ±2 mm (1.6 ±0.1 in) high. The burner shall be attached to the angle block to position the burner at an angle of 20 degrees from vertical.

9.1.5.2 A flat horizontal layer of cotton, 6 ±3 mm (0.25 ±0.12 in) thick and having dimensions of approximately 200 x 200 mm (8.0 x 8.0 in) shall cover the floor of the enclosure and be centered under the specimen. The upper surface of the cotton shall be 230 to 240 mm (9.0 to 9.5 in) below the point at which the tip of the inner blue cone touches the specimen.

9.1.5.3 The test chamber and exhaust system shall be sealed and the fan shall be off during the test. The burner shall be moved into position such that the tip of the inner blue cone of the test flame is applied to the center of the specimen (see Figure 28). After 30 seconds the flame shall be withdrawn and the specimen shall be allowed to burn until it self-extinguishes.

9.1.5.4 After the specimen has extinguished, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.1.6 Results and calculations

9.1.6.1 The length of damage to the specimen shall be measured and recorded. Damage is defined as charring, burning, or melting.

9.1.6.2 Ignition of the cotton, if any, shall be recorded. Flameless charring of the cotton shall be ignored.

9.1.7 Report

The test report shall include, as a minimum, the following:

a) length of damage to the specimen; and

b) indication of ignition of cotton.

9.2 Burning particles (dropping)

9.2.1 Scope

This test establishes the method for determining the resistance to dropping of burning particles of wire or cable insulation during and after the application of a test flame.

9.2.2 Materials and reactants

Materials and reactants shall consist of

a) methane as described in 9.1.2(a); and

b) standard newsprint having a mass of 46.4 to 57.0 g/m^2 (0.086 to 0.105 lb/yd^2), a maximum thickness of 0.11 mm (0.043 in), and a maximum ash content of 6.5%.

9.2.3 Apparatus

The apparatus shall consist of the following:

a) the apparatus as described in 9.1.3(a), (b), and (d), and a means for supporting the test specimen in a vertical position;

b) a test shield of sheet metal 300 ±50 mm (12 ±2 in) wide, 350 ±50 mm (14 ±2 in) deep, and 600 ±50 mm (24 ±2 in) high open at the top and front and provided with means for supporting the test specimen in the vertical position; and

c) a steel plate with a minimum thickness of 3 mm (0.1 in) with approximate dimensions of 200 x 300 mm (8 x 12 in).

9.2.4 Preparation of specimens

9.2.4.1 A specimen 450 to 600 mm (18 to 24 in) in length shall be taken from a sample of wire, cable, or cord, finished or taken from manufacture. The specimen shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours, then straightened and secured vertically with the specimen supports.

9.2.4.2 The bottom support shall be at least 50 mm (2 in) below the point of impingement of the test flame. The top support shall be at least 300 mm (12 in) above of the point of impingement of the test flame.

9.2.5 Procedure

9.2.5.1 The specimen, apparatus, and surrounding air shall be at ROOM TEMPERATURE.

9.2.5.2 The steel plate shall be placed on the floor of the chamber under the specimen. A sheet of newsprint with approximate dimensions of 200 x 300 mm (8 x 12 in) shall be laid flat on the steel plate.

9.2.5.3 The height of the test flame, with the burner vertical, shall be adjusted to 125 ±10 mm (4.9 ±0.4 in), with an inner blue cone 40 ±2 mm 1.6 ±0.1 in) high. The burner shall be attached to the angle block to position the burner at an angle of 20 degrees from vertical.

9.2.5.4 The test chamber and exhaust system shall be sealed and the fan shall be off during the test. The tip of the inner blue cone of the test flame shall be applied to the specimen for 15 seconds, and then removed for 15 seconds. The tip of the blue cone shall impinge the specimen at a distance not greater than 238 mm (9.375 in) above the newsprint (see Figure 29).

9.2.5.5 The application of the flame in 9.2.5.4 shall be repeated until 5 applications of the flame have been made. During the test and up to 60 seconds following the fifth flame application, the newsprint shall be monitored for evidence of ignition caused by dropping of burning particles.

9.2.5.6 After the specimen has extinguished, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.2.6 Results and calculations

Combustion of the newsprint, or the presence of holes in the newsprint, shall be recorded.

9.2.7 Report

The test report shall include, as a minimum, evidence of combustion or holes in the newsprint.

9.3 FT1

9.3.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the vertical propagation of flame.

9.3.2 Materials and reactants

Materials and reactants shall consist of the following:

a) methane as described in 9.1.2(a); and

b) 94 g/m^2 (60 lb) kraft paper with a nominal thickness of 0.13 mm (0.005 in), gummed on one side.

9.3.3 Apparatus

The apparatus shall consist of the following:

a) the apparatus as described in 9.1.3(a), (b), and (d), and a means for supporting the test specimen in a vertical position; and

b) a test shield as described in 9.2.3(b).

9.3.4 Preparation of specimens

9.3.4.1 A specimen having a length of 457 – 610 mm (18 – 24 in) taken from a sample of wire, cable, or cord, finished or taken during manufacture, shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours and straightened.

9.3.4.2 A strip of kraft paper 12.5 ±1 mm (0.5 ±0.1 in) wide shall be moistened just enough to facilitate adhesion. With the gum toward the specimen, the strip shall be wrapped once around the specimen, with its lower edge 254 ±2 mm (10 ±0.1 in) above the point at which the tip of the inner blue cone of the flame impinges on the specimen. The ends of the strip shall be pasted together evenly and trimmed to result in an indicator flag that projects nominally 20 mm (0.75 in) opposite to the side to which the flame shall be applied. On a flat specimen, the flag shall project from the center of the broad face of the specimen.

9.3.5 Procedure

9.3.5.1 The specimen, apparatus, and surrounding air shall be at ROOM TEMPERATURE.

9.3.5.2 The specimen shall be mounted vertically in the supports in the chamber (see Figure 29). The lower specimen support shall be located at least 50 mm (2 in) below the point at which the inner blue cone of the flame shall impinge on the specimen. The blue cone shall impinge the specimen at a distance not greater than 238 mm (9.375 in) above the bottom of the apparatus. The upper specimen support shall be located at least 50 mm (2 in) above the top of the kraft paper flag.

9.3.5.3 With the burner vertical, the height of the test flame shall be adjusted to 125 ±10 mm (5 ±0.4 in), with an inner blue cone 40 ±2 mm (1.6 ±0.1 in) in length. The burner shall then be positioned on the angle block, with its barrel at an angle of 20 degrees to the vertical.

9.3.5.4 The motion of the angle block shall allow smooth removal of the flame from the specimen and smooth reapplication of the flame.

The alignment of the angle block shall be such that the longitudinal axis of the burner barrel and the longitudinal axis of the specimen are in the same plane.

9.3.5.5 The angle block shall be moved into position such that the tip of the inner blue cone of the flame impinges on the outer surface of the specimen for 15 seconds, and is then moved away for 15 seconds. This cycle shall be repeated until 5 applications of the flame have been completed. In all cases, the movement of the angle block shall be smooth and quick, with minimum disturbance of the chamber air. On a flat specimen, the flame shall impinge on the center of the broad face of the specimen. If the specimen changes location due to heating or burning, the position of the burner shall be adjusted so that the point of impingement remains on the same location of the specimen.

9.3.5.6 After the test is completed, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.3.6 Results and calculations

During and after the test, the following shall be recorded:

a) percentage of the indicator flag burned away or charred (other than simply scorched or soot-covered; the portion of the kraft paper in contact with the specimen is not considered part of the flag); and

b) time for flaming of the specimen to self-extinguish, after removal of the burner flame following the fifth application.

9.3.7 Report

The report shall include, as a minimum, the following:

a) percentage of the indicator flag burned away or charred; and

b) indication if flaming of the specimen exceeds 60 seconds after removal of the burner flame following the fifth application.

9.4 FV-2/VW-1

9.4.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the vertical propagation of flame and dropping of flaming particles.

9.4.2 Materials and reactants

Materials and reactants shall consist of the following:

a) methane as described in 9.1.2(a);

b) surgical cotton as described in 9.1.2(b); and

c) kraft paper as described in 9.3.2(b).

9.4.3 Apparatus

The apparatus shall be as described in 9.1.3(a), (b), and (d), and a means for supporting the test specimen in a vertical position.

9.4.4 Preparation of specimens

9.4.4.1 A specimen having a minimum length of 610 mm (24 in) taken from a sample of wire, cable, or cord, finished or taken during manufacture, shall be conditioned at ROOM TEMPERATURE for a minimum of 6 hours and straightened.

9.4.4.2 A strip of kraft paper 12.5 ±1 mm (0.5 ±0.1 in) wide shall be moistened just enough to facilitate adhesion. With the gum toward the specimen, the strip shall be wrapped once around the specimen, with its lower edge 254 ±2 mm (10 ±0.1 in) above the point at which the inner blue cone of the flame impinges on the specimen. The ends of the strip shall be pasted together evenly and trimmed to result in an indicator flag that projects nominally 20 mm (0.75 in) opposite to the side to which the flame shall be applied. On a flat specimen, the flag shall project from the center of the broad face of the specimen.

9.4.5 Procedure

9.4.5.1 The specimen, apparatus, and surrounding air shall be at ROOM TEMPERATURE.

9.4.5.2 The specimen shall be mounted vertically in the supports in the chamber (see Figure 29). The lower specimen support shall be located at least 50 mm (2 in) below the point at which the inner blue cone of the flame shall impinge on the specimen . The upper specimen support shall be located at least 50 mm (2 in) above the top of the kraft paper flag.

9.4.5.3 A continuous horizontal layer of cotton shall be placed on the floor of the test chamber, centered on the vertical axis of the test specimen, extending 75 to 100 mm (3 to 4 in) outward in all directions except in the direction of the burner, where it shall extend to just contact the angle block. The upper surface of the cotton shall be 235 ±6 mm (9.25 ±0.25 in) below the point at which the tip of the blue inner cone of the flame shall impinge on the specimen. There shall be no cotton on the burner, or on or under the angle block.

9.4.5.4 With the burner vertical, the height of the test flame shall be adjusted to 125 ±10 mm (5.0 ±0.4 in), with an inner blue cone 40 ±2 mm (1.6 ±0.1 in) in length. The burner shall then be positioned on the angle block, with its barrel at an angle of 20 degrees to the vertical.

9.4.5.5 The motion of the angle block (to allow smooth removal of the flame from the specimen, and smooth reapplication of the flame) shall not disturb the layer of cotton on the floor of the enclosure.

The alignment of the angle block shall be such that the axis of the burner barrel and the longitudinal axis of the specimen are in the same plane.

9.4.5.6 The angle block shall be moved into position such that the tip of the inner blue cone of the flame impinges on the outer surface of the specimen for 15 seconds, and is then moved away for 15 seconds. This cycle shall be repeated until 5 applications of the flame have been completed. In all cases, the movement of the angle block shall be smooth and quick, with minimum disturbance of the chamber air. On a flat specimen, the flame shall impinge on the center of the broad face of the specimen. If the specimen changes location due to heating or burning, the position of the burner shall be adjusted so that the point of impingement remains on the same location of the specimen.

9.4.5.7 When any specimen emits flaming or glowing particles or flaming drops that fall outside the area of the testing surface covered by the cotton, or fall onto the wedge or burner, or both, the test results shall be discarded and the test repeated. For the repeat test, the area covered by the cotton may be increased, placed over the wedge, or both.

9.4.5.8 When flaming of the specimen persists longer than 15 seconds after removal of the burner flame, the burner flame shall not be re-applied until immediately after the flaming ceases. If flaming ceases and only GLOWING COMBUSTION continues after 15 seconds, the burner flame shall be re-applied.

9.4.5.9 After the test is completed, the exhaust system shall be activated to remove all smoke and fumes from the chamber.

9.4.6 Results and calculations

During and after the test, the following shall be recorded:

a) percentage of the indicator flag burned away or charred (other than simply scorched or soot-covered; the portion of the kraft paper in contact with the specimen is not considered part of the flag);

b) any ignition of the cotton. Flameless charring of the cotton shall be ignored; and

c) time for flaming of the specimen to self-extinguish, after the end of each application of the burner flame.

9.4.7 Report

The report shall include, as a minimum, the following:

a) percentage of the indicator flag burned away or charred;

b) any ignition of the cotton; and

c) indication if flaming of the specimen exceeds 60 seconds after removal of the burner flame following any application.

9.5 FV-1/Vertical flame

This test is identical to that described in 9.4 except that 9.4.5.8, 9.4.6(c), and 9.4.7(c) shall not apply; that is, during the test procedure, the flame shall be reapplied after 15 seconds, regardless of whether flaming of the specimen persists longer than 15 seconds. The time for flaming of the specimen to self-extinguish shall be recorded after removal of the burner flame following the fifth application. Indication of flaming of the specimen in excess of 60 seconds after removal of the flame following the fifth application shall be included in the report.

9.6 Vertical tray flame tests (Method 1 – Vertical tray and Method 2 – FT4)

9.6.1 Scope

This test establishes the method for determining the resistance of a wire, cable, or cord to the propagation of flame, while installed in a vertical tray.

9.6.2 Materials and reactants

Materials and reactants shall consist of

a) propane at a minimum 95% purity, having a heating value of 94 ±2 MJ/m^3 (2540 ±50 Btu/ft^3); and

b) compressed air.

Note: *Propane gas defined as Special Duty Propane in ASTM D1835 or HD-5 Propane as defined in GPA Standard 2140 is recommended.*

CAUTION: Propane gas is denser than air and can settle and become an explosion hazard. Consult the gas supplier for special precautions to be taken.

9.6.3 Apparatus

The test apparatus shall consist of the following:

a) a test enclosure and exhaust duct (see Annex H, H.1 and H.2, and Figures H.1 – H.3), located in a test building that has vents for the discharge of combustion products and provisions for fresh-air intake;

b) an exhaust fan and baffle system capable of producing an exhaust flow rate of 0.65 ±0.5 m^3/s (23.0 ±1.8 ft^3/s) or 5 ±0.4 m/s (16.4 ±1.31 ft/s) in the duct (see Figure H.2);

c) velocity-measuring equipment (see Figure H.1) such as:

1) bi-directional probe (see Figure H.3);

2) temperature probe – Type K with an inconel sheath;

3) low pressure transducer (manometer) having a minimum resolution of 0.025 Pa (0.001 lb/in^2); and

4) computer controls/data acquisition equipment;

d) a gas train system (see Figure H.7) arranged such that the air and propane are mixed through the venturi mixer prior to entering the burner and composed of:

1) propane flow meter capable of measuring a flow rate of 2.3 x 10^{-4} m^3/s (29 ft^3/h) to an accuracy of ± 3% (see Note 2);

2) airflow meter capable of measuring a flow rate of 13.3 x 10^{-4} m^3/s (170 ft^3/h) to an accuracy of ± 3% (see Note 3);

3) needle valves for controlling the flow of propane and air;

4) a venturi mixer (see Note 4);

5) a ribbon burner (see Note 4) having a flame-producing surface (face) consisting of a flat metal plate that is 341 mm (13-7/16 in) long and 30 mm (1-5/32 in) wide. The plate shall have an array of 242 holes drilled in it (see Figure H.5); and

6) pressure regulators for propane and compressed air;

e) an ignition system;

f) steel cable trays (see Figure H.4);

g) wire (copper or steel) ties not larger than 2.1 mm^2 (14 AWG);

h) a flame height gauge (optional, see Figure H.1);

i) a hand-held vane anemometer capable of measuring wind speeds of 1 m/s (3.3 ft/s); and

j) a length-measuring device accurate to 0.1% of length measured.

Note 1: *Provisions for the filtering of discharged gases and for compliance with safety and local environmental codes are not addressed in this Standard.*

Note 2: *A propane flow meter (catalog no. 58-162788-00), available from Dwyer Instruments, 102 Indiana Hwy. 212, Michigan City, IN 46361-0373, USA, has been found to be suitable. Equivalent apparatus is also acceptable.*

Note 3: *An airflow meter (catalog no. RMC-103), available from Dwyer Instruments, 102 Indiana Hwy. 212, Michigan City, IN 46361-0373, USA, has been found to be suitable. Equivalent apparatus is also acceptable.*

Note 4: *A ribbon burner (catalog no. 10L 11-55) and venturi mixer (catalog no. 14-18) available from the AGF Burner Inc., 1955 Swarthmore Ave., Lakewood, NJ 08701, USA, have been found to be suitable. Equivalent apparatus are also acceptable.*

9.6.4 Preparation of specimen

9.6.4.1 General

9.6.4.1.1 Samples shall be taken from finished wire, cable, or cord.

9.6.4.1.2 Provisions shall be made within the chamber for securing the tray in the vertical position in the center of the enclosure after specimens have been attached.

9.6.4.2 Method 1 – Vertical tray specimen mounting

The sample shall be cut into specimens 2440 mm (96 in) nominal in length. Specimens shall be straightened and fastened to the tray in a single layer by means of wire ties at their upper and lower ends and at two other equally spaced points along their lengths (see Figure H.8). Specimens shall be installed in the center 150 mm (6 in) of the tray, one-half cable diameter apart. The lower end of each specimen shall be located not more than 100 mm (4 in) above the bottom end of the cable tray. The number of specimens shall be determined using the following formula:

$$N = (102/D_{mm}) + 0.33$$

or

$$N = (4/D_{in}) + 0.33$$

where

N = number of cables (rounded up to the nearest whole number, e.g., 3.14 = 4 specimens)

D = diameter of the cable, mm (in)

For a flat cable, the equivalent cable diameter shall be calculated as

$$D = 1.128 \times (TW)^{1/2}$$

where

T = length of the minor axis of the flat cable, mm (in)

W = length of the major axis of the flat cable, mm (in)

For ribbon cables, the spacing between adjacent cables shall not be less than 3.2 mm (1/8 in). The full width of the tray may be utilized.

9.6.4.3 Method 2 – FT4 specimen mounting

9.6.4.3.1 Depending upon the outside diameter of the individual cable, the test specimens shall be either separate, individual lengths or a bundle of individual lengths and shall consist of multiple 2440 mm (96 in) lengths of the finished cable. The specimens or specimen bundles shall be centered between the side rails in a single layer (see Figure H.8). The lower end of each specimen or specimen bundle shall be located not more than 100 mm (4 in) above the bottom end of the cable tray. Each specimen or specimen bundle shall be separately attached to each rung of the cable tray using one wrap of copper or steel wire not larger than 2.1 mm^2 (14 AWG).

9.6.4.3.2 For cables smaller than 13 mm (0.51 in), the specimens shall be grouped into untwisted bundles (nominally circular; see Figure H.8) as indicated in Table 8. The bundles shall be spaced one-half bundle diameter apart on the cable tray as measured at the point of attachment to the cable tray.

9.6.4.3.3 For cables 13 mm (0.51 inch) and larger in diameter, each specimen shall be individually attached to the cable tray with a separation of one-half cable diameter or 15 mm (0.59 in) (whichever is less) between specimens. The tray loading shall comply with Table 9.

9.6.4.3.4 For a flat cable, the equivalent cable diameter shall be calculated using the following formula:

$$D = 1.128 \times (TW)^{1/2}$$

where

D = calculated cable diameter, mm (in)

T = length of the minor axis of the cable, mm (in)

W = length of the major axis of the cable, mm (in)

9.6.4.3.5 For ribbon cables, the spacing between adjacent cables shall not be less than 3.2 mm (1/8 in).

9.6.4.4 Conditioning

The mounted test specimens shall be conditioned for at least 3 hours at ROOM TEMPERATURE immediately before the test is started.

9.6.5 Procedure

9.6.5.1 Startup

9.6.5.1.1 At the start of the test, the apparatus and the air in the test area shall be at a temperature of at least 5°C.

9.6.5.1.2 Power shall be applied to the control system.

9.6.5.1.3 The propane flow shall be set to 220 ±8 cm^3/s (28 ±1 ft^3/h) when corrected to standard temperature and pressure (20°C, 101 kPa (14.7 psi)). The airflow shall be set to 1280 ±80 cm^3/s (163 ±10 ft^3/h) when corrected to standard temperature and pressure, resulting in a calculated heat output of 20.5 kW (70,000 BTU/h). The burner shall then be shut off.

9.6.5.1.4 In order to establish and maintain a nominal exhaust flow rate of 0.65 ±0.05 m^3/s (23.0 ±1.8 ft^3/s) in the duct, the velocity in the duct shall be maintained at 5 m/s (16.4 ft/s) by using either manual or automated control baffles in the duct, or by adjusting the exhaust fan speed.

9.6.5.2 Method 1 – Vertical tray

9.6.5.2.1 The prepared tray shall be firmly secured in the vertical position (see Figure H.1).

9.6.5.2.2 The burner shall then be positioned on the side opposite from where the specimens are mounted, with the burner face vertical and its long dimension horizontal. The burner face shall be placed 76 ±5 mm (3.0 ±0.25 in) horizontally from the nearest surface of the specimens, parallel to the tray rungs and centered midway between the side rails of the tray. The center-point of the burner face shall be positioned 457 ±6 mm (18 ±0.25 in) above the bottom end of the tray and midway between two tray rungs (see Figure H.6, Horizontal).

9.6.5.2.3 The door of the chamber shall be closed and remain closed for the duration of the test.

9.6.5.2.4 The burner shall be re-ignited and the gas and airflows shall be adjusted to the values indicated in 9.6.5.1. The burner flame shall be applied continuously for 20 minutes or until the specimen burns to the top of the tray.

9.6.5.2.5 After 20 minutes, the burner flame shall be extinguished and the specimen fire (if any) shall be allowed to burn itself out.

9.6.5.2.6 A record shall be kept of the specimen flame height (cm or in) at one-minute intervals during the 20 minute test, as well as the time in minutes/seconds that specimens continue to flame following removal of the burner flame.

9.6.5.3 Method 2 – FT4

9.6.5.3.1 The prepared tray shall be firmly secured in the vertical position (see Figure H.1).

9.6.5.3.2 The burner shall then be positioned on the same side of the tray where the specimens are mounted, with the burner face angled 20 degrees ±2 degrees upward from the horizontal (see Figure H.6, Angled). The top of the burner shall be located 305 ±25 mm (12 ± 1 in) above the base of the tray, parallel to the tray rungs and centered midway between the side rails of the tray. The leading edge of the burner shall be placed 76 ±5 mm (3.0 ±0.25 in) horizontally from the nearest surface of the specimens.

9.6.5.3.3 The door of the chamber shall be closed and remain closed for the duration of the test.

9.6.5.3.4 The burner shall be re-ignited and the gas and airflows shall be adjusted to the values indicated in 9.6.5.1. The burner flame shall be applied continuously for 20 minutes or until the specimen burns to the top of the tray.

9.6.5.3.5 After 20 minutes, the burner flame shall be extinguished and the specimen fire (if any) shall be allowed to burn itself out.

9.6.5.3.6 A record shall be kept of the specimen flame height (cm or in) at one-minute intervals during the 20 minute test, as well as the time in minutes/seconds that specimens continue to flame following removal of the burner flame.

9.6.6 Results and calculations

9.6.6.1 Data acquisition

The exhaust speed data system shall measure the exhaust speed every 5 seconds and generate a graph of velocity for the duration of the test (see Figure H.9 for a typical plot of velocity graph).

9.6.6.2 Evaluation of damage

9.6.6.2.1 After burning has ceased and the specimens are allowed to cool, they shall be wiped clean, and the maximum extent of char determined. Soot that can be removed with a cloth shall be ignored.

Note: *For information, other damage such as melt or blistering may also be recorded.*

9.6.6.2.2 The limit of charring shall be determined by pressing against the specimen surface with a sharp object. Where the surface of the specimen changes from a resilient surface to a brittle or crumbling surface, the limit of charring has been determined.

9.6.6.2.3 In the event that materials do not char upon exposure to flame due to the characteristics of the compounds used, other significant damage in the vicinity of the maximum visible flame height that results in the overall specimen diameter being visibly reduced or increased shall be considered “char”.

9.6.6.3 Acceptance criteria

9.6.6.3.1 Method 1 – Vertical tray

The char height of all specimens shall be less than 2440 mm (96 in) when measured from the bottom of the tray.

9.6.6.3.2 Method 2 – FT4

The char height on the most centrally located specimens shall not exceed 1500 mm (59 in) when measured from the lower edge of the burner face.

9.6.7 Report

The report shall include, as a minimum, the following:

a) description of specimens – that is, wire or cable size, Type designation, component makeup and the number of specimen lengths or bundles;

b) test method (vertical tray or FT4);

c) char height;

d) flame height in 1 minute intervals;

e) after-burn time; and

f) velocity graph.

9.7 ST1 limited smoke

9.7.1 Scope

This test establishes the method for determining the total smoke released and peak smoke release rate in a wire, cable, or cord during the vertical tray flame tests in 9.6.

9.7.2 Apparatus

The apparatus shall be as described in 9.6.3, and also consist of the following:

a) smoke measuring equipment (see H.5 of Annex H); and

b) data acquisition system (see H.5 of Annex H).

9.7.3 Preparation of specimens

Specimens shall be prepared in accordance with 9.6.4.

9.7.4 Procedure

9.7.4.1 Pretest smoke measuring equipment calibration

9.7.4.1.1 At the start of each day of testing, the light source and photoelectric cell shall be calibrated using 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 neutral-density filters. Each filter shall be positioned in front of the photoelectric cell to cover the entire width of the light path. The attenuation of incident light by the neutral-density filters shall be used to calibrate the optical density as follows:

$$OD = \log_{10}\left(\frac{I_0}{I}\right)$$

where

OD = optical density

I_0 = clear-beam photoelectric cell signal

I = photoelectric cell signal attenuated by the neutral-density filter

Note: *Units of I_0 and I are the same, determined by the equipment used.*

Note: *Wratten filters from Kodak Company have been found to be suitable for the purpose. Equivalent apparatus are also acceptable. Filters calibrated to a set of calibrated filters traceable to national standards are available from a professional photography supplies vendor.*

9.7.4.1.2 The calculated values of OD for each filter shall agree within ±3 percent of the calculated neutral-density values. The average deviation of all of the measurements shall be within ±1 percent.

9.7.4.2 Test

The smoke measuring equipment and data acquisition systems shall be turned on, and the remainder of the procedure shall be carried out in accordance with 9.6.5.

9.7.5 Results and calculations

9.7.5.1 Smoke release rate

The smoke release rate (SRR) shall be calculated using the optical density per linear path length in the duct and the volumetric flow rate. The following equation shall be used to determine the SRR:

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

where

SRR = smoke release rate, m^2/s

OD = optical density

M_1 = volumetric flow rate, m^3/s, in the exhaust duct, referred to 298K

0.4064 = path length in the duct, m

9.7.5.2 Acceptance criteria

9.7.5.2.1 Method 1 – Vertical tray

For each test, in addition to compliance with 9.6.6.3.1, the total smoke released in 20 minutes shall not exceed 95 m^2, and the peak smoke release rate shall not exceed 0.25 m^2/s.

9.7.5.2.2 Method 2 – FT4

For each test, in addition to compliance with 9.6.6.3.2, the total smoke released in 20 minutes shall not exceed 150 m^2, and the peak smoke release rate shall not exceed 0.40 m^2/s.

9.7.6 Report

The report shall include, as a minimum, the information in 9.6.7 and the following:

a) total smoke released; and

b) peak smoke release rate.

9.8 Fire propagation/RPI

9.8.1 Scope

This test establishes the method to determine the resistance to fire propagation of wire, cable, or cord.

9.8.2 Materials and reactants

The materials and reactants shall consist of gas for an ignition source.

9.8.3 Apparatus

9.8.3.1 General

The apparatus shall consist of the following:

a) a chamber in accordance with Figure 30, containing the following:

1) three air-tight doors with windows;

2) vents located at the lower ends of the lateral doors, to regulate air velocity;

3) a metallic structure that supports and permits vertical sliding of the oven (see Figures 31 and 32 for dimensions);

4) an extractor (exhaust) mounted at the top of the chamber, with its intake located along the chamber axis;

5) an electrical oven comprising essentially a tube of aluminum silicate having an inside diameter of 100 ±3 mm (4 ±0.1 in), an outside diameter of 115 mm ±3.5 mm (4.5 ±0.15 in), and a length of 203 ±6 mm (8 ±0.25 in); on which a 1.307 mm^2 (16 AWG) ceramic insulated nickel-chromium resistance wire is wound;

6) a variable power supply capable of providing the required current;

7) two gas burners provided with a V-shaped deflector in accordance with Figure 33. The burners shall produce a flame 15 ±5 mm (0.6 ±0.2 in) in diameter and a blue cone 20 ±5 mm (0.8 ±0.2 in) in length, and shall be fixed in a mechanism that maintains a constant distance E between the burners and the test specimen;

8) metallic chimney with an internal diameter of between 120 and 125 mm (4.8 and 5 in) along the same axis as the oven, attached to the metallic structure and at 30 ±1 mm (1.2 ±0.04 in) above the oven when at its highest position, and shall have three series of slots in the periphery, separated 120 degrees apart as indicated in Figure 34;

9) a stainless steel tube with the dimensions indicated in Figure 35;

10) a temperature measuring device having a range of 0 to 1200°C, that includes a Type K thermocouple attached to the stainless steel tube;

11) a copper bar of minimum 99% purity, with its surface blackened by passing it over the flame of a candle. A thermocouple shall be located inside the bar and connected to a temperature measuring device having a range of 0 to 1200°C. The construction of the bar and thermocouple shall be in accordance with Figure 36; and

12) inorganic thermal insulation to cover the upper end of the oven;

b) an anemometer with an accuracy of ±3% and fins having a diameter of 95 ±5 mm (3.75 ±0.2 in) to measure the velocity of air that passes through the chimney; and

c) a timing device capable of measuring the specified time in seconds, having a resolution and accuracy of 1 second.

9.8.3.2 Calibration of oven

Note: *It is recommended that the oven be calibrated every six months or less, depending on the frequency of use.*

9.8.3.2.1 During oven calibration and air velocity adjustment, the air surrounding the chamber shall be calm and at a temperature greater than 15°C. The copper bar shall be suspended from the metallic structure in such a way that when the oven is at its highest position, the bar is centered on the axis of the oven. The bar shall be at a temperature less than 55°C. The oven shall be moved to its lowest position, with the upper end covered with the inorganic thermal insulation, and heated until the temperature measured with the thermocouple attached to the stainless steel tube has stabilized. Stabilization is achieved when the temperature recorded does not vary by more than 5°C in an hour.

9.8.3.2.2 Once the oven temperature has stabilized, the oven shall be uncovered and moved to its highest position within 5 seconds. The temperature of the copper bar shall be recorded at 5 seconds and 35 seconds. The rate of temperature rise shall be calculated using the following formula:

$$V = \frac{T_{35} - T_5}{30}$$

where

V = rate of temperature rise, °C/s

T_{35} = recorded temperature after 35 seconds, °C

T_5 = recorded temperature after 5 seconds, °C

9.8.3.2.3 The required rate of temperature rise shall be 3.3 ±0.1°C/s. If this value is not obtained, the entire calibration procedure shall be repeated with an adjusted power supply setting until the required rate of temperature rise is achieved. This power supply setting shall be used for the test.

Note: *The temperature of the oven is typically greater than* **780°C** *when it is stabilized.*

9.8.3.3 Adjusting the air velocity

The anemometer shall be placed between the bottom of the chimney and the oven while at its highest position (and while the oven is turned off). The extractor shall be turned on and the lower vents adjusted until an air velocity of 120 ±10 m/min (394 ±33 ft/min) has been obtained. The determination of air velocity shall be the average of three measurements taken at 5 minute intervals, beginning 10 minutes after the extractor has been turned on.

9.8.4 Preparation of specimens

Two specimens, each a minimum of 1600 mm (63 in) in length, shall be taken from the same sample of wire, cable, or cord, finished or taken during manufacture. The specimens shall be prepared in accordance with one of the following, as appropriate:

a) if the diameter of the sample is larger than 25 mm (1 in), and less than or equal to 70 mm (2.75 in), the specimen shall consist of a single length;

b) if the diameter of the sample is larger than 15 mm (0.6 in) and less than or equal to 25 mm (1 in), the specimen shall consist of three lengths arranged in parallel and tied by metallic strands at each end, at a point corresponding to the middle of the oven, and at a point corresponding to the middle of the chimney. The specimen shall be arranged such that one length is placed toward the rear of the chamber, in accordance with Figure 37; or

c) if the diameter of the sample is less than or equal to 15 mm (0.6 in), the specimen shall consist of 7, 12, 19, or more lengths tied together, such that the total diameter of the bundle is between 30 and 45 mm (1.20 and 1.75 in). The bundle shall be twisted in layers such that the lay of twist is approximately 15 times the diameter of the bundle. The bundle shall be tied in accordance with Item (b).

9.8.5 Test procedure

9.8.5.1 The air surrounding the chamber shall be free from drafts and at a temperature greater than 15°C. With the oven at the lowest position, and the inorganic thermal insulation covering in place, the heat shall be applied until the temperature stabilizes, as described in 9.8.3.2.

9.8.5.2 The specimen shall be mounted in a vertical position using clamps or ties at both ends of the specimen. The chimney shall be closed, and the burners ignited and adjusted to a distance E from the surface of the specimen, determined by the following formula:

$$E = D + d + 10\text{ mm}$$

or

$$E = D + d + 0.4\text{ in}$$

where

E = distance between the axes of the burners, mm (in)

D = diameter of the specimen, mm (in)

d = diameter of the flames, mm (in)

9.8.5.3 The inorganic thermal insulation covering shall be removed from the oven and the oven moved to its highest position within 5 seconds.

9.8.5.4 The extractor shall be turned on and the timing device started. After 10 minutes, the extractor shall be turned off for 1 minute, and then turned on for the remainder of the test.

9.8.5.5 When the timing device reads 30 minutes, the oven shall be moved to its lowest position and turned off. The extractor shall remain on. The burners shall be turned off and the specimen shall be allowed to self-extinguish.

9.8.5.6 The specimen shall be marked at the bottom of the chimney to serve as a reference point and removed. The specimen shall then be examined, and the height of degradation from the reference point shall be measured. Only the carbonized portion of the specimen shall be considered as having been degraded by the fire. Deposits produced from combustion, as well as melting, softening, and blisters in the specimen, shall be ignored.

9.8.5.7 If there is doubt as to whether a particular portion is included in the measurement, the specimen shall be cleaned and afterwards, pressure applied with a knife in the area in question. Breaks or cracks that occur in the specimen as a result shall be considered as degradation and that portion of the specimen shall be included in the measurement.

9.8.5.8 The procedures in 9.8.5.2 – 9.8.5.7 shall be repeated on the second specimen.

9.8.6 Results and calculations

The length of degradation of both specimens shall be recorded.

9.8.7 Report

The report shall include, as a minimum, the following:

a) specimen diameters;

b) number of conductors in the specimens; and

c) lengths of the degradation.

9.9 Smoke emission

9.9.1 Scope

This test establishes the method for determining the specific optical density and the smoke obscuration value during combustion of a wire or cable.

Note: *Testing of flat cables is under consideration.*

9.9.2 Materials and reactants

The materials and reactants shall consist of the following:

a) filtered compressed air available at a minimum flow rate of 500 cm^3/min (30 in^3/min) and a pressure between 0.10 and 0.17 MPa (15 and 25 lbf/in^2); and

b) propane having 95% minimum purity, available at a minimum flow rate of 50 cm^3/min (3 in^3/min).

Caution: *Propane gas is denser than air and can settle and become an explosion hazard. Consult the gas supplier for special precautions to be taken.*

9.9.3 Apparatus

The apparatus shall consist of the following:

a) a smoke density (NBS) chamber* in accordance with ASTM E662 or NMX-J-474-ANCE;

b) a rigid inorganic thermal insulation having a nominal thickness of 12.7 mm (0.50 in);

c) cloth suitable for cleaning optical windows; and

d) aluminum foil 0.040 ±0.002 mm (0.0016 ±0.0001 in) thick.

**Stanton Redcroft or Superpress chambers have been found to be suitable. Equivalent apparatus are also acceptable.*

9.9.4 Preparation of specimens

9.9.4.1 Three specimens shall be prepared in accordance with one of the following means. Items (b) and (c) only apply to thermoplastic materials:

a) for wire or cable up to and including 10 mm (0.40 in) in diameter, samples of finished wire or cable shall be cut into 76 ±1.5 mm (3 ±0.06 in) lengths and arranged in one layer, in parallel and in contact with one another, so as to fill the tray. If it is not possible to fill the tray due to the individual diameters of the wire or cable, the maximum number of wires or cables shall be arranged, and spaced as evenly as possible, across the tray;

b) for wire or cable greater than 10 mm (0.40 in) in diameter, specimens shall be prepared from samples of compression-molding plaques of jacket or insulation material, 76 ± 1.5 mm^2 (3 ±0.06 in^2) and having a thickness of 2 ±0.2 mm (0.08 ±0.008 in); or

c) in the case of multiconductor cables having a diameter greater than 10 mm (0.40 in), jacket and insulation materials shall be tested separately. The jacket specimen shall be prepared in accordance with Item (b), and the insulated conductors shall be prepared in accordance with either Item (a) or Item (b), based upon the insulated conductor diameter.

9.9.4.2 The specimens shall be conditioned at 60 ± 3°C for 24 hours, then maintained at 23 ±3°C and relative humidity of 50 ±5% for 1 hour.

9.9.4.3 Each specimen shall be wrapped with a single sheet of aluminum foil, with the dull side of the foil in contact with the specimen, then mounted in the holding tray so that the wires or cables are vertical when the tray is mounted in the chamber. The foil shall be cut away carefully to expose the front face of the specimen. The rigid inorganic thermal insulation shall be placed to the rear of the specimen to hold the specimen in place, and the holding clamp inserted.

9.9.5 Procedure

9.9.5.1 All equipment shall be calibrated in accordance with the equipment manufacturer's instructions.

9.9.5.2 The smoke chamber shall be free of contaminants. The glass surfaces of the emitter and receiver of the optical system shall be cleaned using ethyl alcohol or other adequate cleaner.

9.9.5.3 The smoke extraction system, the ventilation window, and the chamber door shall be closed, and the smoke chamber pressurized through the "flame/air" duct to 75 mm (3 in) of water. The air supply shall then be shut off, and the time required for the pressure to fall to 50 mm of water (2 in) shall not be less than 5 minutes. If the time is less than 5 minutes, the smoke chamber is not adequately sealed, and the safety seal of aluminum foil shall be changed.

9.9.5.4 The tray, along with the rigid inorganic thermal insulation, but with no specimen, shall be placed in front of the oven.

9.9.5.5 The chamber shall be heated to 35 ±2°C for a minimum of 1 hour. The optical system shall be adjusted to 0% and 100% of transmittance on the data acquisition system.

9.9.5.6 Adjustment of the oven radiation power shall be made using a calibrated radiometer. The voltage produced by the radiometer shall be equal to the value specified in the radiometer calibration report, for a radiation power of 2.5 ± 0.05 W/cm^2. The oven radiation power shall be adjusted as frequently as required to maintain the specified value.

9.9.5.7 The burner shall be positioned 6.4 ±0.8 mm (0.25 ±0.03 in) above the bottom opening of the tray and at a distance of 6.4 ±1.5 mm (0.25 ±0.06 in) from the face of the tray, then ignited. The gas flow rate shall be adjusted to 50 cm^3/min (3 in^3/min) and the airflow rate to 500 cm^3/min (30 in^3/min).

9.9.5.8 The tray that contains the specimen shall be mounted beside the tray having only the rigid inorganic thermal insulation. The tray with the specimen shall be pushed in the front of the oven, displacing the other tray. The door to the chamber shall be closed and percentage transmittance data collection started. Data collection shall be carried out at a rate of at least once every 60 seconds.

Once the photomultiplier indicates a reduction in transmittance, the ventilation window shall be completely closed. If the level of transmittance falls to lower than 0.1%, the window of the chamber shall be covered to avoid the influence of external light on the measurement.

9.9.5.9 The test shall continue for 3 minutes after the minimum transmittance is reached, or for 20 minutes of testing, whichever occurs first.

9.9.5.10 The remaining specimens shall be tested in accordance with 9.9.5.1 – 9.9.5.9. If any test shows abnormalities, such as the specimen falling from the tray, melted material totally covering the tray, temporary extinguishing of the flame, or movement of the specimen from the irradiation zone, these and all previous results shall be discarded, and three new specimens shall be tested.

9.9.5.11 If the highest test result exceeds the lowest test result by 50% or less, all three results shall be recorded. If the highest test result exceeds the lowest result by more than 50%, three additional specimens shall be tested and all six results shall be recorded.

9.9.5.12 The test shall be terminated by turning off the data acquisition system and purging the chamber by turning on the blower and opening the vents.

9.9.6 Results and calculations

9.9.6.1 The specific optical densities for each specimen shall be determined from Table 10 using the percent transmittance values obtained during each minute of the test.

9.9.6.2 The maximum specific optical density, Dm, for each specimen, corresponding to the minimum transmittance, shall be determined from Table 10 or by automated means. The average value for the specimens shall be calculated.

9.9.6.3 The smoke obscuration value for each specimen, VOF_4, shall be calculated using the following formula:

$$VOF_4 = d_1 + d_2 + d_3 + \frac{d_4}{2}$$

where

VOF_4 = the smoke obscuration value

d_1, d_2, d_3, and d_4 = the specific optical densities recorded at each of the first 4 minutes

The average value for the specimens shall be calculated.

9.9.7 Report

The report shall include, as a minimum, the following information:

a) number of lengths mounted on the tray;

b) specimen type (length or plaque); and

c) individual and average values of VOF_4 and D_m.

9.10 Halogen acid gas emission

9.10.1 Scope

This test establishes the method for determining the amount of halogen acid gas, evolved during the combustion of polymeric materials taken from electrical cables, in equivalent hydrochloric acid amount.

9.10.2 Apparatus, equipment and reactants

9.10.2.1 Apparatus and equipment

9.10.2.1.1 Apparatus shall include the following:

a) Tube furnace with uniform temperature rise control, capable of producing a temperature up to 1200°C. The minimum length of the furnace shall be 300 mm (11.81 in);

b) Glazed porcelain combustion boats nominally 75 mm x 10 mm x 9 mm (2.95 in x 0.39 in x 0.35 in);

c) High temperature heating tape capable of maintaining a minimum temperature of 150°C on the surface of the glass tube;

d) Three water traps nominally 55 ±5 mm (2.17 ±0.20 in) in diameter;

e) Air flow meter with a range of 0 to 200 ml/min;

f) Chronometer with a resolution of 1 second;

g) Glass beakers with capacities of 600 ml and 250 ml;

h) Wash bottle;

i) 500 ml volumetric flask;

j) 100 ml volumetric flask or pipette;

k) 1 ml volumetric pipette;

l) 25 ml graduated buret;

m) buret stand;

n) buret clamp;

o) potentiometer (mV);

p) measuring electrode (silver or platinum);

q) calomel reference electrode;

r) magnetic agitator;

s) magnetic bar; and

t) a precision scale with a resolution of 0.001 g.

9.10.2.1.2 The complete test arrangement shall be as illustrated in Figure 38.

9.10.2.1.3 Figure 38 also illustrates the design and the assembly of the combustion tube used in the test.

9.10.2.2 Materials and reactants

The materials and reactants shall consist of the following:

a) distilled water;

b) dry compressed air;

c) 0.1 normal solution of sodium hydroxide (NaOH);

d) concentrated nitric acid (HNO_3);

e) 0.1 normal solution of silver nitrate; and

f) chromic acid solution (6 g potassium dichromate in a minimum amount of distilled water combined with 200 ml of concentrated sulfuric acid).

9.10.3 Preparation of specimens

Component material shall be taken from finished wire or cable, or from wire or cable during manufacture. A quantity of material sufficient for performing a minimum of three tests shall be taken. Any contamination of the test specimen shall be avoided.

9.10.4 Procedure

9.10.4.1 The combustion boat shall be conditioned for two hours at the maximum test temperature in an oven, or subjected for one minute to the blue cone of the flame of a Bunsen burner, and allowed to cool to room temperature. A combustion boat shall not be used after exposure to acid eight times.

Note: *Conditioning is carried out in order to remove any organic residues prior to the test.*

9.10.4.2 A 0.5 – 1 g specimen shall be placed into the combustion boat.

9.10.4.3 The combustion boat with the sample inside shall be inserted into the combustion tube so that the tube is centered in oven.

9.10.4.4 The combustion and gas collection system shall be installed in accordance with Figure 38.

9.10.4.5 The wash bottles (see Figure 38, part number 11) shall contain 100 ml each of 0.1 N NaOH. The second and third traps shall have a sintered glass diffuser.

9.10.4.6 The dry air supply shall be started through the system and stabilized at a rate of 110 ±25 ml/min. Care shall be taken to ensure that there are no air leaks in the system. This can be verified by applying soapy water with a brush to joints in the system and no bubbles form as a result. Regulation of air flow from the system shall be performed with the air flow meter and stopwatch.

9.10.4.7 The heating tape shall be placed into the system between the combustion furnace and the first water trap of NaOH. The heating tape shall maintain a minimum temperature of 150°C on the surface of the glass ducts during testing.

9.10.4.8 The oven temperature shall be brought to 800 ±10°C at a rate of 20°C/min. Once this temperature is reached, it shall be held for 20 minutes then turned off.

9.10.4.9 At the conclusion of the specified time, the water trap system shall be disconnected, starting from the trap furthest from the furnace.

9.10.4.10 The air supply shall be disconnected and the system shall be allowed to cool.

9.10.4.11 The combustion boat with solid wastes shall be removed, preventing solid waste from contaminating the combustion tube.

9.10.4.12 The contents of the water traps shall be combined into a 500-ml volumetric flask. The inside of the combustion tube, the water traps, and the system connections shall be washed with distilled water. The wash water shall be added to the volumetric flask.

9.10.4.13 The volume in the flask shall be increased to a maximum of 500 +0, -1 ml by adding distilled water.

9.10.4.14 From the 500-ml solution, 100 ml of the solution obtained in the previous step shall be extracted and poured into a beaker, to which 1 ml of concentrated nitric acid shall be added. Both electrodes shall be inserted into the solution and connected to the potentiometer. The silver nitrate solution shall be titrated into the solution, with steady agitation during the entire titration.

9.10.4.15 The quantity of silver nitrate solution in milliliters and the corresponding value in millivolts as indicated by the potentiometer shall be recorded.

9.10.4.16 For each specimen to be analyzed, three titrations shall be made, as well as a control test (without specimen). The result shall be the average of the three titrations.

Note 1: *For rapid control testing, preheat the combustion tube at 800°C, adjust the air flow and subsequently place the combustion boat with the specimen into the combustion area. The results of such a test are only for guidance of the expected value, but they are not acceptable as precise values for the specimen under study.*

Note 2: *Sintered glass diffusers may be cleaned using chromic solution.*

9.10.5 Results and calculations

9.10.5.1 Determination of the volume of silver nitrate in the equivalence point

9.10.5.1.1 The equivalence point by graphical method shall be determined by constructing a graph for each of the degrees and qualifications in black, placing the milliliters used in the y-axis. The equivalence point (turning point) is calculated through the graph as shown in Figure 40. Alternatively the graphical method can be applied to any calculation method for estimating the equivalence point.

9.10.5.1.2 Figure 40 shows a typical titration curve for titration of the sample. Figure 39 shows where the point of equivalence is obtained (volume of silver nitrate solution used in the calculations) by graphical method.

9.10.5.1.3 The control titration is obtaining a curve similar to that shown in Figure 41 (undefined potential at the beginning of the curve), indicating the absence of halogens in the solution under analysis.

9.10.5.2 Determination of amount of halogen acid gas

9.10.5.2.1 The quantity of halogen gas shall be expressed as hydrogen chloride in milligrams (mg) per gram (g) of sample, or as a percentage of hydrogen chloride as follows:

$$HCl_{mg/g} = \frac{36.5 \text{ x } (a - b)\, N \frac{V_f}{A}}{m}$$

$$HCl_{\%} = \frac{36.5 \text{ x } (a - b)\, N \frac{V_f}{A}}{m \text{ x } 10}$$

where

$H_{mg/g}$ = quantity of halogen acid gas evolved, mg/g

$HCl_{\%}$ = quantity of halogen acid gas evolved, %

a = volume of the silver nitrate solution at the equivalence point used in the determination of the sample ml

b = volume of silver nitrate solution used in the control test, ml

N = normality of the silver nitrate solution, equivalent weight per liter

V_f = volume of the volumetric flask, 500 ml

A = amount of solution extracted in accordance with 9.10.4.13, (100 ml)

m = mass of the sample, g

9.10.5.2.2 Following the calculations, the three determinations shall be averaged. If any individual result differs from the average by more than 5%, the test shall be considered invalid and an additional set of three specimens shall be tested. If the individual results from the additional set of specimens continue to differ from the average by more than 5%, the test shall be considered invalid.

9.10.6 Report

The report shall include, as a minimum, the following:

a) Name of test laboratory;

b) Type product;

c) Mass of specimens in each determination;

d) Volume of silver nitrate used in each determination including during the control test;

e) Percent of evolved hydrogen chloride per gram of sample for each determination;

f) Average values obtained;

g) Comments and observations about results;

h) Test date; and

i) Product type.

9.11 Acid gas emission

9.11.1 Scope

9.11.1.1 This test establishes the method for determining the amount of acid gas, other than hydrogen fluoride, evolved during the combustion of nonmetallic component materials of wire or cable.

9.11.1.2 This test method establishes the method for determining the acid gas content of materials containing chlorine, bromine, and other elements, if they release acid gases, but is not recommended for use with fluoropolymer materials. When the method is used on materials capable of generating acid gases other than hydrogen chloride (such as hydrogen bromide or sulphur-containing acids, or acetic acid), either instead of or as well as hydrogen chloride, the results do not represent the actual acid species emitted.

9.11.1.3 In order to know what species are actually present as acid gases, the type of elements responsible for the acid gas emission in the compound being tested shall be defined.

9.11.2 Materials and reactants

The materials and reactants shall consist of the following:

a) water having a pH of 6 to 7 and a maximum conductivity of 10 µS/cm;

b) dry compressed air;

c) 0.1 normal solution of sodium hydroxide (NaOH); and

d) methyl red indicator solution.

9.11.3 Apparatus

The apparatus shall be as illustrated in Figure 38, except that the water traps shall be connected by fitted glass. The apparatus shall include the following main components:

a) three water traps nominally 25 x 200 mm (1 x 8 in);

b) quartz glass combustion tube with ground glass connections at the inlet, for air input, and discharge end, having an internal diameter of approximately 25 mm (1 in) and minimum length of two times the length of the furnace (preferred length is 700 to 900 mm (28 to 35 in));

c) glazed porcelain combustion boats nominally 75 mm (3 in) long, 10 mm (0.4 in) wide, and 9 mm (0.4 in) deep. Boats shall be preconditioned at the test temperature for a minimum of 2 hours then returned to ROOM TEMPERATURE. Boats shall be used a maximum of 8 times;

Note: *Used boats are likely to result in lower values.*

d) tube furnace having an internal length of 300 to 400 mm (12 to 16 in), capable of producing a temperature of 1200°C;

Note: *The Lindberg Model 55035 has been found suitable. Equivalent apparatus is also acceptable.*

e) a temperature measuring device equipped with a Type K thermocouple;

f) an airflow meter with a range of 0 to 200 mL/min (12 in^3/min);

g) a high temperature heating tape capable of maintaining a minimum temperature of 150°C on the surface of the glass tube;

h) an exhaust system to remove vapors emitted from the apparatus;

i) a balance capable of weighing 1.0 g, accurate to within 0.1 mg;

j) a temperature controller for heating tape;

k) a timing device capable of measuring the specified times in seconds, having a resolution of 1 second and an accuracy of ±0.5 seconds;

l) 250 ml beakers;

m) a volumetric flask of 1 L capacity;

n) a 5 ml pipette;

o) a titrating buret of 50 to 100 ml capacity capable of reading to ±0.10 ml;

p) a titration flask;

q) a buret stand;

r) a buret clamp;

s) a ceramic wool plug;

t) a pH meter capable of measuring ±0.01 pH units;

u) a calomel reference electrode; and

v) a magnetic agitator.

9.11.4 Preparation of specimens

Component material shall be taken from finished wire or cable or from wire or cable during manufacture. A one-piece specimen shall be cut from the jacket or insulation, of sufficient length to yield a mass of 0.5 ±0.05 g. The mass of the specimen shall be recorded to the nearest 0.001 g.

9.11.5 Procedure

9.11.5.1 Method 1

9.11.5.1.1 This test produces acceptable results on wire and cable insulation and jacketing materials at levels of 4% and greater by mass of acid gas evolved (when calculated as HCl) with a tolerance of 1.4% on the value.

9.11.5.1.2 Water shall be added to each water trap to a minimum of 100 mm (4 in) above the bubble outlet level. 5.00 ml of NaOH solution shall be added to each water trap using the pipette. Based on experience, it is likely that smaller quantities of NaOH will be required for materials that evolve low levels of acid gas.

9.11.5.1.3 The combustion tube shall be placed in the furnace, with the furnace located at the air inlet end of the combustion tube (see Figure 42(a)). The water traps shall be connected to the combustion tube and the tube to the variable airflow. The airflow rate shall be adjusted to 100 to 125 ml/min (6.1 to 7.6 in^3/in). The airflow measurement shall be taken after the last water trap. The water traps shall be disconnected from the combustion tube and the thermocouple inserted into the combustion tube at the midpoint of the furnace. Care shall be taken to ensure that there are no leaks in the air system.

Note: *The presence of leaks can be verified by the formation of bubbles after applying a soap solution to the joints.*

9.11.5.1.4 With the air flowing, the furnace control shall be adjusted to obtain an air temperature inside the combustion tube of 800 ±10°C. The thermocouple shall be removed after the temperature inside the tube has stabilized.

9.11.5.1.5 The specimen shall be weighed to the nearest 0.001 g and the mass recorded. The combustion boat containing the specimen shall be inserted through the outlet end of the combustion tube and positioned just before the entrance of the furnace. The water traps shall be reconnected.

9.11.5.1.6 The heating tape shall be wrapped around the glass tubing connecting the combustion tube to the first water trap, and around the combustion tube for a length of approximately 100 mm (4 in) (see Figure 42(b)). The power to the heating tape shall be adjusted to maintain a minimum temperature of 150°C on the surface of the glass tube during the test.

9.11.5.1.7 The furnace shall be moved in five steps along the combustion tube, to position the specimen in the center of the furnace (see Figure 42(c)). The first three moves shall be approximately 25 mm (1 in) each, with two additional moves made to position the specimen at the center of the furnace. The time intervals between moves shall be nominally 1 minute.

9.11.5.1.8 Heating shall be maintained for an additional 10 minutes minimum. The heating tape shall be removed and the furnace moved toward the discharge end of the tube to burn off any deposits (see Figure 42(c)). The movement of the furnace along the tube shall be accomplished in one step, and the furnace shall remain in place for 5 minutes +5 seconds. The airflow and furnace shall be turned off at this time.

9.11.5.1.9 The water traps shall be disconnected and their contents combined.

9.11.5.1.10 The tubing connections and the empty water traps shall be thoroughly washed with water until no acid remains. The washings shall be checked with methyl red indicator. If the solution turns red, the washings contain acid and further washings are necessary. The washings shall then be added to the solution from the water traps.

9.11.5.1.11 The combined washings and water from the water traps shall be titrated using the NaOH solution until the methyl red indicator endpoint (red to yellow) is reached. The total volume of NaOH solution used in the titrating step and the volume originally added to the water traps shall be recorded.

9.11.5.1.12 The procedures in 9.11.5.1.1 – 9.11.5.1.11 shall be repeated with two additional specimens.

9.11.5.2 Method 2

9.11.5.2.1 This test determines the amount of acid gas byproducts (expressed as a corresponding percentage of HCl) that have evolved during the pyrolysis or combustion of nonmetallic component materials where the resultant solution has a pH value greater than 3.26 (less than 4% acid gas when calculated as HCl).

9.11.5.2.2 Water shall be added to each water trap to a minimum of 100 mm (4 in) above the bubble outlet level.

9.11.5.2.3 The combustion tube shall be placed in the furnace, with the furnace located at the air outlet end of the combustion tube (see Figure 43(a)). The water traps shall be connected to the combustion tube and the tube to the variable airflow. The airflow rate shall be adjusted to 100 to 125 ml/min (6.1 to 7.6 in^3/in). The airflow measurement shall be taken after the last water trap. The water traps shall be disconnected from the combustion tube and the thermocouple inserted into the combustion tube at the midpoint of the furnace. Care shall be taken to ensure that there are no leaks in the air system.

Note: *The presence of leaks can be verified by the formation of bubbles after applying a soap solution to the joints.*

9.11.5.2.4 With the air flowing, the furnace control shall be adjusted to obtain an air temperature inside the combustion tube of 800 ±10°C. The thermocouple shall be removed after the temperature inside the tube has stabilized.

9.11.5.2.5 At the outlet end, a snug-fitting ceramic wool plug approximately 25 mm (1 in) long shall be inserted into the combustion tube to a position just at the entrance of the furnace. The combustion boat containing the specimen shall be inserted through the outlet end of the combustion tube and positioned just before the entrance of the furnace. The water traps shall be reconnected.

Note: *The plug will trap solid combustion products and prevent carry-over into the water traps. The residue, which may contain attached acid gases, will be burnt off at the last stage (see Figure 43(c)).*

9.11.5.2.6 The airflow to the combustion tube shall be disconnected.

9.11.5.2.7 The heating tape shall be wrapped around the glass tubing connecting the combustion tube to the first water trap, and around the combustion tube for a length of approximately 100 mm (4 in) (see Figure 43(c)). The power to the heating tape shall be adjusted to maintain a minimum temperature of 150°C on the surface of the glass tube during the test.

9.11.5.2.8 The specimen shall be weighed to the nearest 0.001 g and the mass recorded. The combustion boat containing the specimen shall be inserted through the inlet end of the combustion tube and positioned just before the entrance of the furnace (see Figure 43(b)).

9.11.5.2.9 The airflow shall be reconnected to the combustion tube, maintaining the initial flow rate.

9.11.5.2.10 The furnace shall be moved in six steps along the combustion tube, to position the specimen in the center of the furnace (see Figure 43(b)). The first three moves shall be approximately 25 mm (1 in) each, and the three additional moves made to position the specimen at the center of the furnace. The time intervals between moves shall be nominally 1 minute.

9.11.5.2.11 Heating shall be maintained for an additional 10 minutes minimum. The heating tape shall be removed and the furnace moved toward the discharge end of the tube, to burn off any deposits (see Figure 42(c)). The movement of the furnace along the tube shall be accomplished in one step, and the furnace shall remain in place for 5 minutes +5 seconds. The airflow and furnace shall be turned off at this time.

9.11.5.2.12 The water traps shall be disconnected and their contents combined.

9.11.5.2.13 The contents of the water traps shall be combined into a 1 L volumetric flask. The inside of the water traps and the system connections shall be washed with water. The wash water shall be added to the volumetric flask. The volume in the flask shall be increased to precisely 1 L by adding water.

9.11.5.2.14 The pH measurement shall be made on the solution taken from the 1 L flask.

9.11.5.2.15 The procedures in 9.11.5.2.1 – 9.11.5.2.14 shall be repeated for two additional specimens.

9.11.6 Results and calculations

9.11.6.1 Method 1

9.11.6.1.1 The quantity of acid gas evolved shall be expressed as hydrogen chloride as a percentage. The quantity shall be calculated as follows:

$$\%\ \text{acid gas evolved} = \frac{V \times N \times K}{m \times 10} = \frac{V \times 0.365}{m}$$

where

V = total volume of NaOH solution, ml

N = normality of the NaOH solution

K = equivalent weight of the acid gas; for HCl, K = 36.5

m = mass of the test sample as weighed into the combustion boat, weighed to 0.001 g

9.11.6.1.2 Following the calculations, the three determinations shall be averaged. If any individual result differs from the average by more than 10%, the result shall be discarded and up to three additional specimens shall be tested. If any individual result continues to differ from the average by more than 10%, the test shall be considered invalid.

9.11.6.2 Method 2

Following the pH measurements, the three determinations shall be averaged. If any individual result differs from the average by more than 10%, the result shall be discarded and up to three additional specimens shall be tested. If any individual result continues to differ from the average by more than 10%, the test shall be considered invalid.

> **Note:** *For the purpose of this procedure, the equivalence between % acid gas as HCl and pH is shown in Annex I, using* **0.5 g** *of material and* **1 L** *water.*

9.11.7 Report

The report shall include, as a minimum, the average quantity of acid gas evolved.

9.12 Flame test for portable cables/FT5 (United States and Canada only)

9.12.1 Scope

This test establishes the method for determining the resistance of a portable cable to the propagation of flame.

9.12.2 Apparatus

The apparatus shall consist of a rectangular test gallery 430 ±5 mm deep × 370 ± 5 mm high × 990 ±5 mm wide (16.93 ±0.20 in deep x 14.57 in ±0.20 in high x 38.98 ±0.20 in wide) that includes:

a) a source of electric current (either ac or dc) for loading the cable specimen, with means for close regulation;

b) a suitable ammeter to measure the electric current imposed on the cable specimen conductors;

c) a suitable temperature-measuring device to determine the conductor temperature;

d) a rack for supporting the cable specimen (the rack shall have three metal rods installed on the same level with spaces of 405 ±5 mm (15.95 in ± 0.20 in) between the left and the middle rod and 205 ±5 mm (8.07 ±0.20 in) between the right and the middle rod. The rods shall be protected with heat-resisting material to reduce the cooling effect. The height of the rack shall be sufficient to permit the tip of the inner cone of the burner flame to touch the jacket of the cable specimen when the flame is adjusted to the appropriate height.);

e) an electric timer or stopwatch to measure the duration of the tests;

f) a standard 9.5 mm (0.37 in) premixed burner for igniting the cable specimen; and

g) a ventilated hood or canopy that keeps the specimen substantially free from external air currents.

9.12.3 Preparation of specimens

9.12.3.1 The specified number of cable specimens, each 1.00 ±0.05 m (3.28 ±0.16 feet) long, shall be cut from a cable sample. Each specimen shall have 125 ±5 mm (4.92 ±0.20 in) of jacketing and 65 ±5 mm (2.56 ±0.20 in) of conductor insulation removed from each conductor at both ends.

9.12.3.2 The test specimen shall be placed on the rack and connected to the electric current source, centered on the two outside supporting rods with approximately 25 ±2 mm (0.98 ±0.08 in) of jacket extending beyond each rod. The thermocouple of the temperature-measuring device shall be held in close contact with the conductor under a flap of jacket and insulation 660 ±5 mm (25.98 ±0.20 in) from the left end of the specimen. The flap shall be held tightly, after insertion of the thermocouple, by tying it with a tie wire.

9.12.4 Procedure

9.12.4.1 The specimen shall be heated with electric current corresponding to 5 times the rated current in the Canadian Electrical Code, Part I until the conductor reaches a temperature of 205 ±5°C;

9.12.4.2 After reaching this temperature, the flame of a premixed gas burner, as described in 9.1.3(d), adjusted to give an overall free flame height of 125 mm (4.92 in) and an inner cone of 75 mm (2.95 in) with natural gas, having a heat content of 37 ±1 MJ/m^3, shall be applied directly beneath the specimen at a point 355 ±5 mm (13.98 ±0.20 in) from its left end.

9.12.4.3 After the specimen has been subjected to external flame for 1 minute, the heating current and gas flame shall be cut off simultaneously. Specimens of flat cable shall be tested with the flame source impinging on the flat surface.

Note: *In Canada, an alternative procedure is described in CFR, Title 30, Chapter 1, Section 7.407.*

9.12.5 Results

The length of char on each specimen and the length of time for the flame to completely extinguish shall be recorded.

9.12.6 Report

The report shall include the following as a minimum:

a) the length of char on each specimen; and

b) the length of time for the flame to completely extinguish.

Table 1
Adjustment factors for dc resistance of conductors

(See 3.4.5.1)

Temperature of conductor		Multiplying factor for adjustment to resistance at			
		25°C (77°F)		20°C (68°F)	
°C	°F	Copper	Aluminum and copper-clad aluminum	Copper	Aluminum and copper-clad aluminum
10	50.0	1.061	1.063	1.041	1.042
11	51.8	1.057	1.059	1.037	1.038
12	53.6	1.053	1.054	1.033	1.033
13	55.4	1.048	1.050	1.028	1.029
14	57.2	1.044	1.045	1.024	1.024
15	59.0	1.040	1.041	1.020	1.020
16	60.8	1.036	1.037	1.016	1.016
17	62.6	1.032	1.033	1.012	1.012
18	64.4	1.028	1.028	1.008	1.008
19	66.2	1.024	1.024	1.004	1.004
20	68.0	1.020	1.020	1.000	1.000
21	69.8	1.016	1.016	0.996	0.996
22	71.6	1.012	1.012	0.992	0.992
23	73.4	1.008	1.008	0.989	0.988
24	75.2	1.004	1.004	0.985	0.984
25	77.0	1.000	1.000	0.981	0.980
26	78.8	0.996	0.996	0.977	0.976
27	80.6	0.992	0.992	0.973	0.972
28	82.4	0.989	0.989	0.970	0.969
29	84.2	0.985	0.985	0.966	0.965
30	86.0	0.981	0.981	0.962	0.961
31	87.8	0.977	0.977	0.958	0.957
32	89.6	0.974	0.973	0.955	0.954
33	91.4	0.970	0.970	0.951	0.950
34	93.2	0.967	0.966	0.948	0.947
35	95.0	0.963	0.962	0.944	0.943

Table 2
Rate of jaw separation of tensile machine

(See 3.5.1.4)

Conductor material	Rate of separation of jaws, mm/s (in/s)
Annealed soft copper (uncoated and coated)	Not exceeding 5 (0.2)
8000 Series aluminum alloys	0.4 (0.02)
Other metals and other tempers of copper	1 (0.04)

Table 3
Temperature variations

(See 4.2.3(i))

Set temperature range, °C	Maximum variation in set temperature, ±°C
≤180	2
>180 to 300	3
>300 to 400	4
>400 to 500	5

Table 4
Test temperature for dry temperature rating of new materials

(See 4.3.4.2)

Temperature rating (°C)	60	75	80	90	105	125	150	180	200	250
Aging temperature (°C)	67	82	87	97	113	133	158	189	209	260

Table 5
Specimen preparation for tension and elongation test

(See 7.22.3)

Type of cable	Test	Total length of specimen, m	Conductor assembly	Condition of cable ends	Spacing between jaws, mm
Armored	Tensile	1.2	Withdrawn	Not specified	1000
	Elongation		Not removed	Cut off square	
Other than armored	Tensile and elongation	Not specified	Not removed	Not specified	To permit 1000 gauge mark spacing

Table 6
Test current and fuse protection for ″-R″ cords

(See 7.29.2)

Conductor size, AWG	Load current, Amps		Circuit protection, Amps
	Service cords	Heater cords	
18	10	10	15
17	12	13	18
16	13	15	20
15	16	17	25
14	18	20	30

Table 7
Mandrel diameters for ozone test

(See 8.2.4.2(a))

Outside diameter of test specimen, mm	Mandrel diameter as a multiple of the outside diameter of the test specimen
Less than 12.7	4
Greater than or equal to 12.7 and less than 19.0	5
Greater than or equal to 19.0 and less than 31.7	6
Greater than or equal to 31.7 and less than 44.4	8
44.4 and greater	10

Table 8
Cables smaller than 13 mm (0.51 in) in diameter

(See 9.6.4.3)

Cable diameter mm (in)		Number of specimens in each bundle	Number of bundles in tray
From	But less than		
	3 (0.12)	19	13
3 (0.12)	5 (0.20)	19	8
5 (0.20)	6 (0.24)	7	9
6 (0.24)	9 (0.35)	3	10
9 (0.35)	11 (0.43)	3	8
11 (0.43)	13 (0.51)	3	7

Table 9
Cables 13 mm (0.51 in) or larger in diameter

(See 9.6.4.3)

Cable diameter mm (in)		Number of specimens in tray
From	But less than	
13 (0.51)	15 (0.59)	11
15 (0.59)	19 (0.75)	9
19 (0.75)	21 (0.83)	8
21 (0.83)	26 (1.02)	7
26 (1.02)	28 (1.10)	6
28 (1.10)	39 (1.54)	5
39 (1.54)	52 (2.05)	4
52 (2.05)	73 (2.87)	3
73 (2.87)	120 (4.72)	2

Table 10
Conversion of % transmittance to specific optical density

(See 9.9.6.1 and 9.9.6.2)

Parameters and range of transmittance (T)	% T	0	1	2	3	4	5	6	7	8	9
		Specific optical density (D)									
Multiplier 100 with ND-2 filter	90	6	5	5	4	4	3	2	2	1	1
	80	13	12	11	11	10	9	9	8	7	7
	70	20	20	19	18	17	16	16	15	14	14
100 at 10% T	60	29	28	27	26	26	25	24	23	22	21
	50	40	39	37	36	35	34	33	32	31	30
	40	53	51	50	48	47	46	45	43	42	41
	30	69	67	65	64	62	60	59	57	55	54
	20	92	89	87	84	82	79	77	75	73	71
	10	132	127	122	117	113	109	105	102	98	95
Multiplier 10 with ND-2 filter	$90x10^{-1}$	138	137	137	136	136	135	134	134	133	133
	80	145	144	143	143	142	141	141	140	139	139
	70	152	152	151	150	149	148	148	147	146	146
10 at 1% T	60	161	160	159	158	158	157	156	155	154	153
	50	172	171	169	168	167	166	165	164	163	162
	40	185	183	182	180	179	178	177	175	174	173
	30	201	199	197	196	194	192	191	189	187	186
	20	224	221	219	216	214	211	209	207	205	203
	10	264	259	254	249	245	241	237	234	230	227
Multiplier 1 with ND-2 filter	$90x10^{-2}$	270	269	269	268	268	267	266	266	265	265
	80	277	276	275	275	274	273	273	272	271	271
	70	284	284	283	282	281	280	280	279	278	278
1 at 0.1% T	60	293	292	291	290	290	289	288	287	286	285
	50	304	303	301	300	299	298	297	296	295	294
	40	317	315	314	312	311	310	309	307	306	305
	30	333	331	329	328	326	324	323	321	319	318
	20	356	353	351	348	346	343	341	339	337	335
	10	396	391	386	381	377	373	369	366	362	359

Table 10 Continued on Next Page

Table 10 Continued

Parameters and range of transmittance (T)	% T	0	1	2	3	4	5	6	7	8	9
		Specific optical density (D)									
Multiplier 0.1 with ND-2 filter	$90x10^{-3}$	402	401	401	400	400	399	398	398	397	397
	80	409	408	407	407	406	405	405	404	403	403
	70	416	416	415	414	413	412	412	411	410	410
0.1 at 0.01% T	60	425	424	423	422	422	421	420	419	418	417
	50	436	435	433	432	431	430	429	428	427	426
	40	449	447	446	444	443	442	441	439	438	437
	30	465	463	461	460	458	456	455	453	451	450
	20	488	485	483	480	478	475	473	471	469	467
	10	528	523	518	513	509	505	501	498	494	491
Multiplier 1 without ND-2 filter	$90x10^{-4}$	534	533	533	532	532	531	530	530	529	529
	80	541	540	539	539	538	537	537	536	535	535
	70	548	548	547	546	545	544	544	543	542	542
0.01 at 0.001% T	60	557	556	555	554	554	553	552	551	550	549
	50	568	567	565	564	563	562	561	560	559	558
	40	581	579	578	576	575	574	573	571	570	569
	30	597	595	593	592	590	588	587	585	583	582
	20	620	617	615	612	610	607	605	603	601	599
	10	660	655	650	645	641	637	633	630	626	623
Multiplier 0.1 without ND-2 filter	$90x10^{-5}$	666	665	665	664	664	663	662	662	661	661
	80	673	672	671	671	670	669	669	668	667	667
	70	680	680	679	678	677	676	676	675	674	674
0.001 at 0.00001 % T	60	689	688	687	686	686	685	684	683	682	681
	50	700	699	697	696	695	694	693	692	691	690
	40	713	711	710	708	707	706	705	703	702	701
	30	729	727	725	724	722	720	719	717	715	714
	20	752	749	747	744	742	739	737	735	733	731
	10	792	787	782	777	773	769	765	762	758	755
	00	–	924	885	861	845	832	821	812	805	798

Figure 1
Bending fatigue

(See 3.5.3.2)

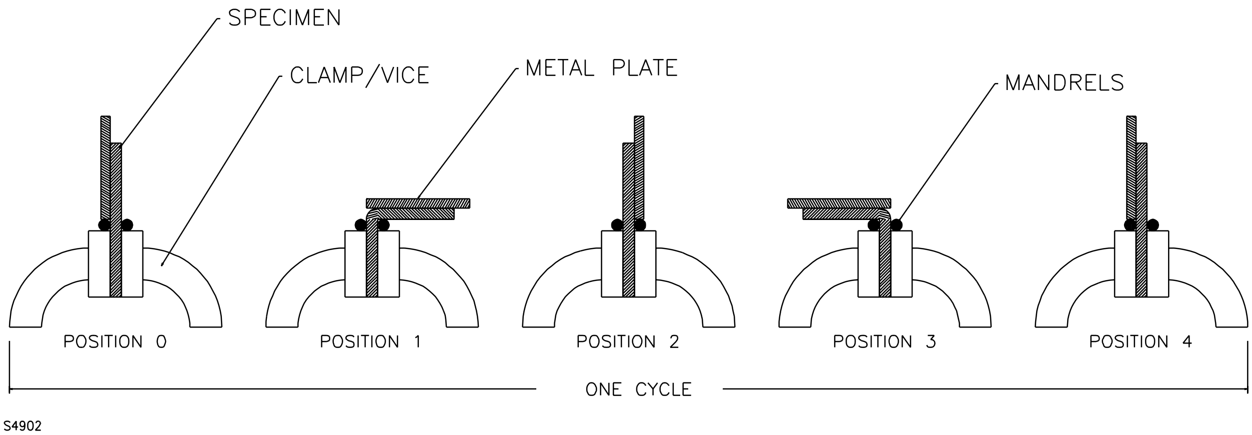


Figure 2
Connection of jigs (duplex receptacles)

(See 3.6.2)

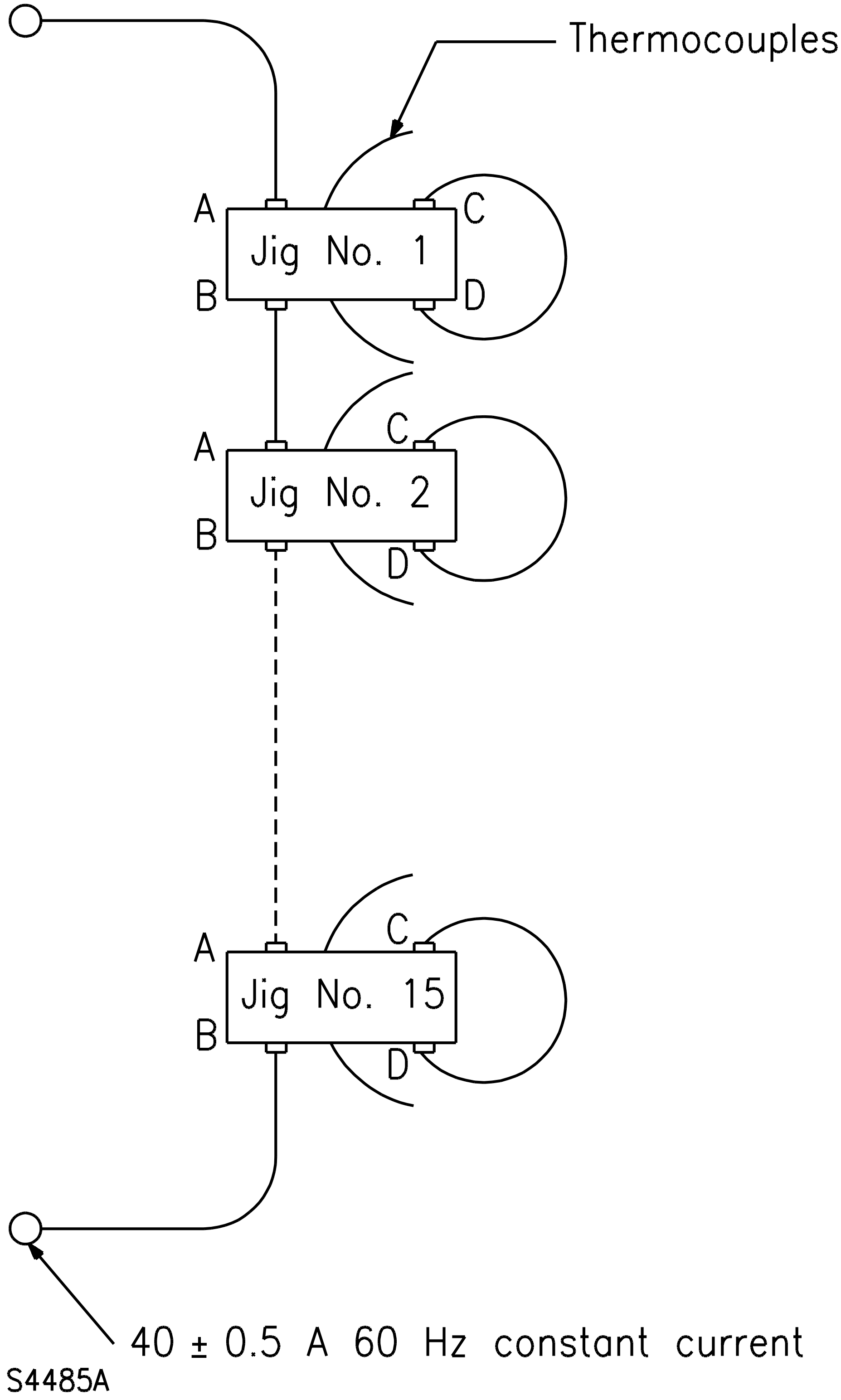
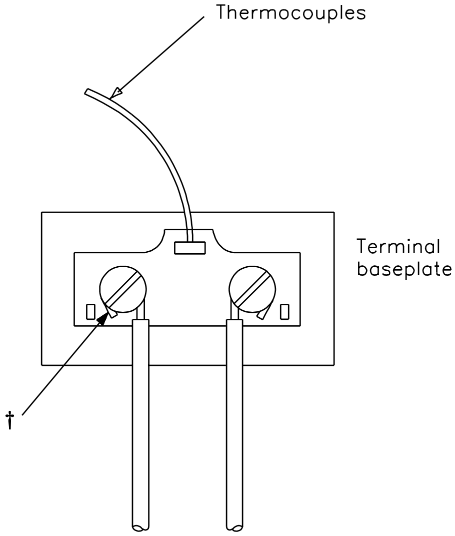


Figure 3
Detail of the connection of jigs (duplex receptacles)

(See 3.6.2 and 3.6.4.1)

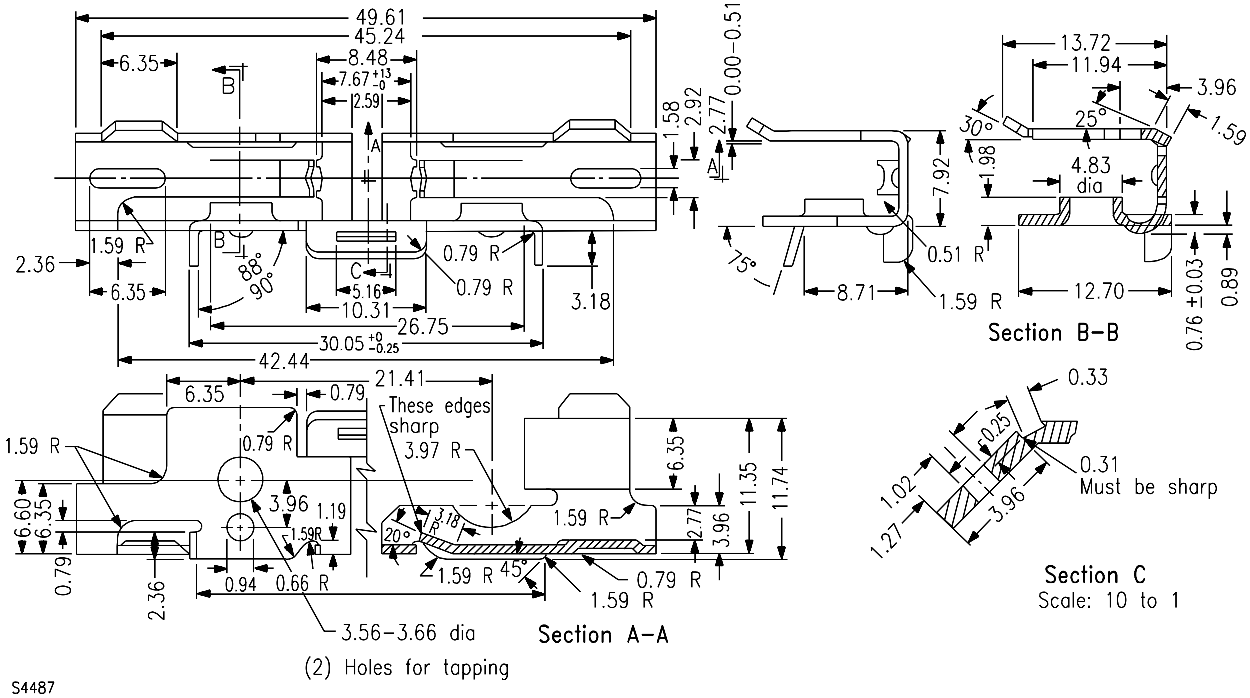


† *The terminal screws on each terminal baseplate are to be connected by means of ACM conductors that are looped under the screwhead in opposite directions.*

S4486

Figure 4
Terminal baseplate (70/30 brass)

(See 3.6.2 and 3.6.4.2)



Notes:

(1) Dimensions of the contacts used for receiving the blades of a plug have been omitted.

(2) Dimensions are given in millimeters.

Figure 5
Description of screw

(See 3.6.2)

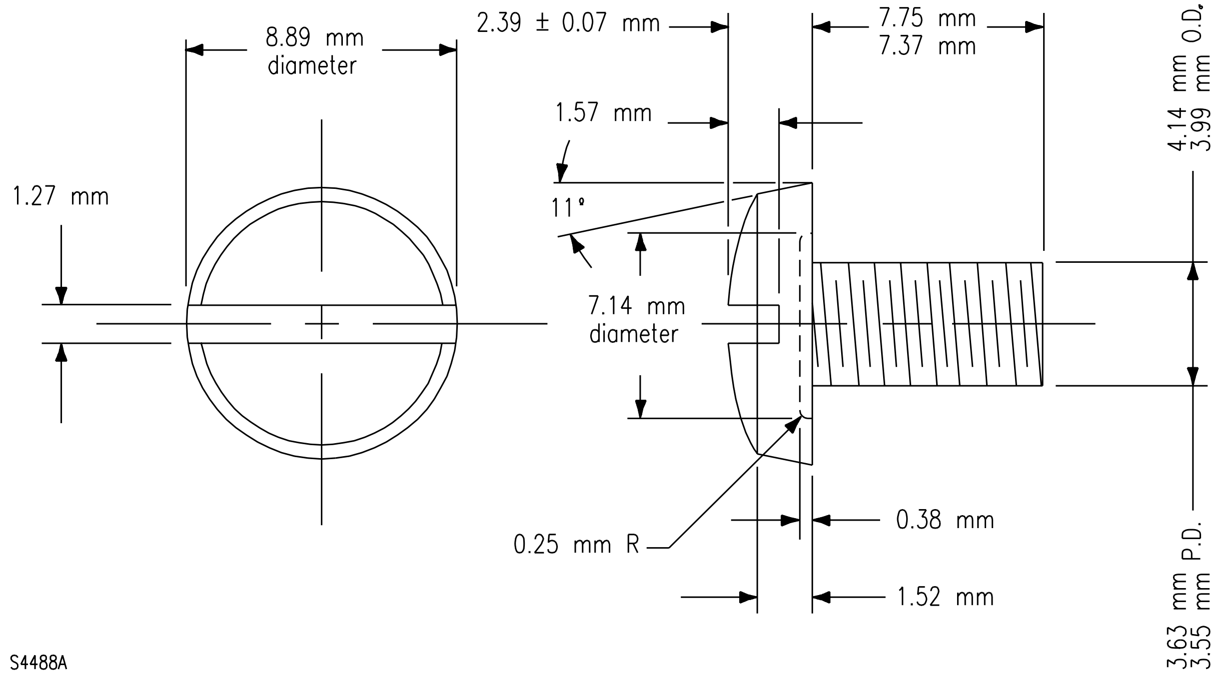


Figure 6
Annular section of insulation removed

(See 4.2.5.1.1)

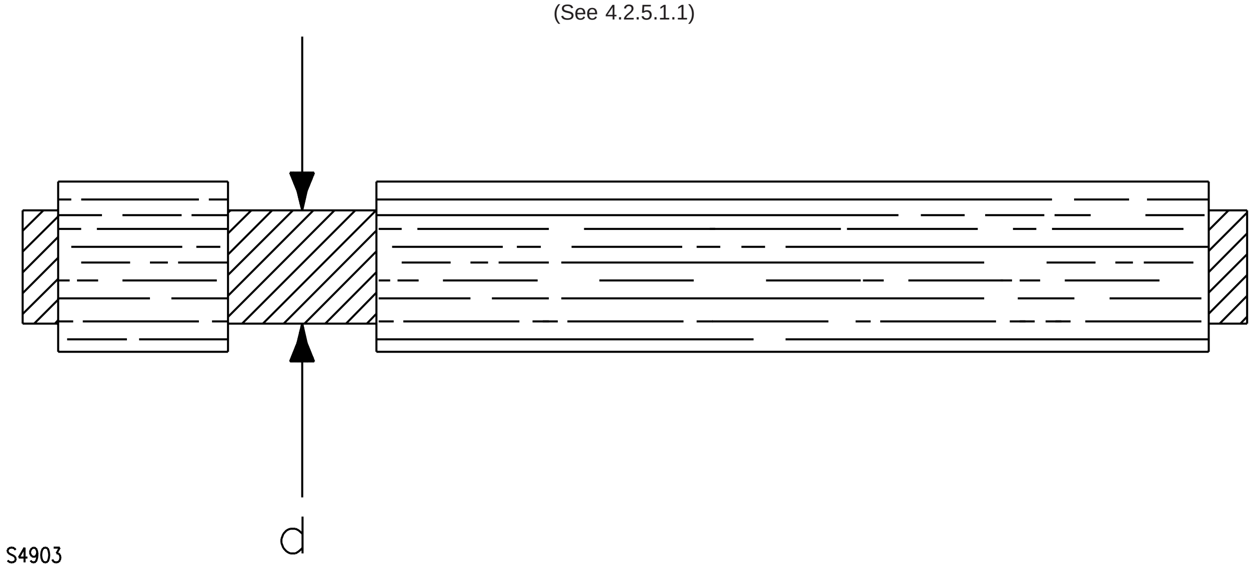
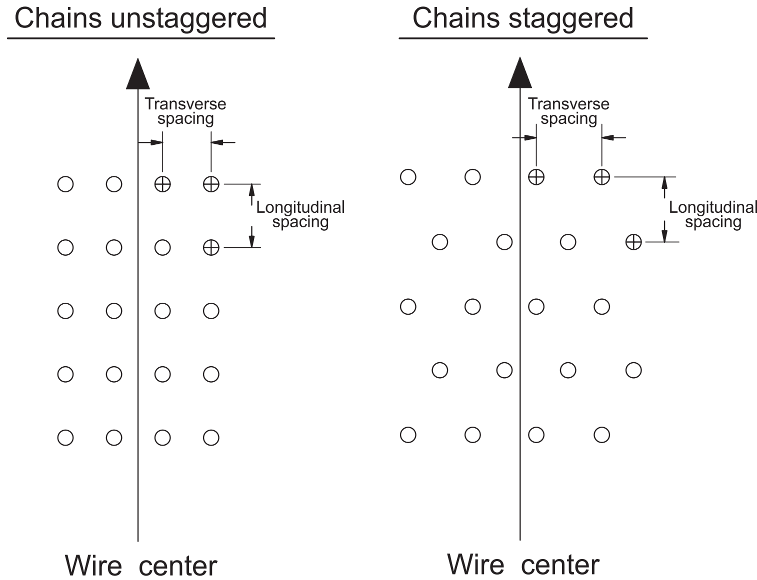


Figure 7
Bead chain configuration - top view

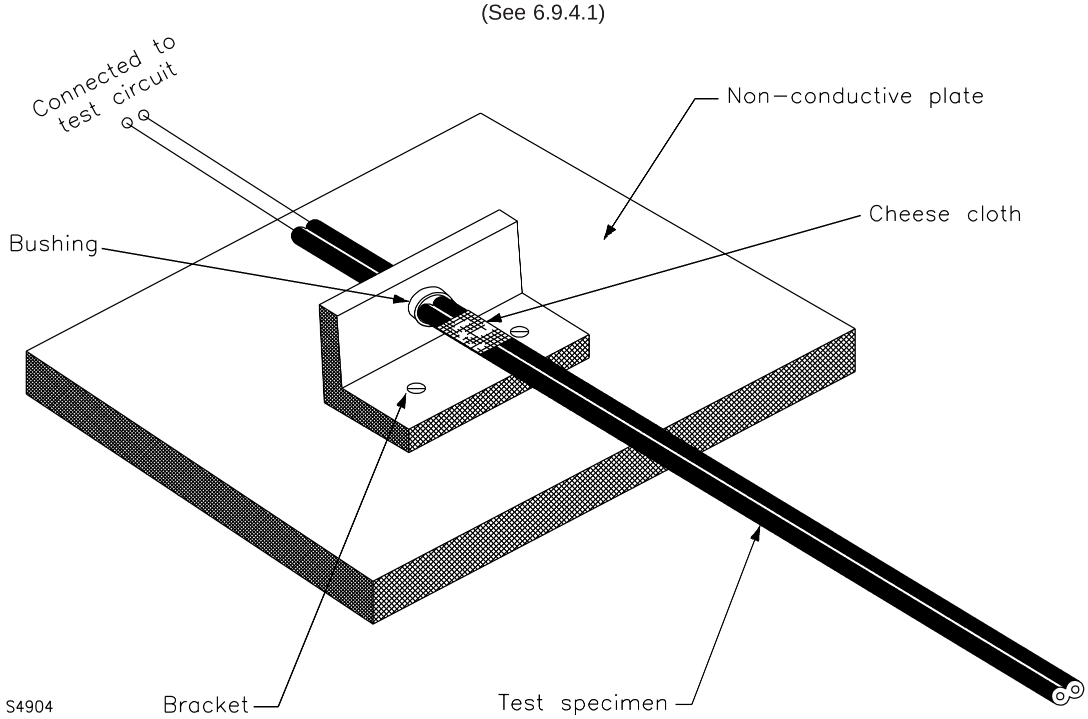
(See 6.7.2(c))



S5408

Figure 8
Flex arcing test jig

(See 6.9.4.1)



S4904

Figure 9
Schematic diagram of electrical circuit for flex arcing test

(See 6.9.4.3)

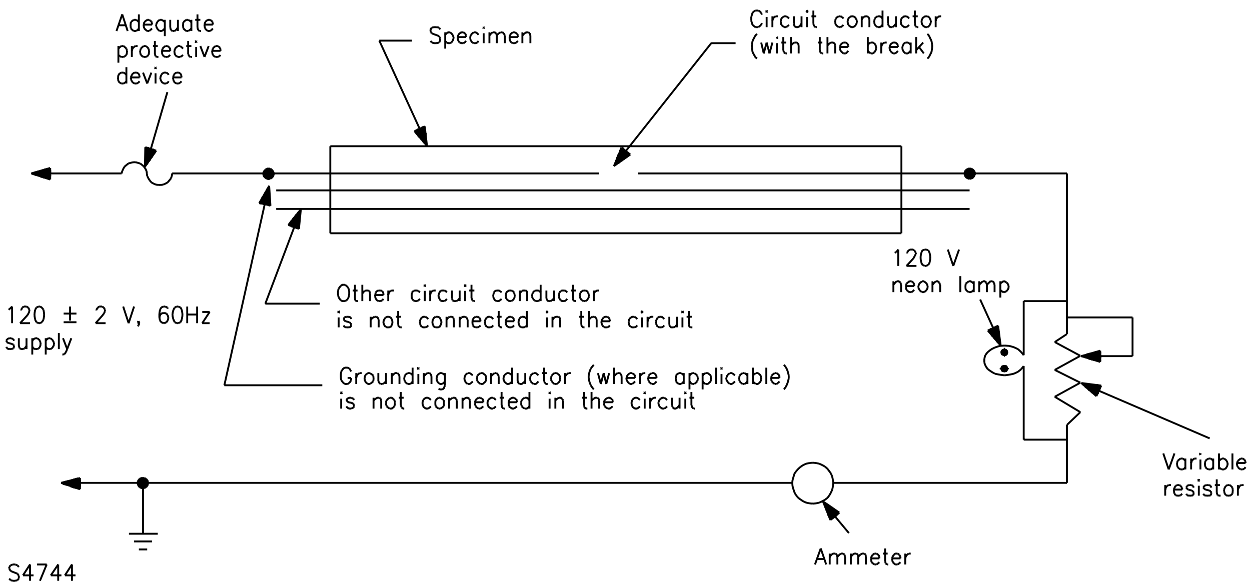


Figure 10
Circuit for measuring ac leakage current from each circuit conductor to grounding conductor

(See 6.11.4.1)

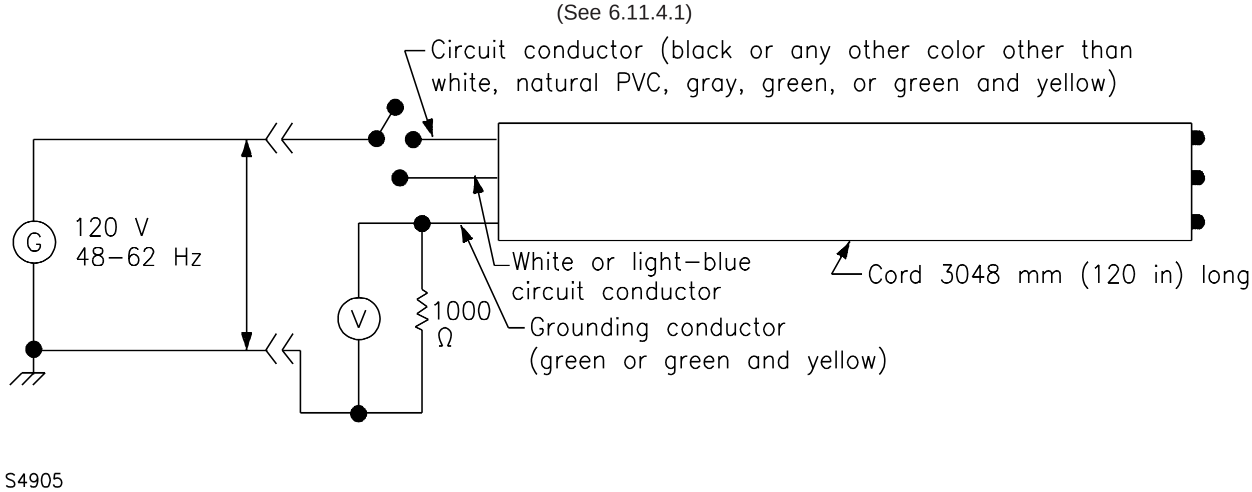
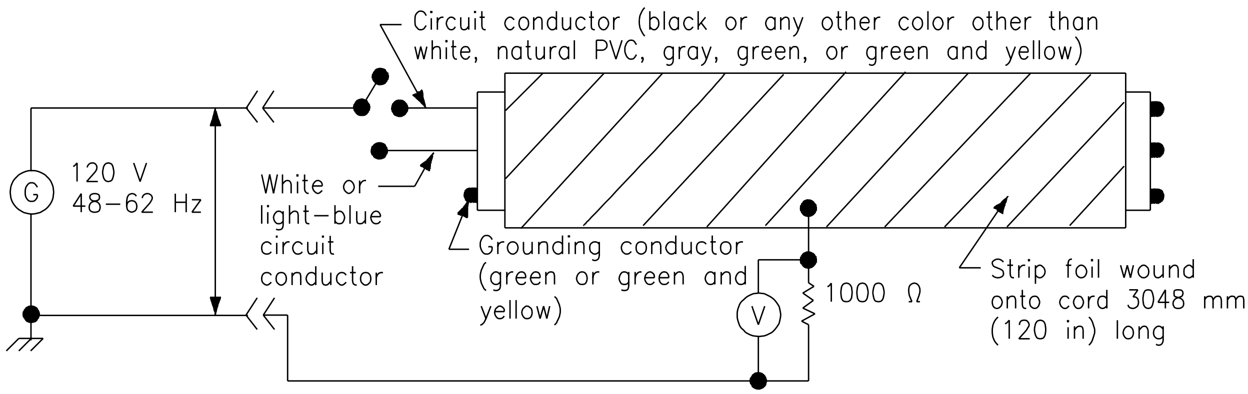


Figure 11
Circuit for measuring ac leakage current from each circuit conductor to the jacket

(See 6.11.4.2)



S4906

Figure 12
Apparatus for resistance of armor test

(See 6.13.2(a))

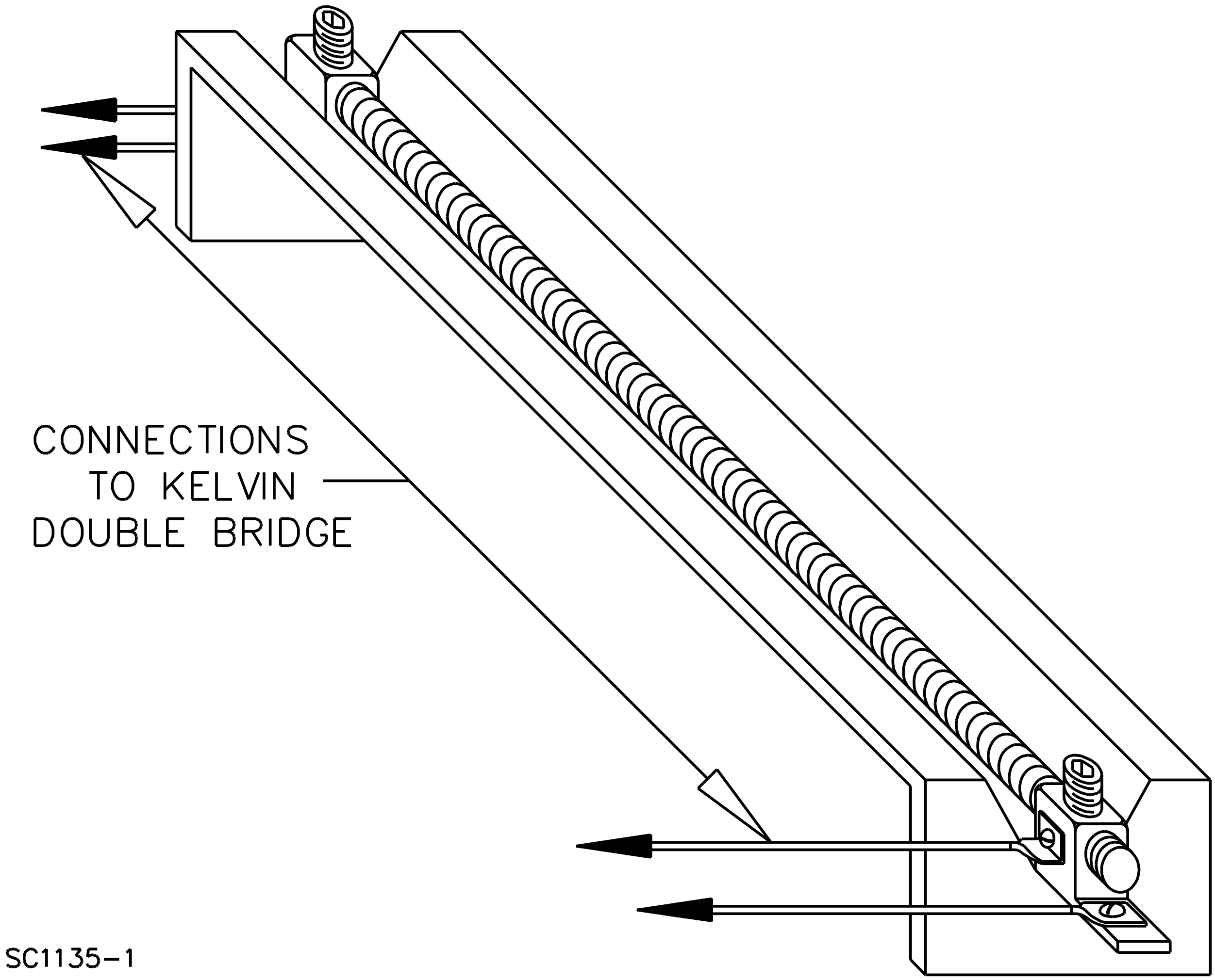


Figure 13
Apparatus for deformation test

(See 7.8.2(d))

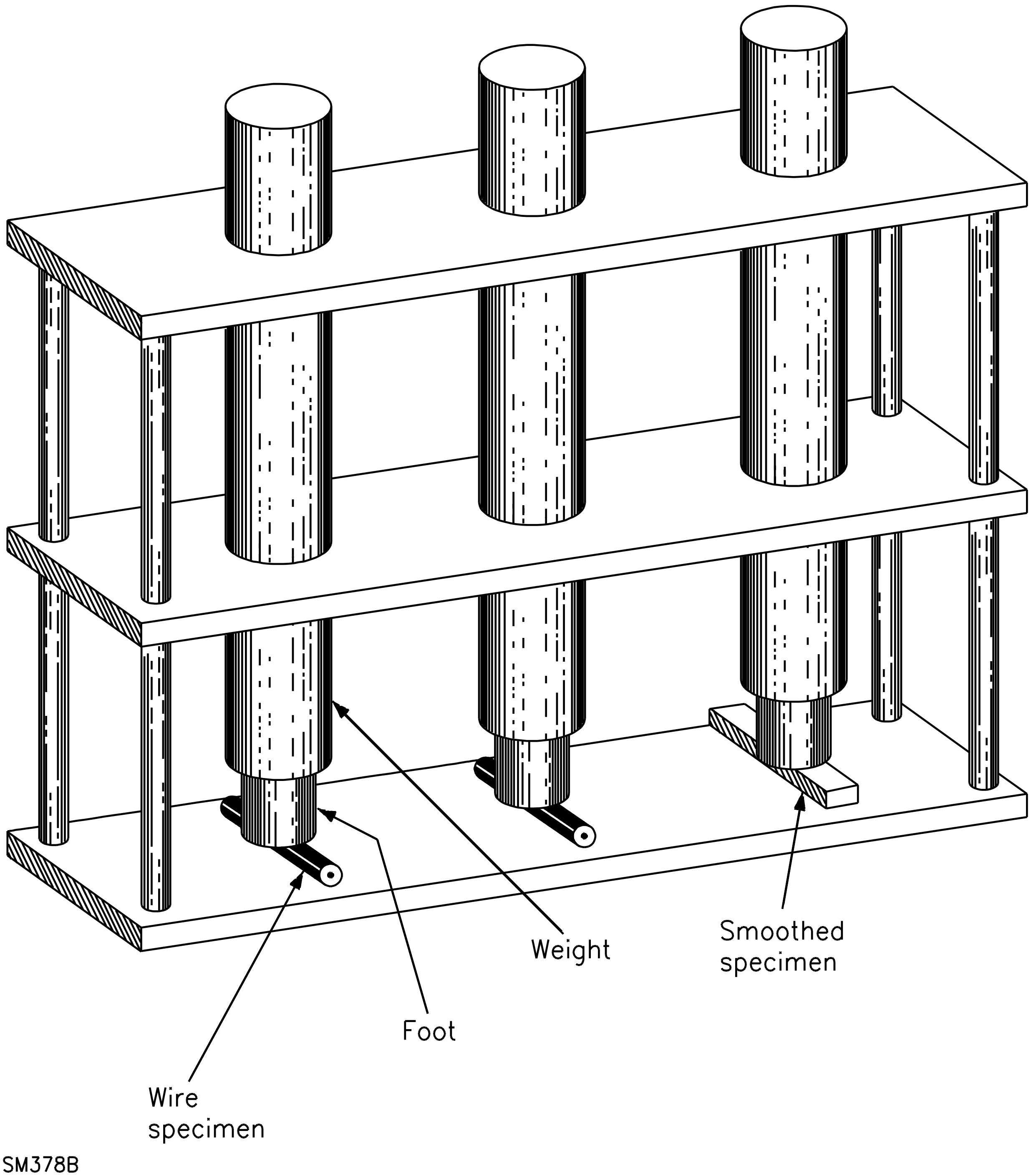
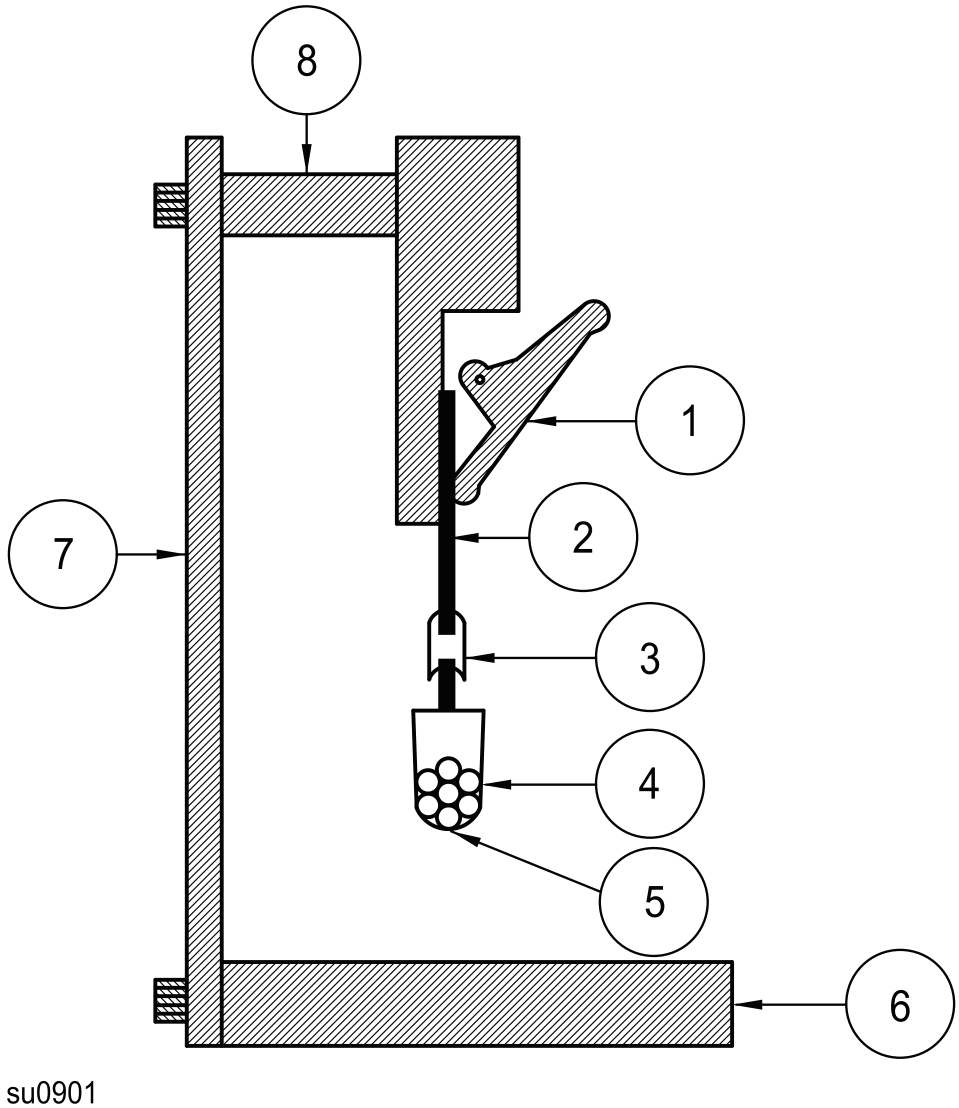


Figure 14
Apparatus for hot creep and set test

(See 7.9.2(c))



1 Upper gripping assembly

2 Specimen

3 Lower gripping assembly

4 Receptacle for weights

5 Added weights

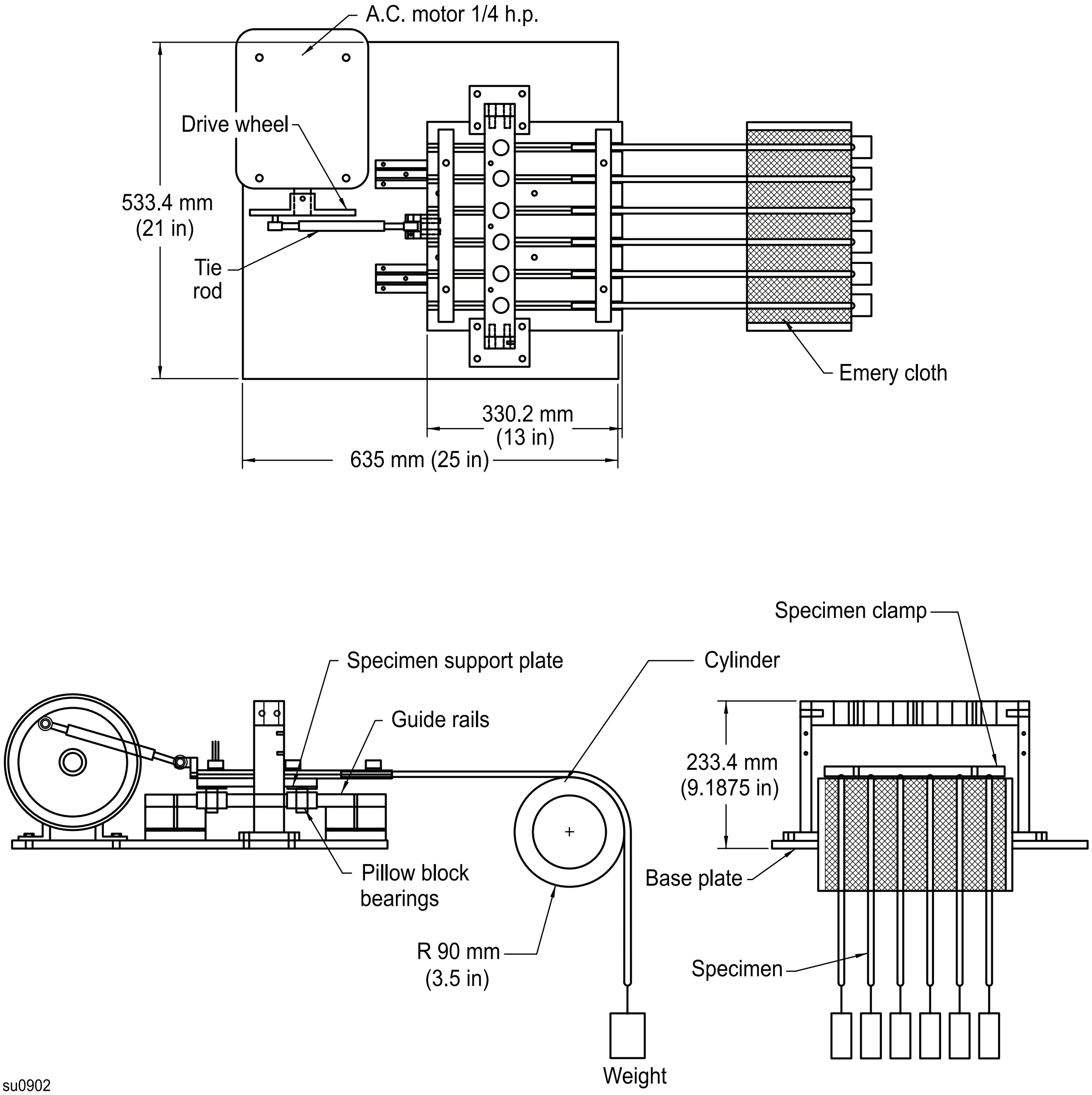
6 Steel base

7 Vertical support

8 Support arm

Figure 15
Apparatus for abrasion test

(See 7.10.2(a))

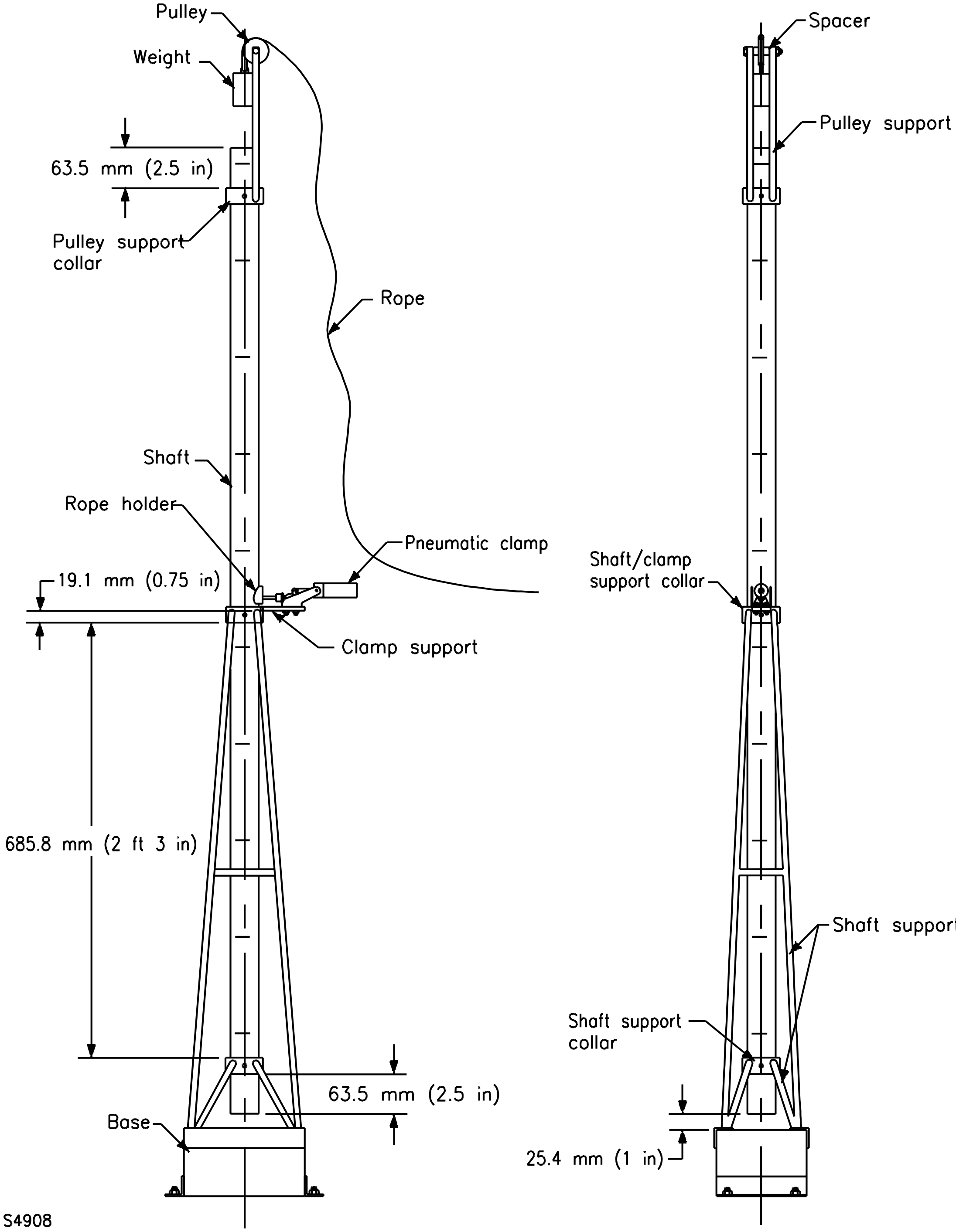


su0902

Note: This figure represents typical apparatus. Dimensions are suggested only, unless specified in the test clause.

Figure 16
Apparatus for impact test

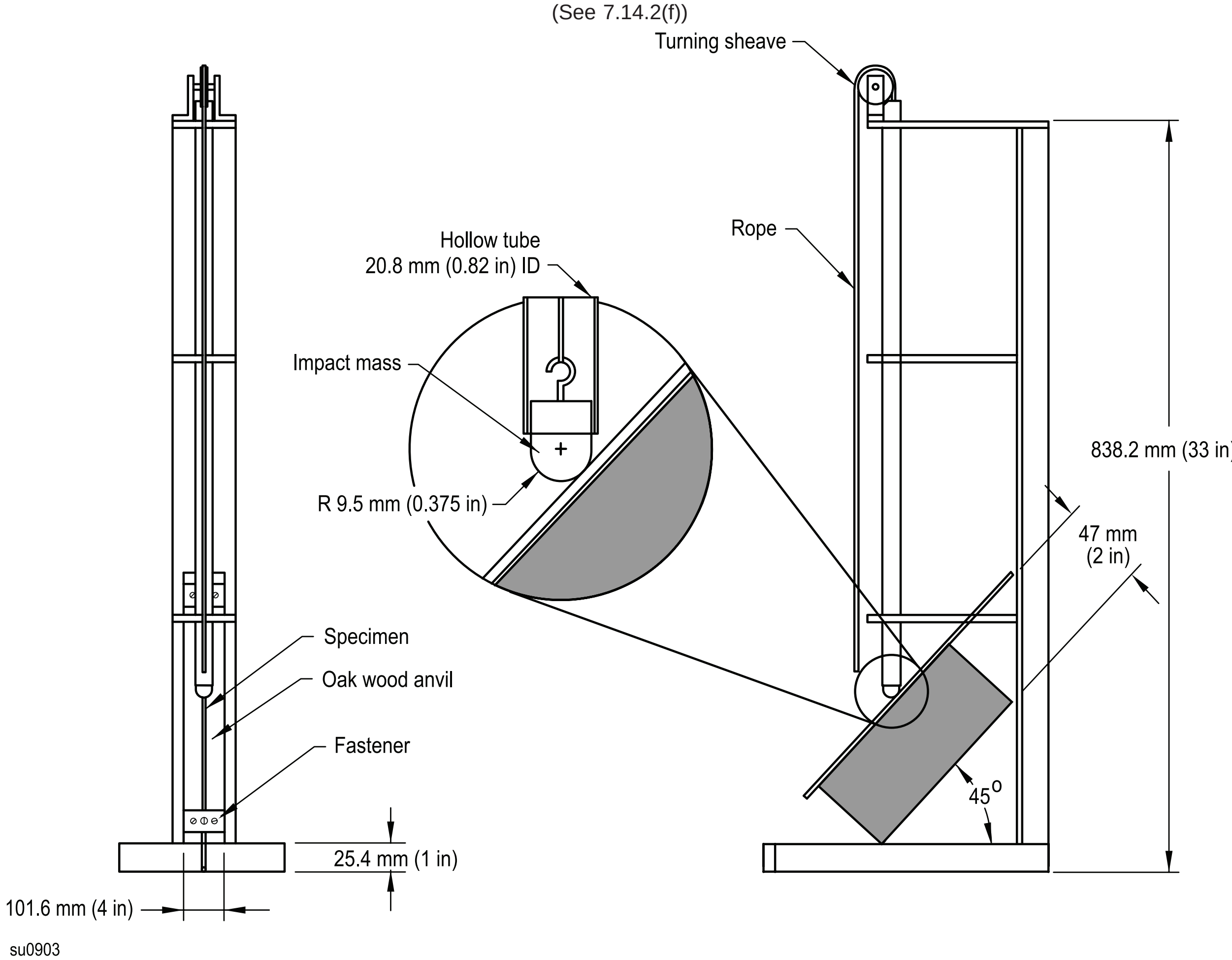
(See 7.7.2(c) and 7.13.2(a))



Note: This figure represents typical apparatus. Dimensions are suggested only, unless specified in the test clause.

Figure 17
Apparatus for glancing impact

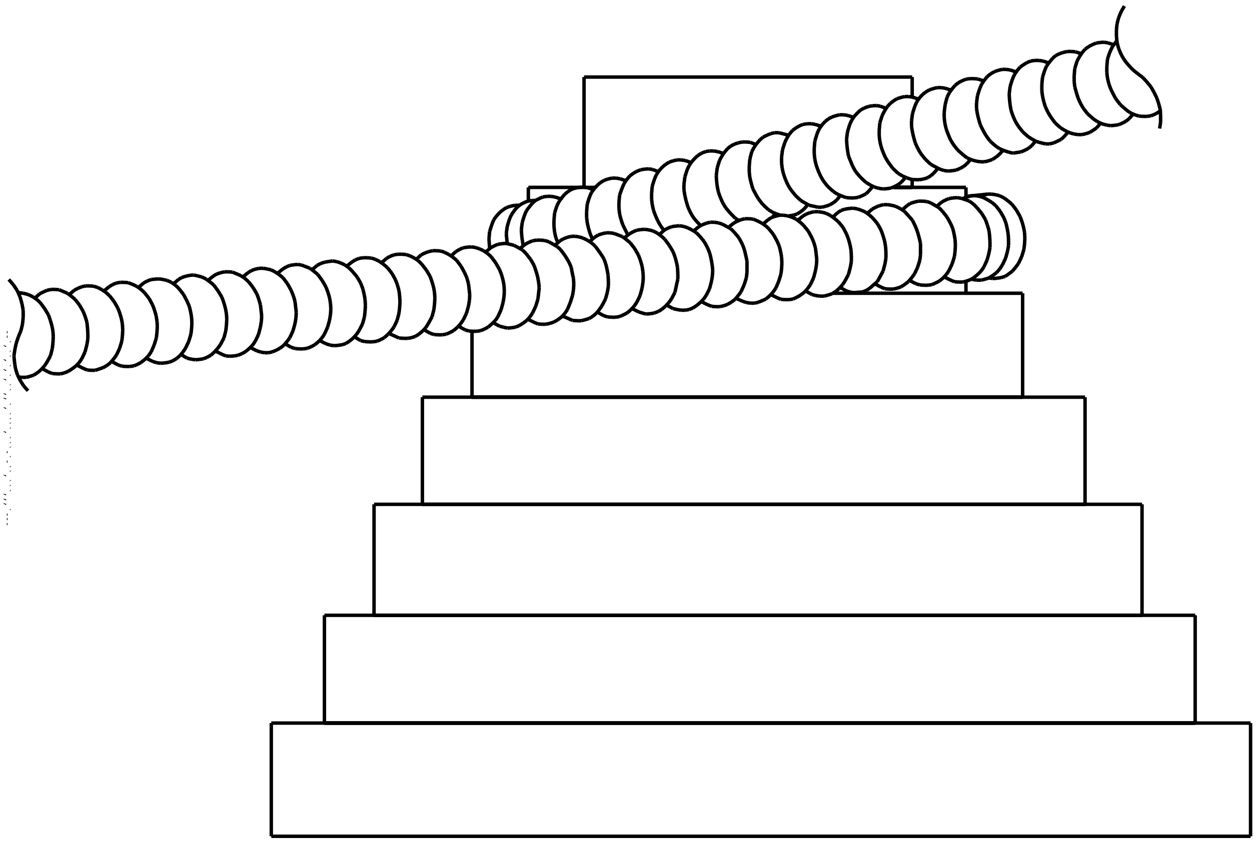
(See 7.14.2(f))



Note: This figure represents typical apparatus. Dimensions are suggested only, unless specified in the test clause.

Figure 18
Apparatus for flexibility of armor test

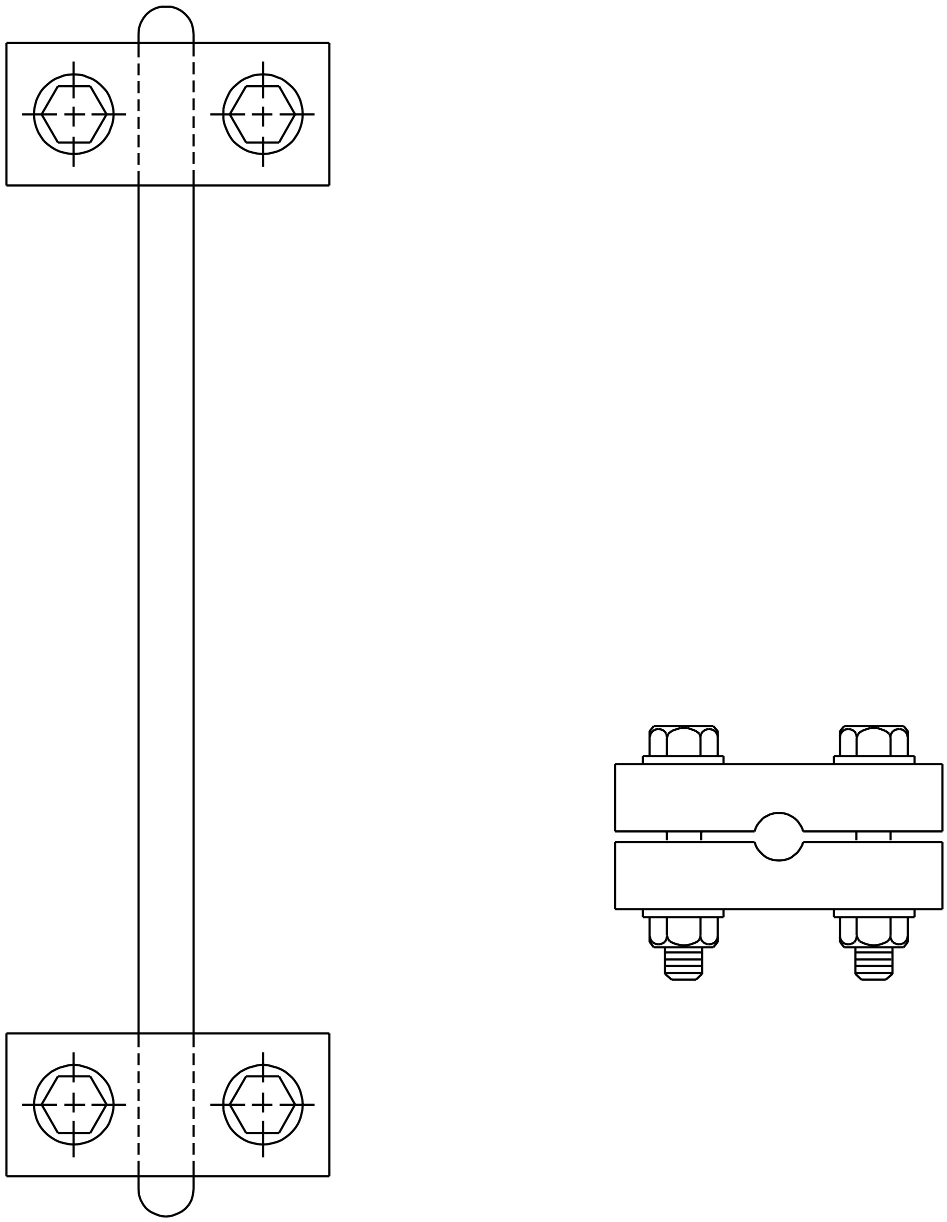
(See 7.17.2(a))



SB1134

Figure 19
Apparatus for mechanical strength test

(See 7.21.2(c) and 7.22.2(b))



S4910

Figure 20
Preparation of multiconductor parallel specimens for tightness of insulation test

(See 7.24.3.2)

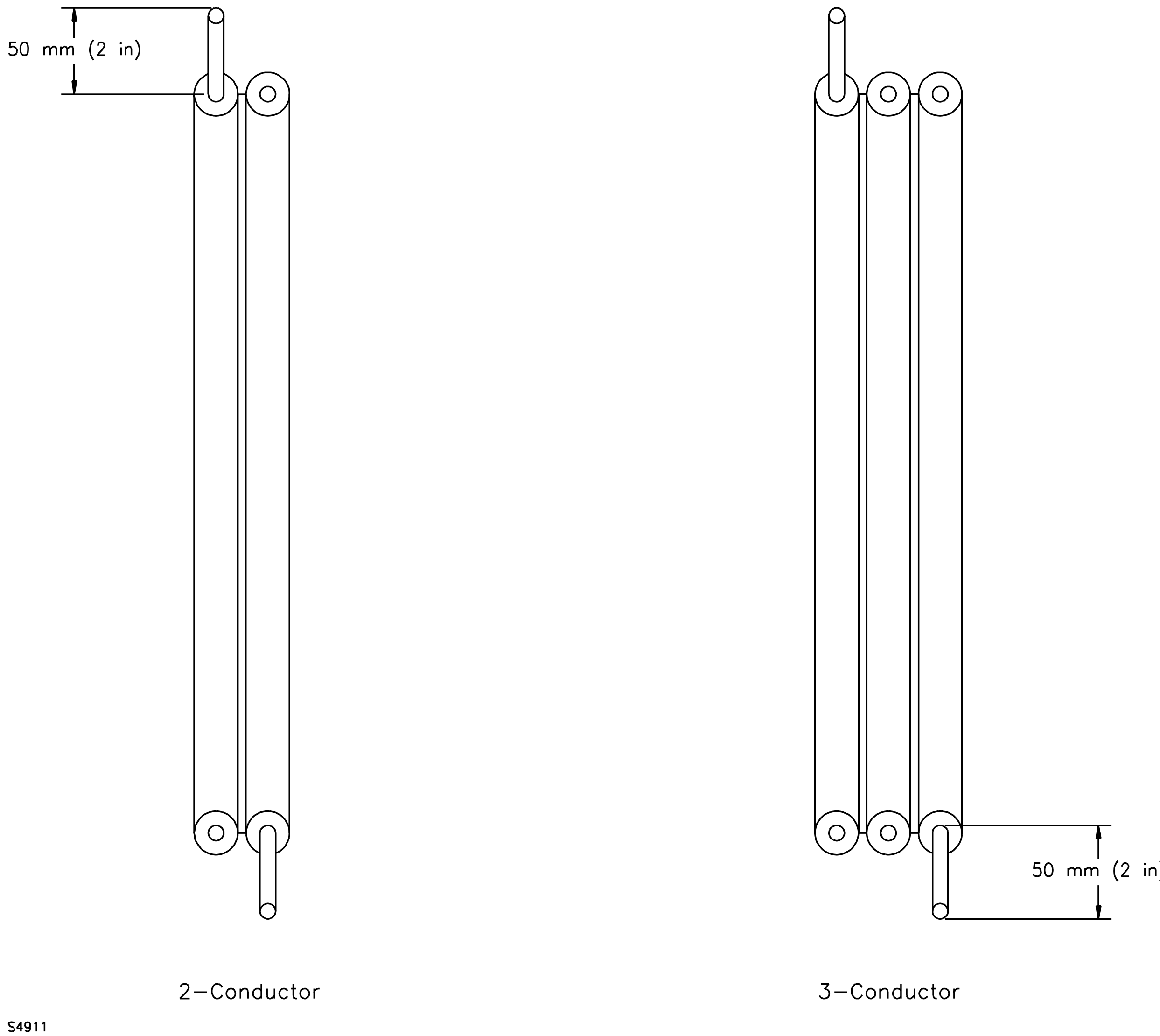


Figure 21
Apparatus for flexing of shielded cords

(See 7.26.2(a) and 7.26.4.2)

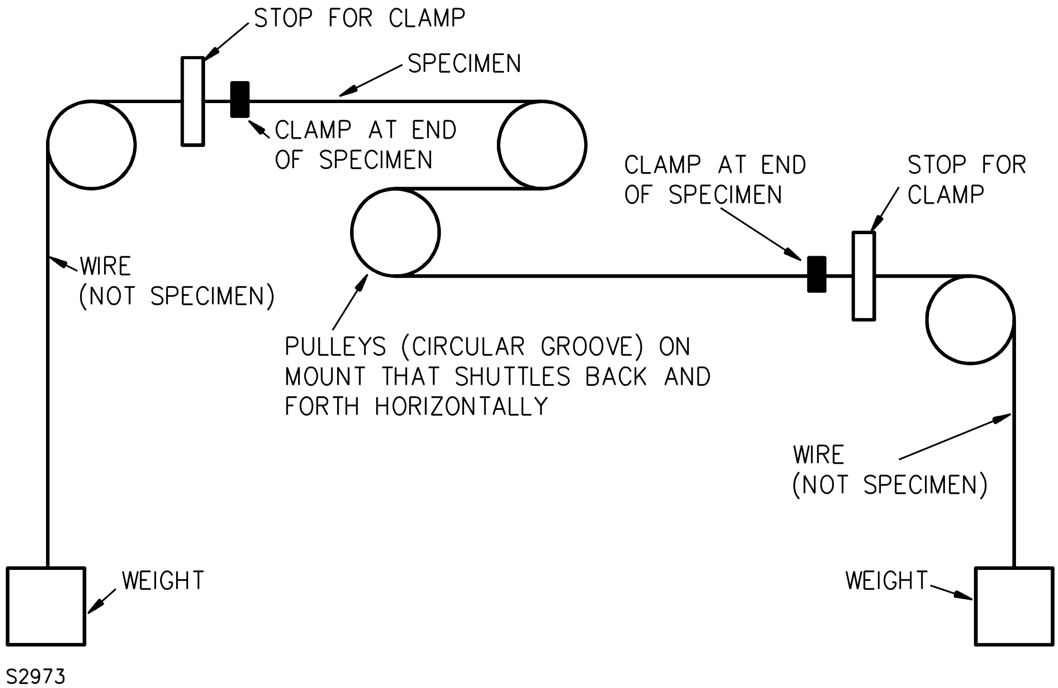
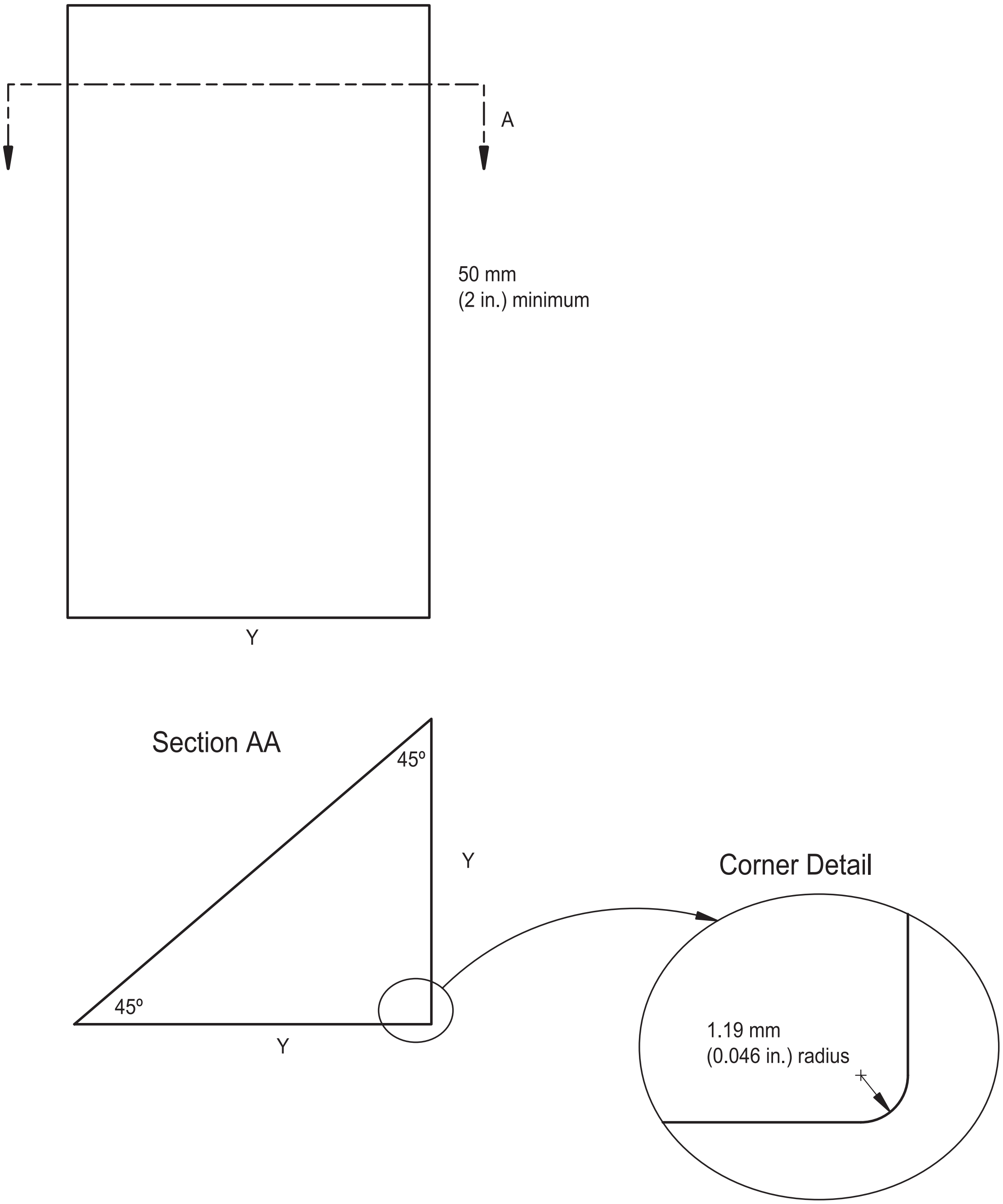


Figure 22
Mandrel crushing test

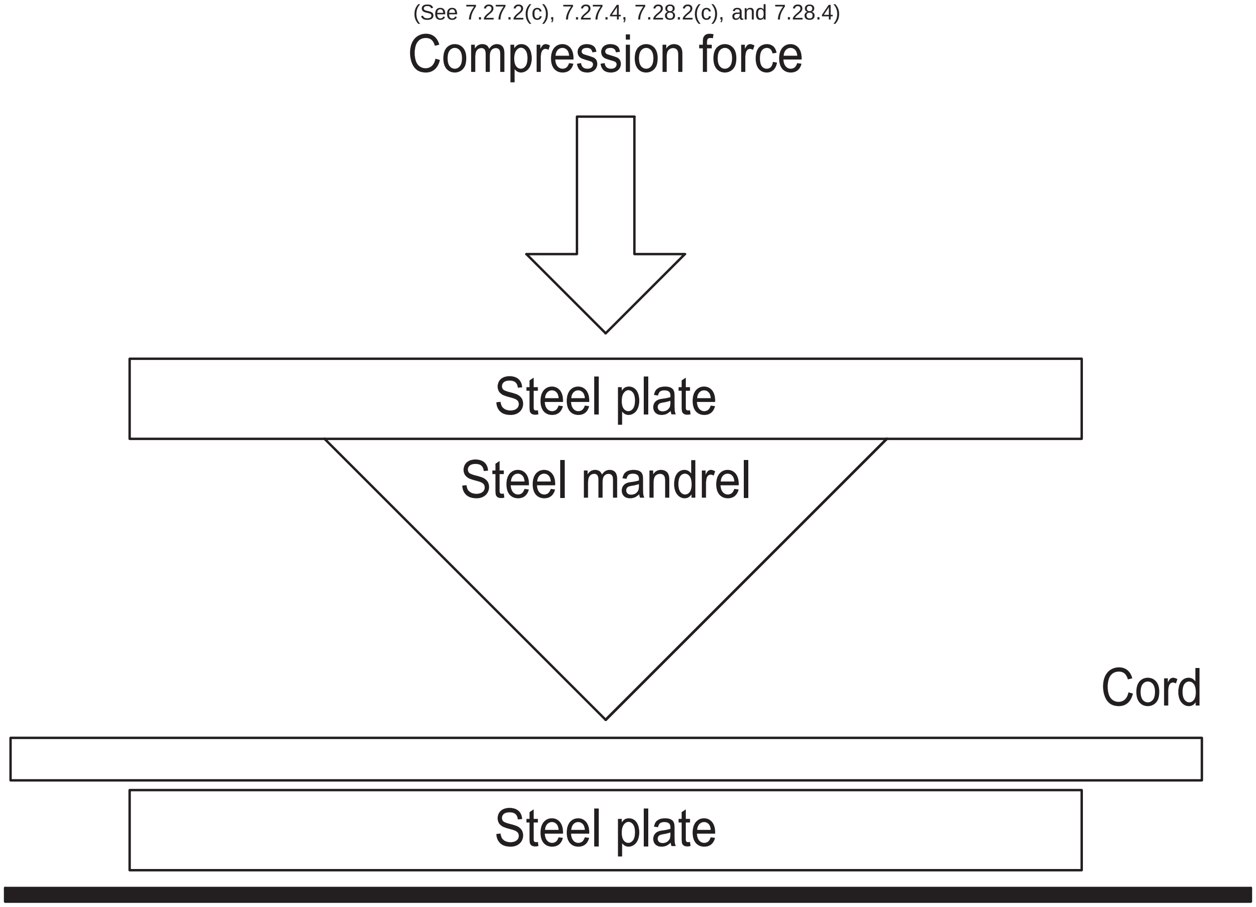
(See 7.27.2(c) and 7.28.2(c))



su0258

Figure 23
Mandrel pinching test

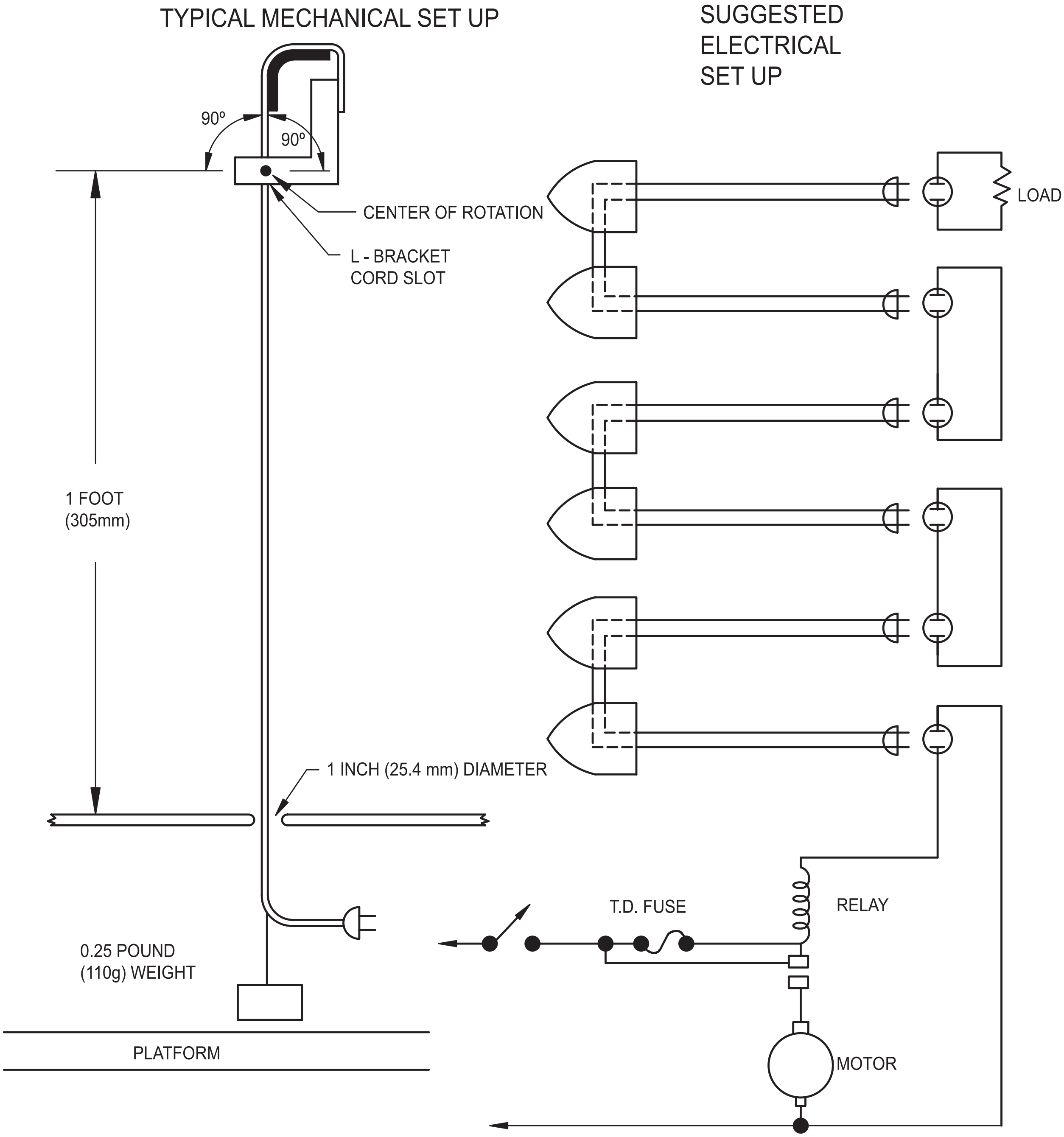
(See 7.27.2(c), 7.27.4, 7.28.2(c), and 7.28.4)



s5549

Figure 24
Flexing apparatus

(See 7.29.2 and 7.29.4.3)



su0004a

Figure 25
Flexing apparatus – L-bracket slot details

(See 7.29.2 and 7.29.4.1)

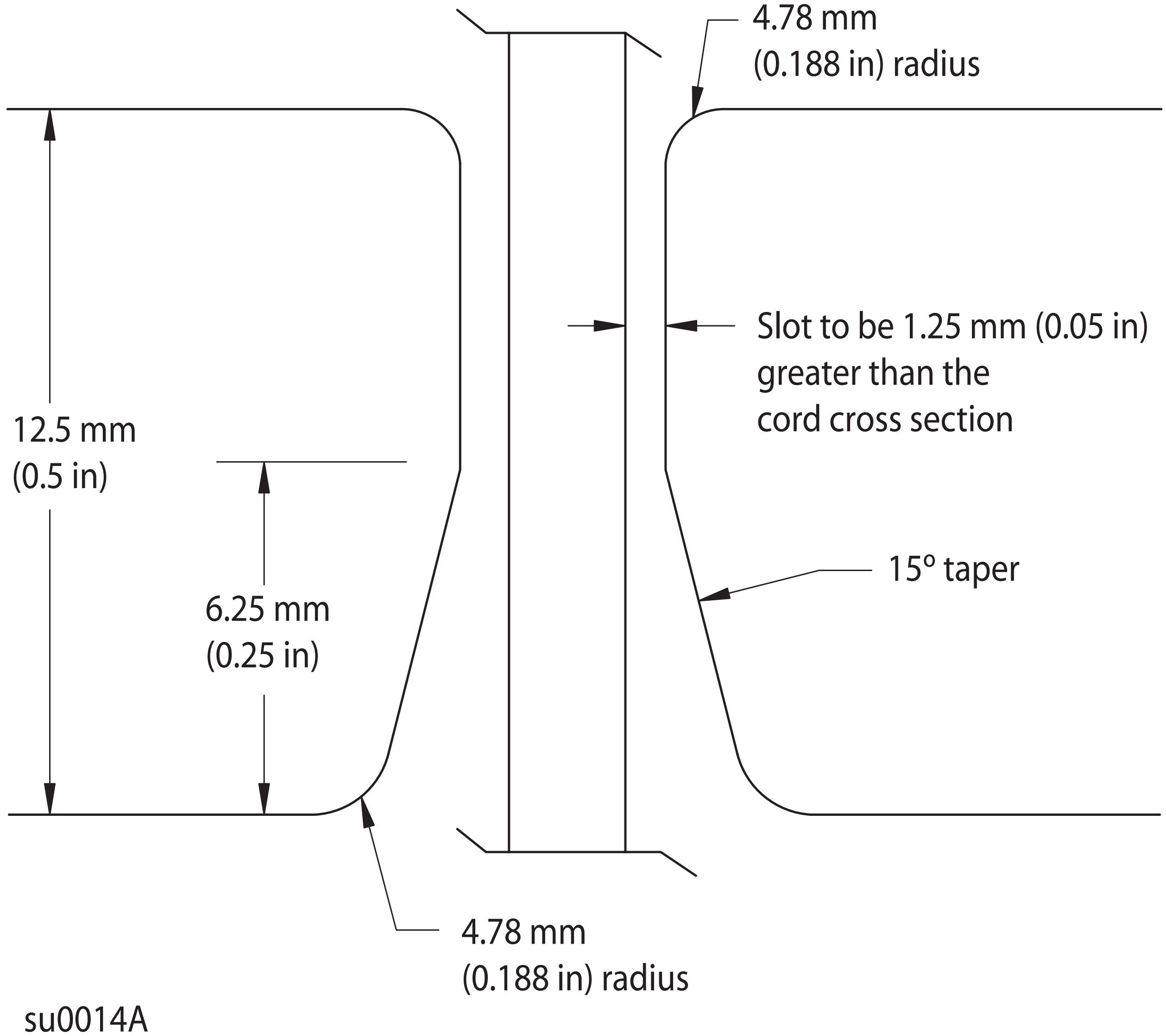


Figure 26
Flexing apparatus - cord attachment bracket

(See 7.29.2 and 7.29.4.1)

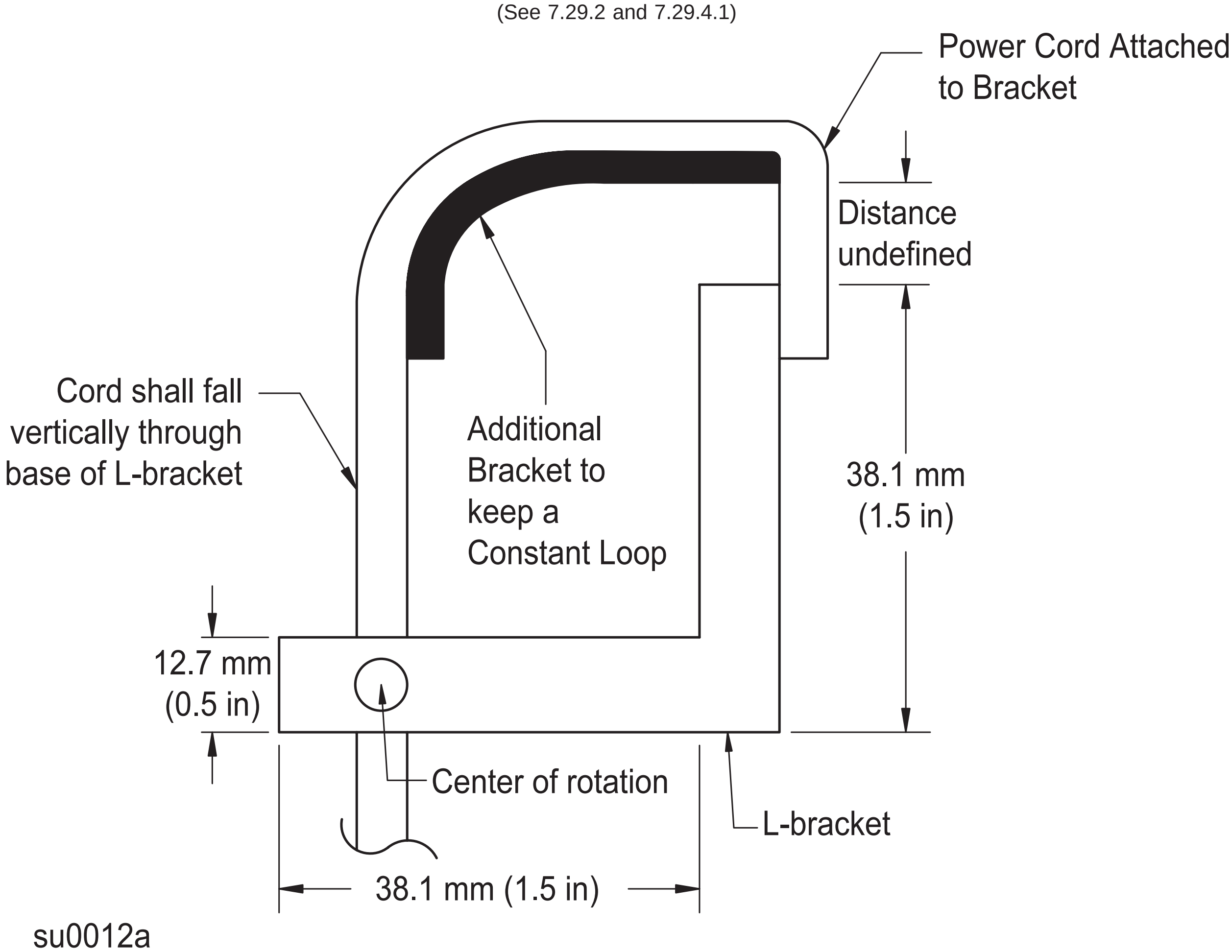
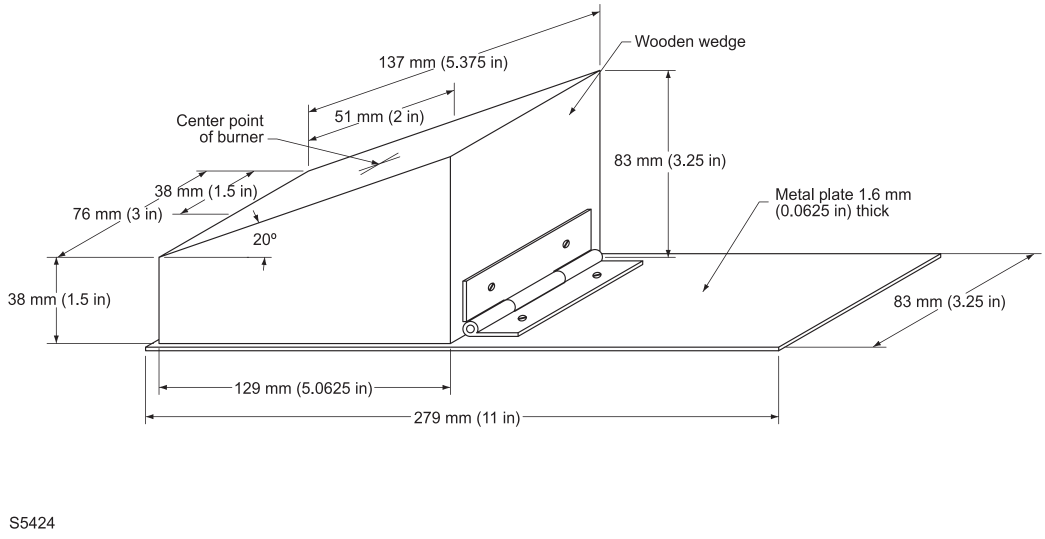


Figure 27
Angle block

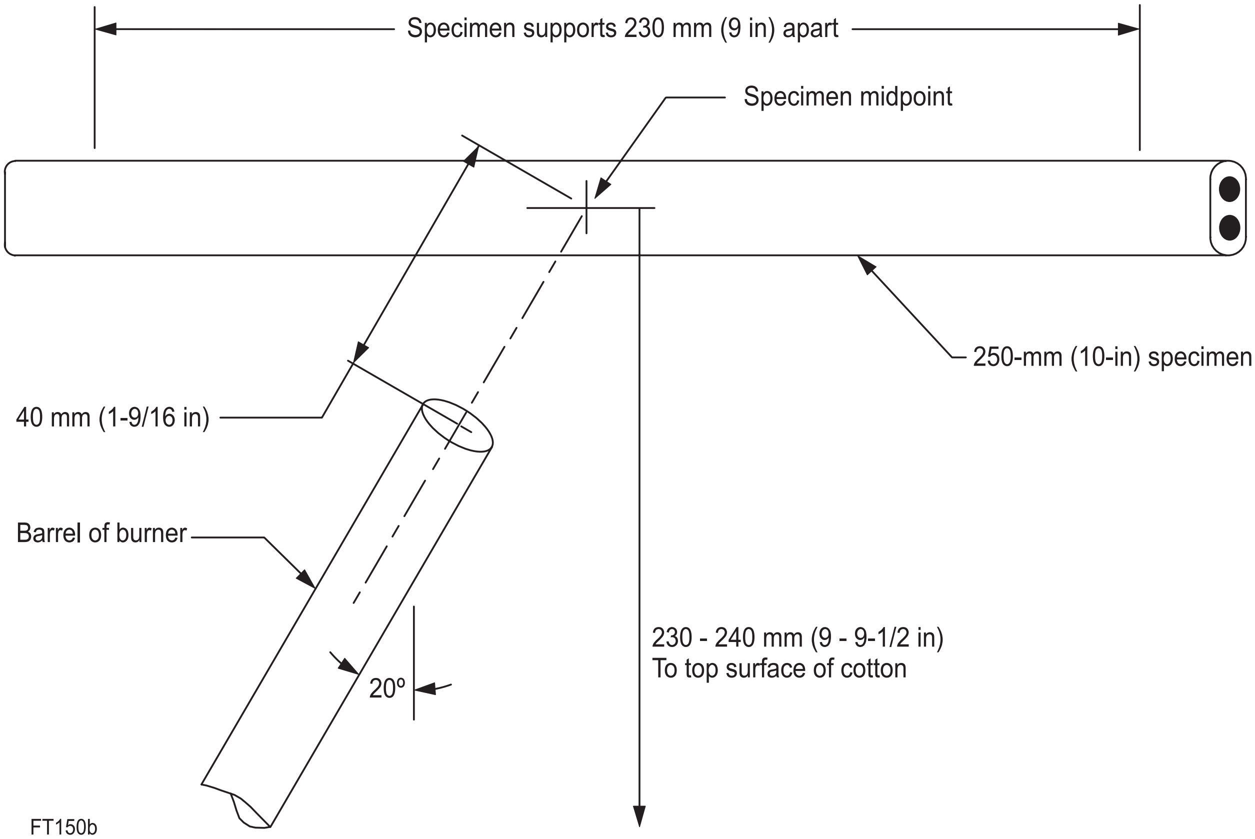
(See 9.1.3(b))



Note: This figure represents typical apparatus. Dimensions are suggested only, unless otherwise specified in the test. Hinge is optional.

Figure 28
Flame application on horizontal specimen

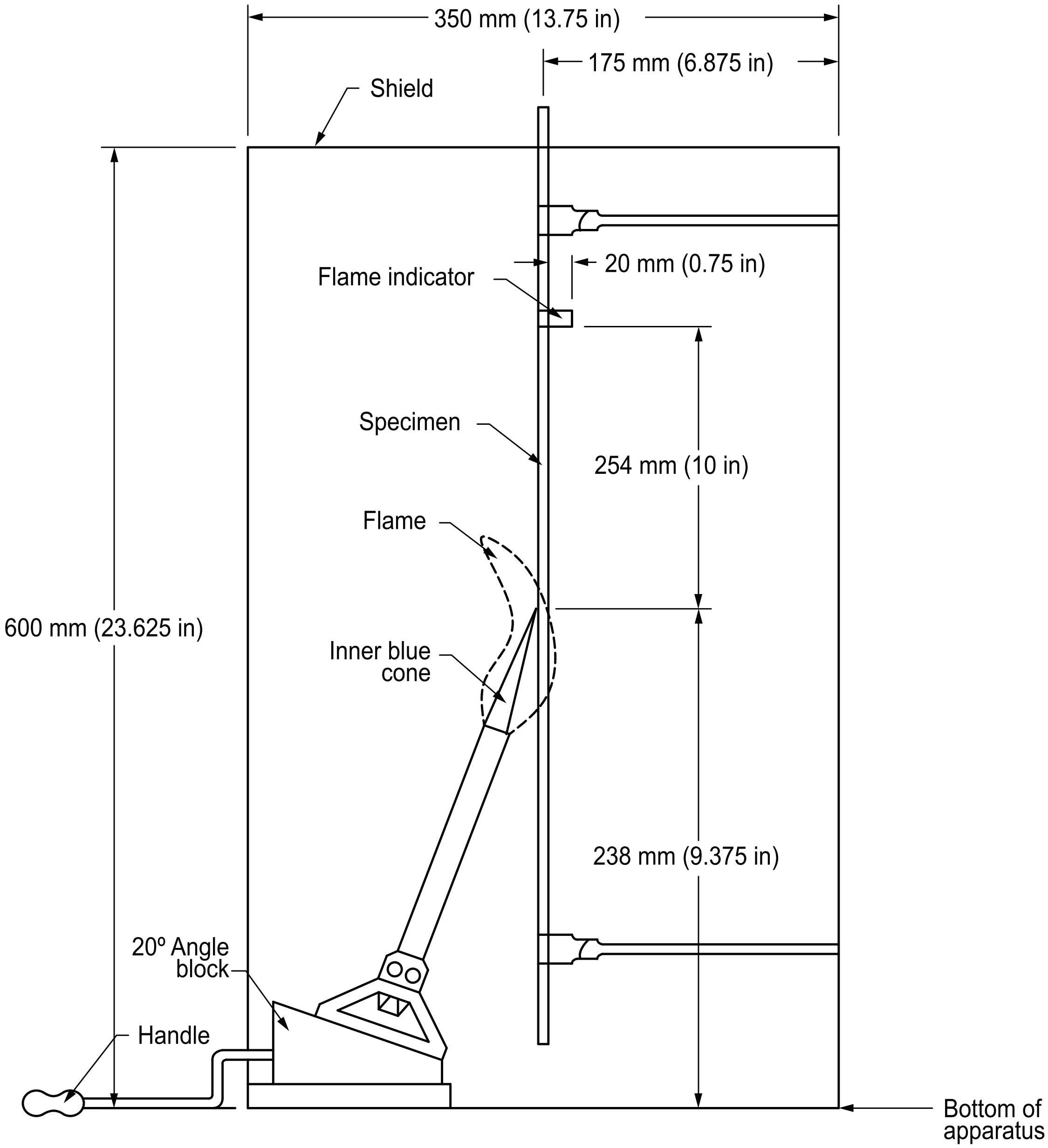
(See 9.1.5.3)



Note: This figure represents typical apparatus. Dimensions are suggested only, unless otherwise specified in the test.

Figure 29
Flame application on vertical specimen

(See 9.2.5.4, 9.3.5.2, and 9.4.5.2)



su1461a

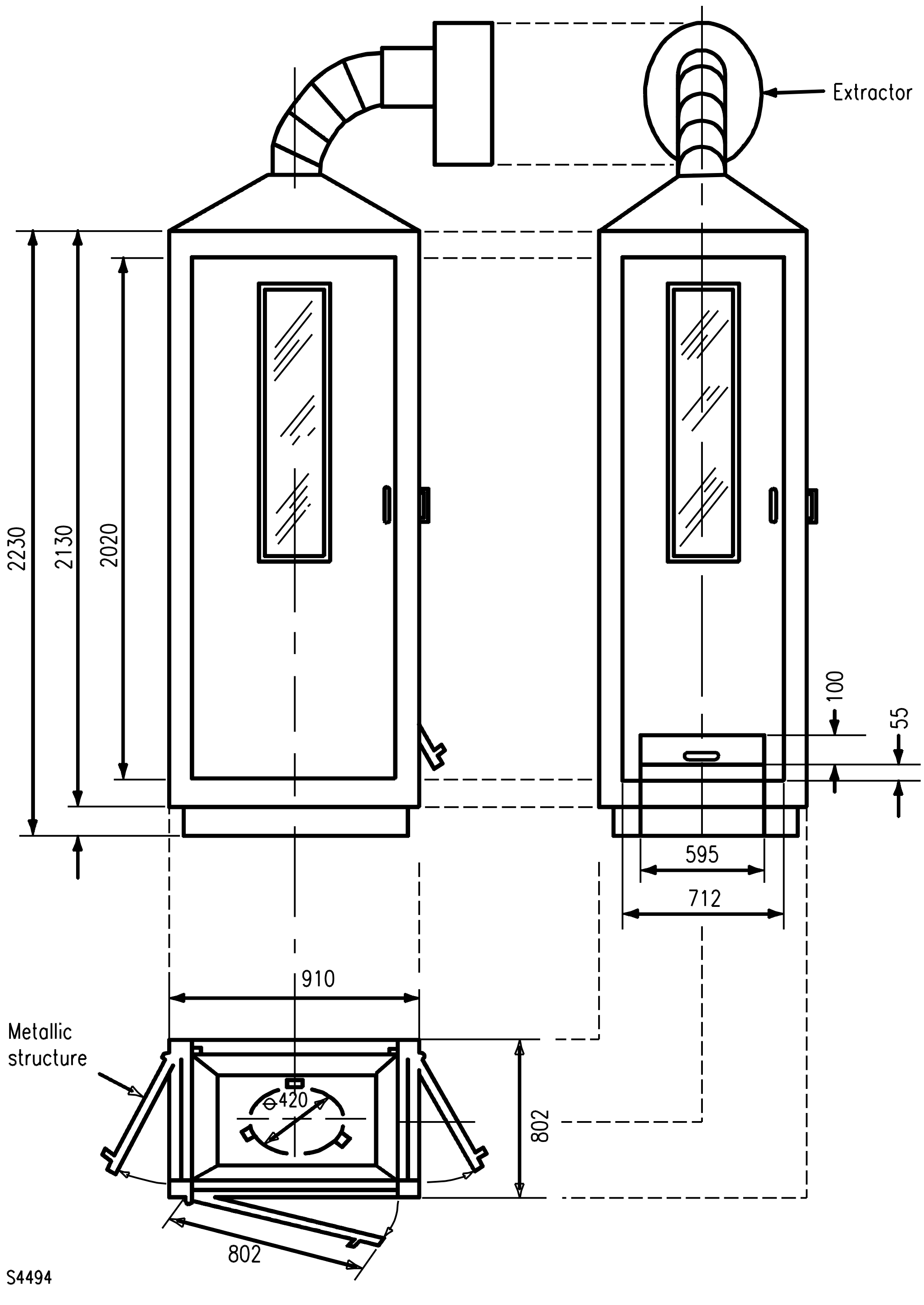
Note 1: This figure represents typical apparatus. Dimensions are suggested only, unless otherwise specified in the test. Handle is optional.

Note 2: Shield not present for the vertical flame test/VW-1/FV-2.

Note 3: Flag indicator is not present for the burning particles test.

Figure 30
Chamber for fire propagation test

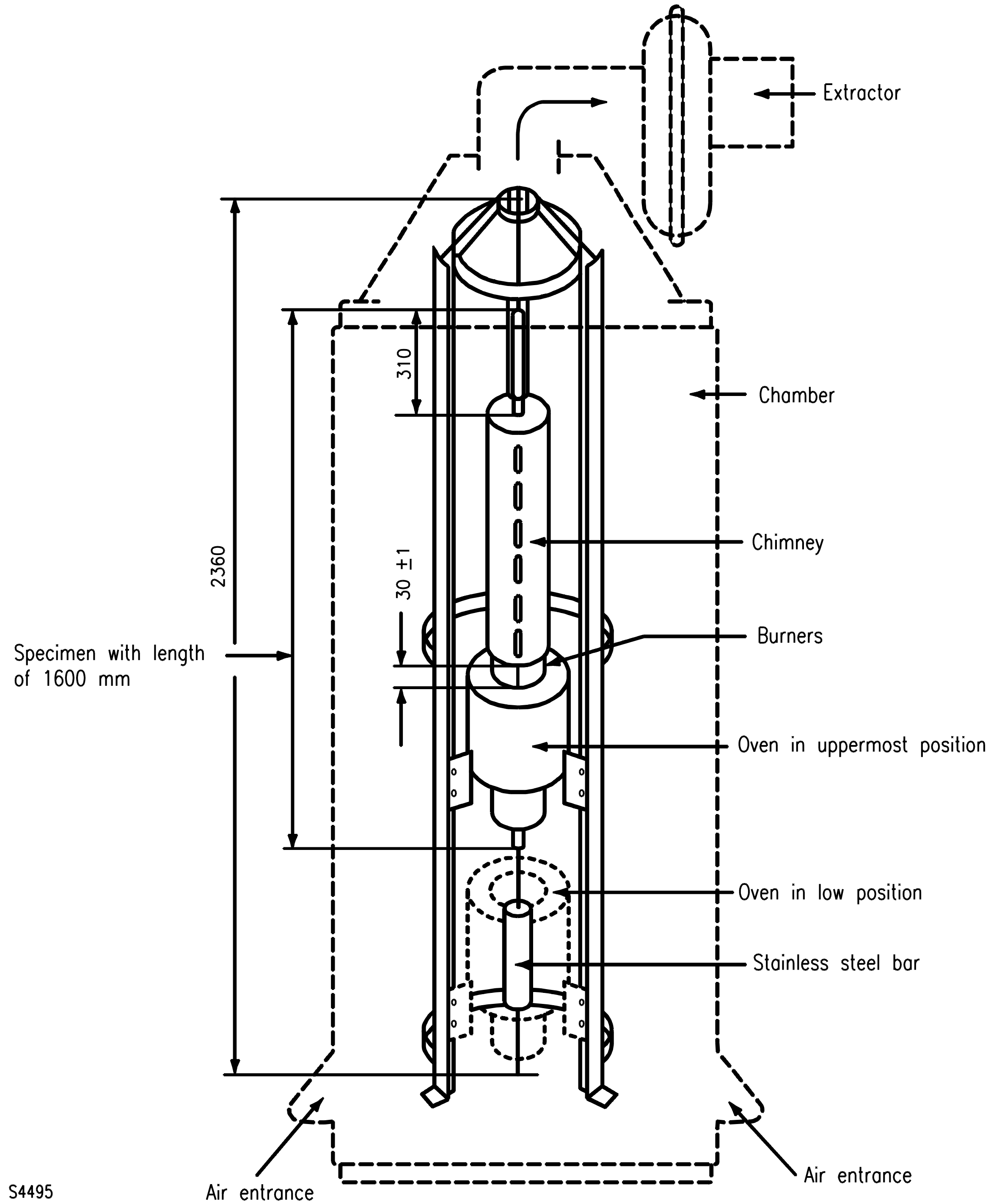
(See 9.8.3.1(a))



Dimensions in mm.

Figure 31
Detail 1 of dimensions for fire propagation test chamber

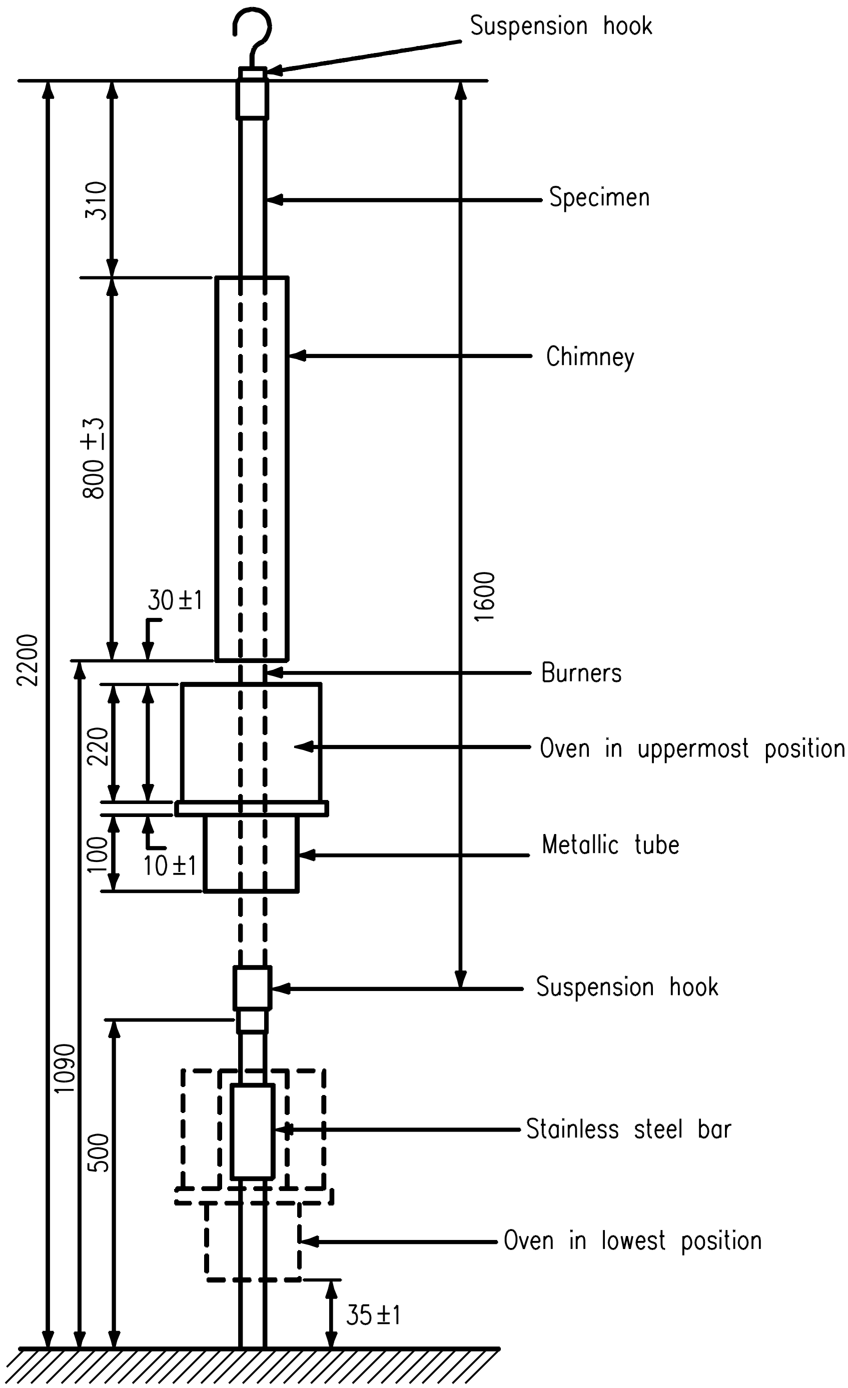
(See 9.8.3.1(a))



Dimensions in mm.

Figure 32
Detail 2 of dimensions for fire propagation test chamber

(See 9.8.3.1(a))

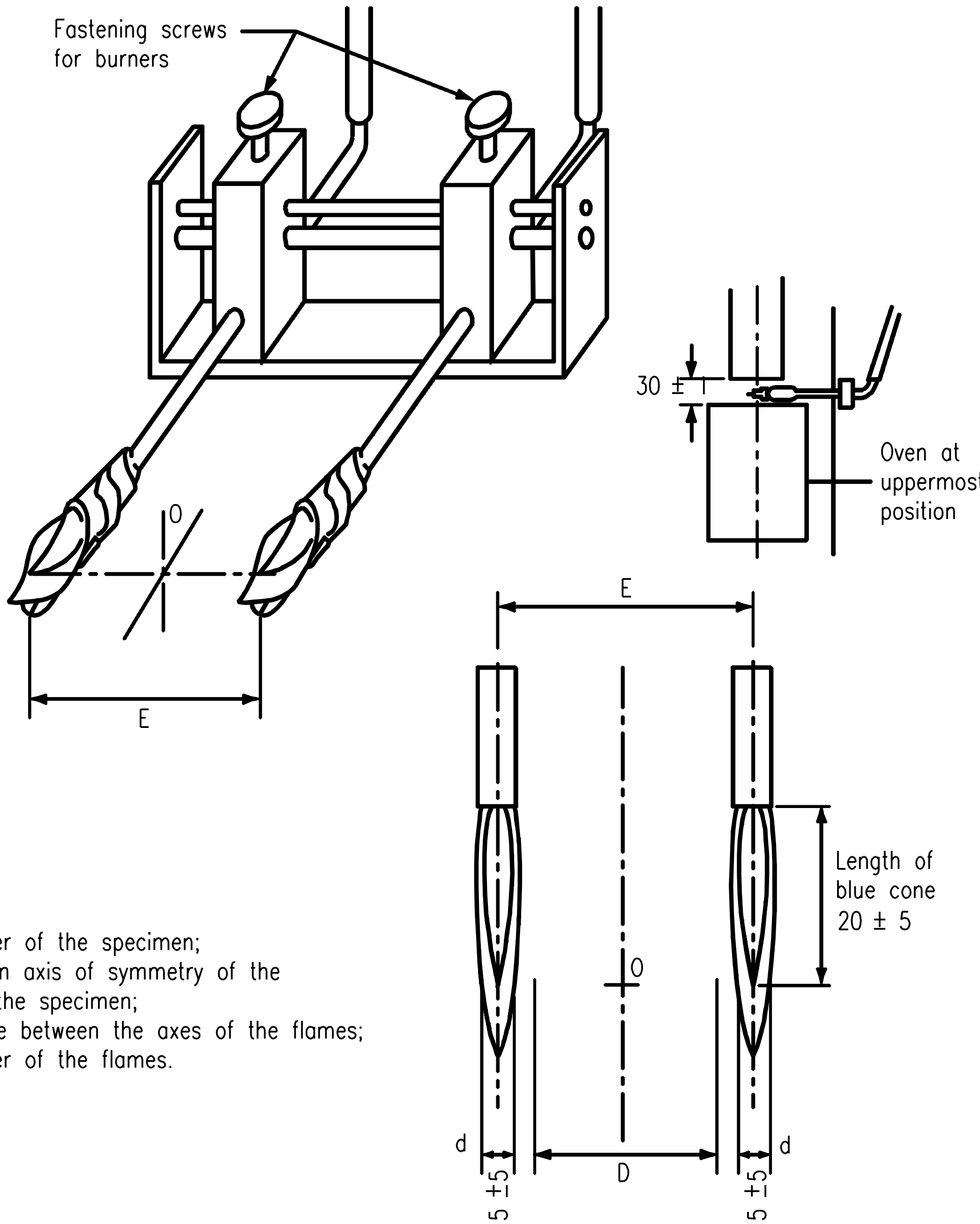


S4496

Dimensions in mm.

Figure 33
Burners for fire propagation test

(See 9.8.3.1(a))



Legend:

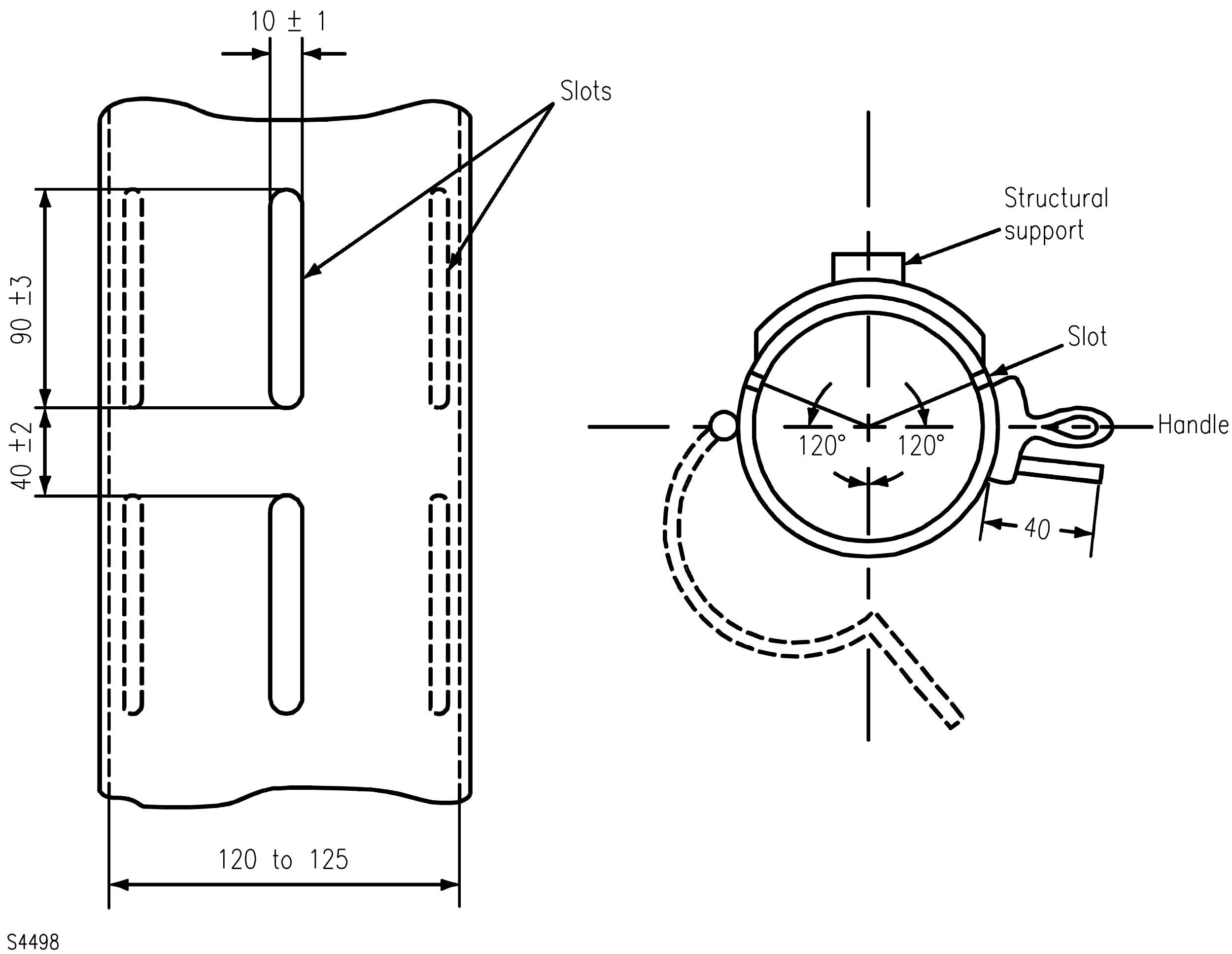
D is the diameter of the specimen;
O is the common axis of symmetry of the chimney and the specimen;
E is the distance between the axes of the flames;
d is the diameter of the flames.

S4497

Dimensions in mm.

Figure 34
Metallic chimney of fire propagation test chamber

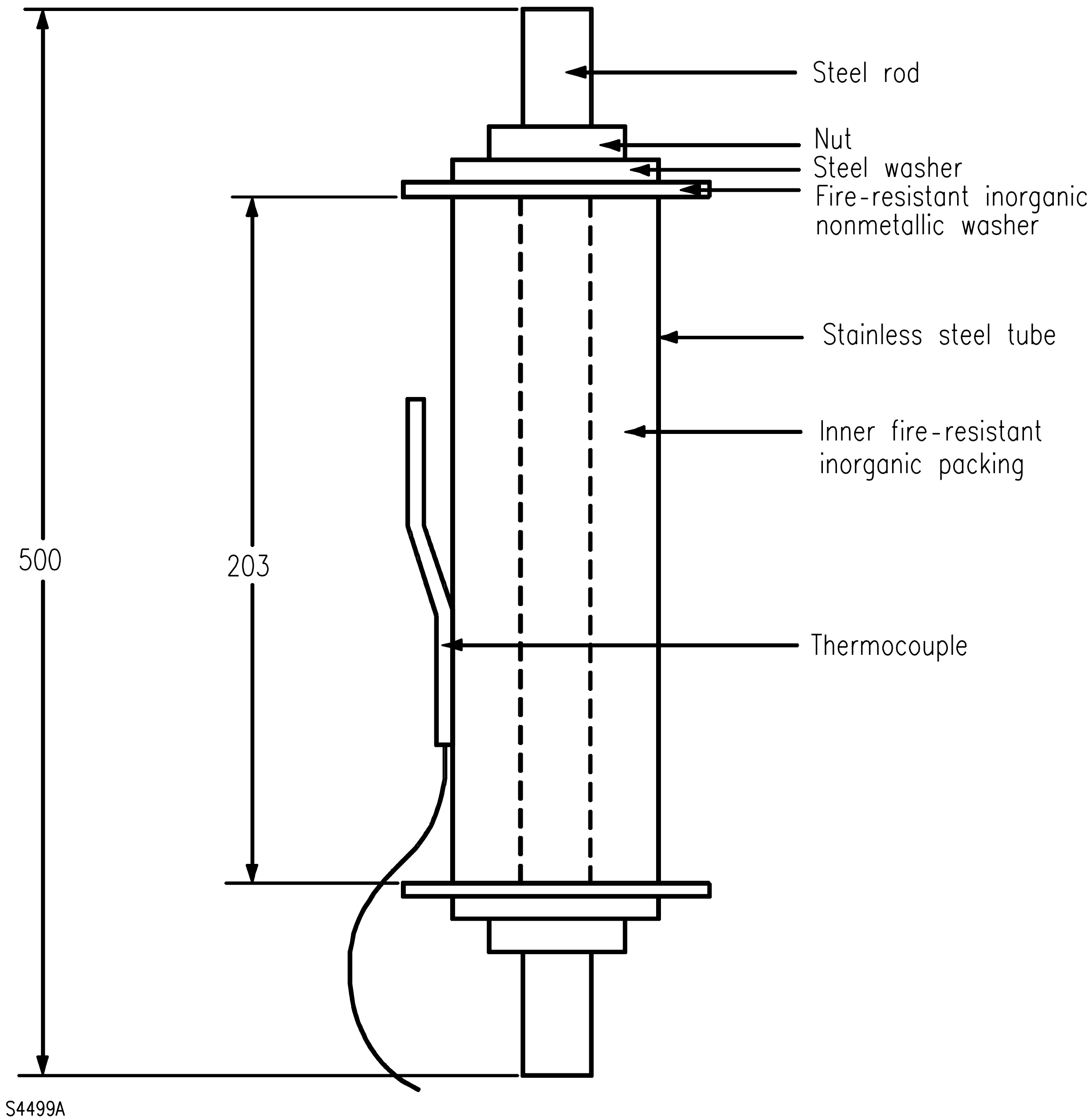
(See 9.8.3.1(a))



Dimensions in mm.

Figure 35
Stainless steel tube in fire propagation test chamber

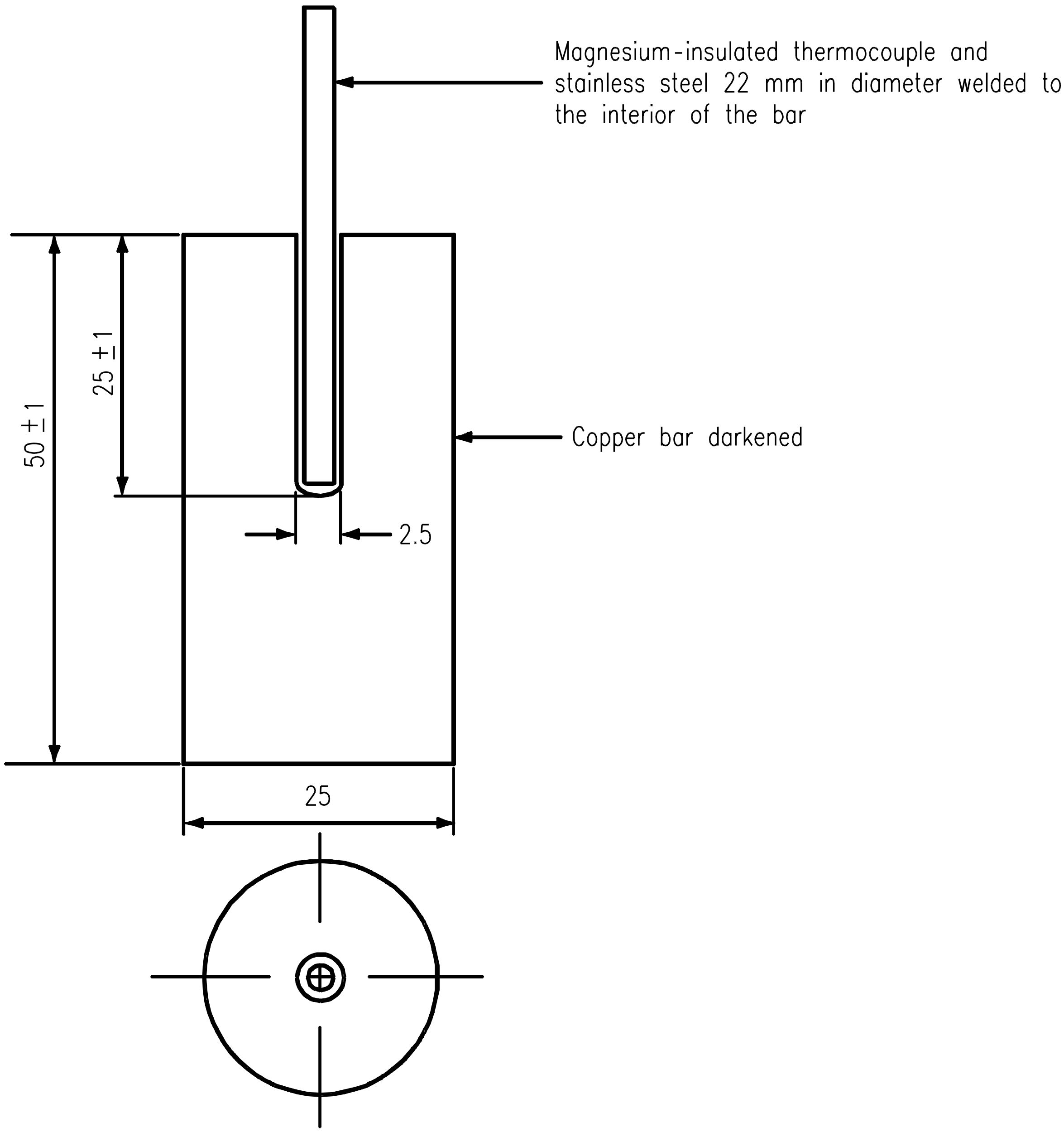
(See 9.8.3.1(a))



Dimensions in mm.

Figure 36
Copper bar for flame temperature calibration in fire propagation test

(See 9.8.3.1(a))

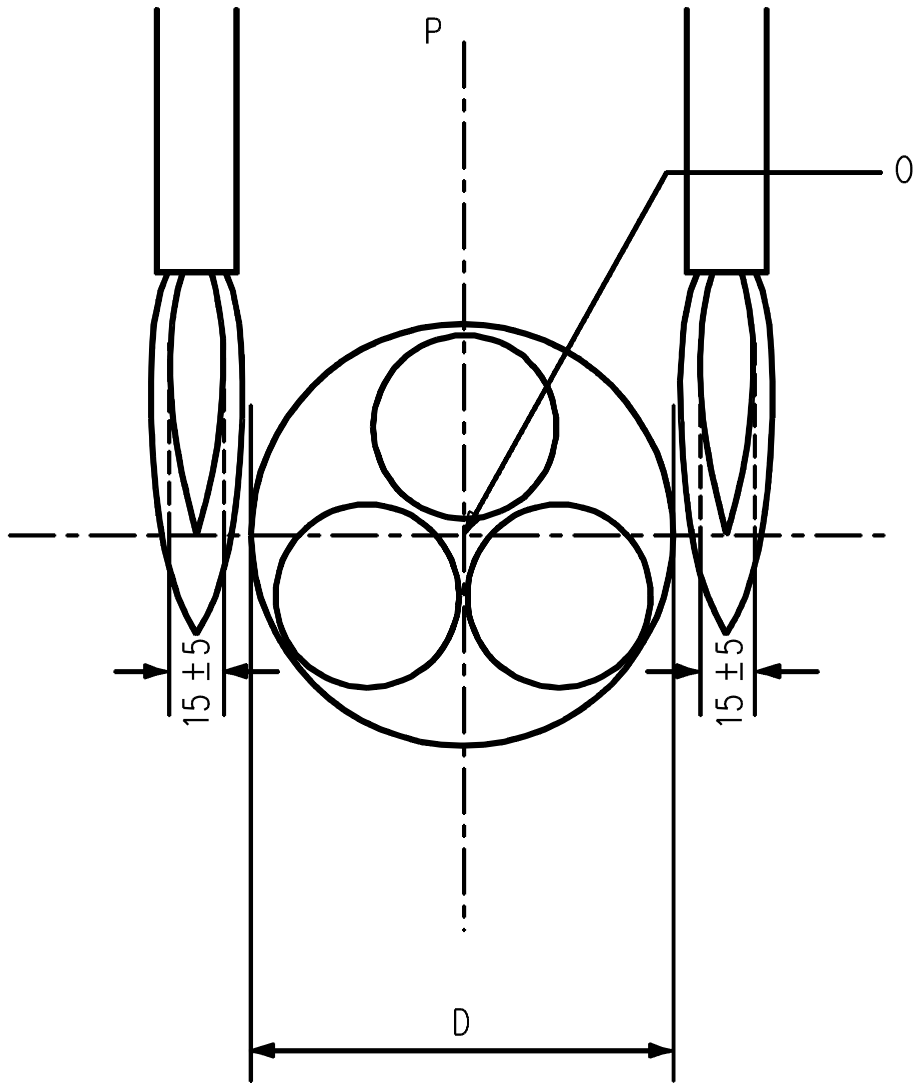


S4500

Dimensions in mm.

Figure 37
Arrangement of specimen between burners used in fire propagation test chamber

(See 9.8.4(b))



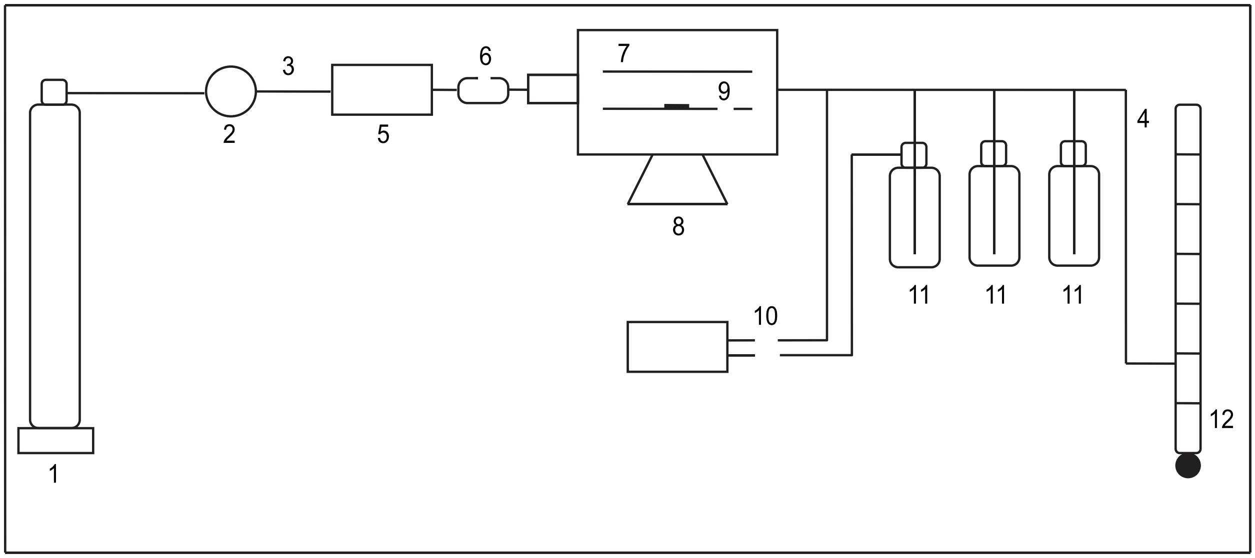
Legend:
O is the common axis of symmetry between chimney and oven;
P is the plane of symmetry of the valves;
D is the diameter of the specimen.

S4501

Dimensions in mm.

Figure 38
Arrangement of test equipment for halogen acid gas emission test

(See 9.10.2, 9.10.4.4, 9.10.4.5 and 9.11.3)



su1914

Legend:

1 Dry compressed air

2 Gas pressure regulator

3 Silicon hose

4 Flexible hose or fitted glass

5 Flow controller (rotameter)

6 Connector

7 Combustion tube with accessories

8 Tubular furnace

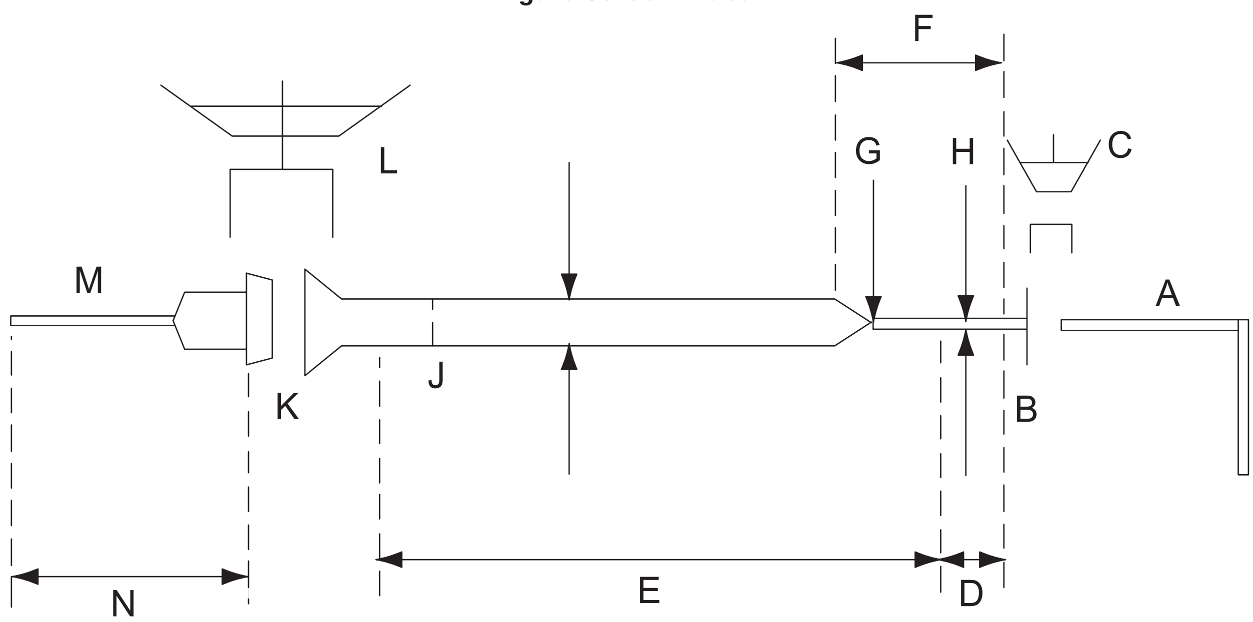
9 Porcelain combustion boat

10 Rheostat connected to heating tape

11 Water traps

12 Flowmeter to measure 0 to 200 ml/min

Figure 38 Continued



S5412

Legend:

A – Borosilicate tube with circular joint

B – 29/9 Male and female joint elements

C – Clamps for joint No. 29

D – Portion of tube protruding from the oven, 30 to 50 mm

E – Portion of tube inside the oven (length of oven)

F – Length of lower diameter

G – Inside diameter, 13 mm

H – Outside diameter, 17 mm

I – Outside diameter, 25 mm

J – Inside diameter, 19 mm

K – 35/25 male and female joint elements*

L – Clamps for joint No. 35

M – Connection between borosilicate and circular joint

N – Length of borosilicate connection, 50 to 100 mm

O - Furnace wall thickness (representative)

* 29/9 and 25/25 joint elements for B and K, respectively, have been found suitable.

Figure 39
Typical titration plot

(See 9.10.5.1.2)

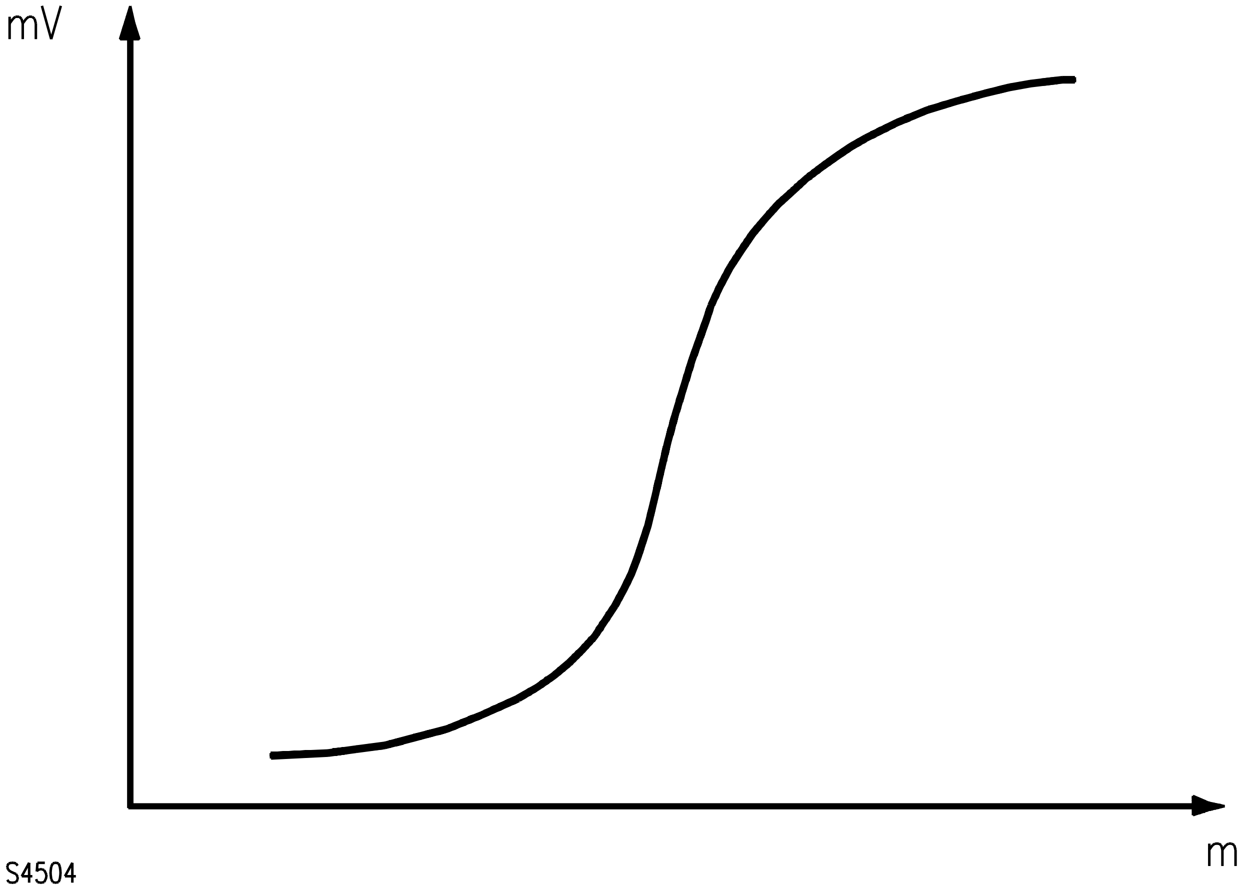


Figure 40
Geometric determination of the point of equivalency

(See 9.10.5.1)

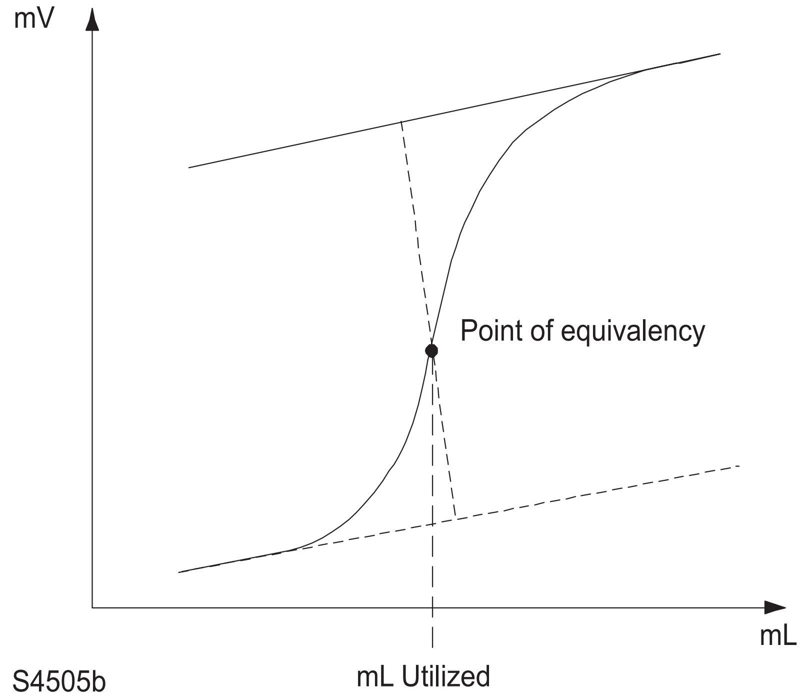


Figure 41
Blank titration plot

(See 9.10.5.1)

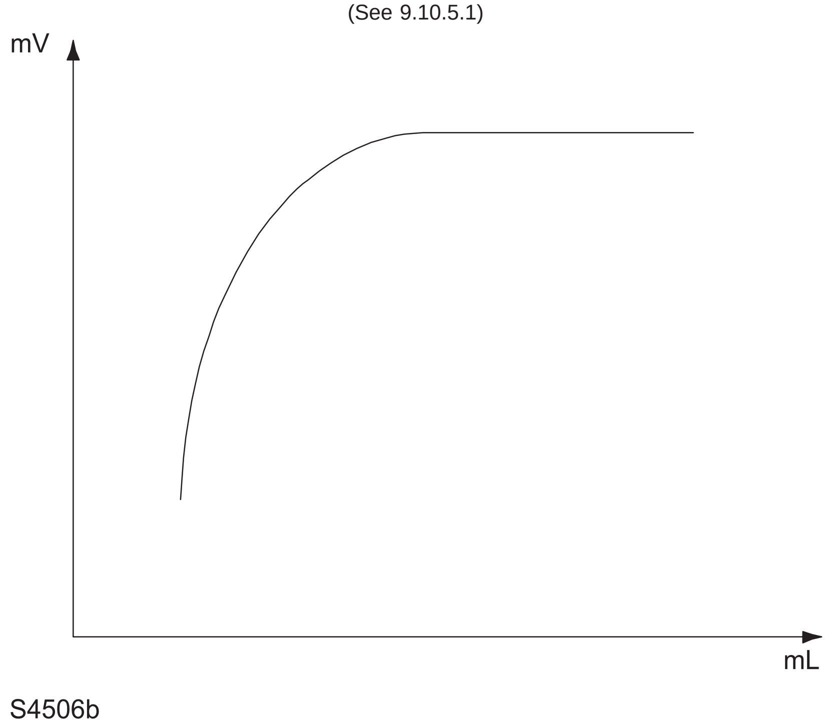
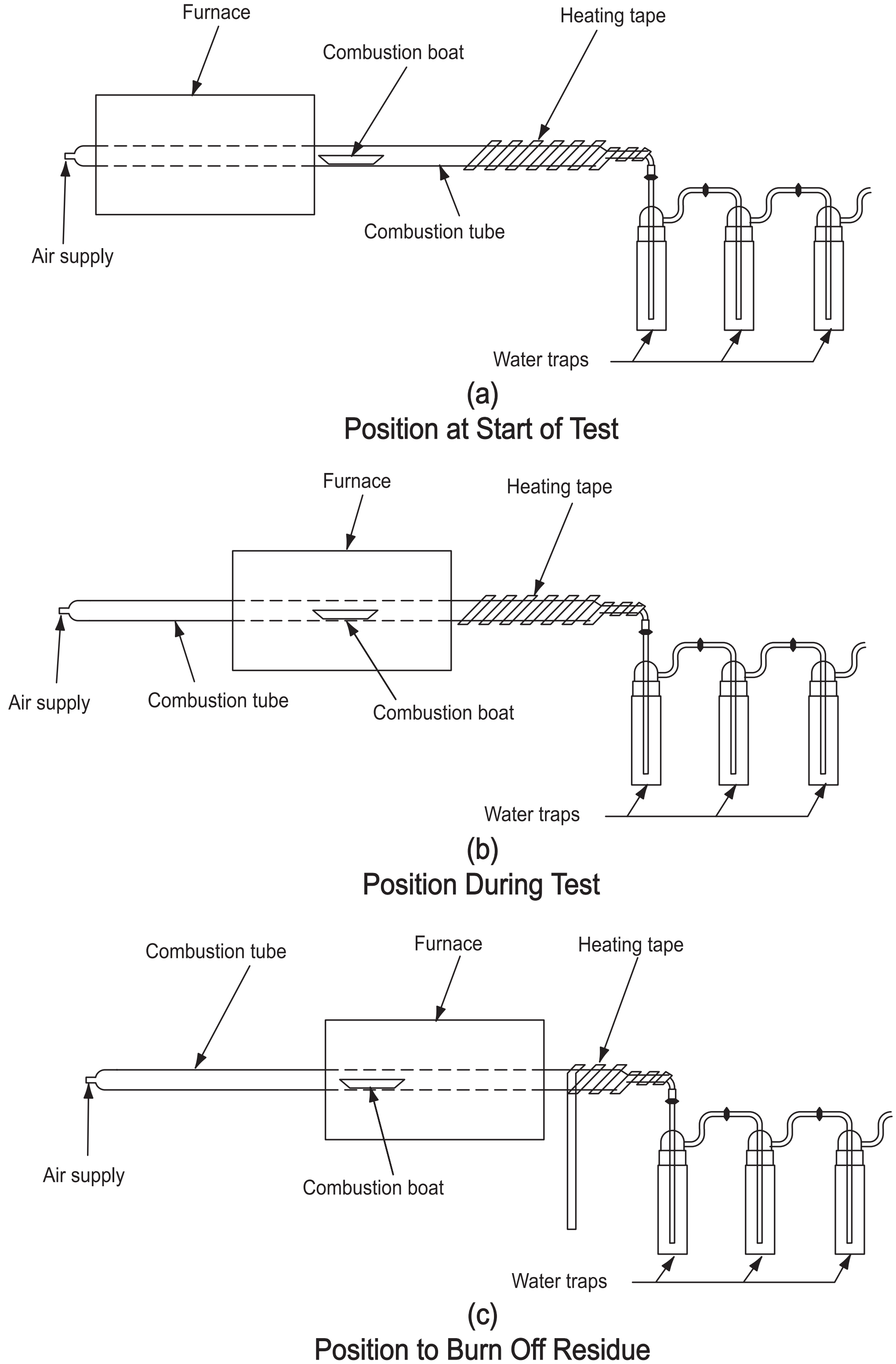


Figure 42

Acid gas evolution test apparatus – Method 1

(See 9.11.5.1.3, 9.11.5.1.6, 9.11.5.1.7, 9.11.5.1.8, and 9.11.5.2.11)



(a)
Position at Start of Test

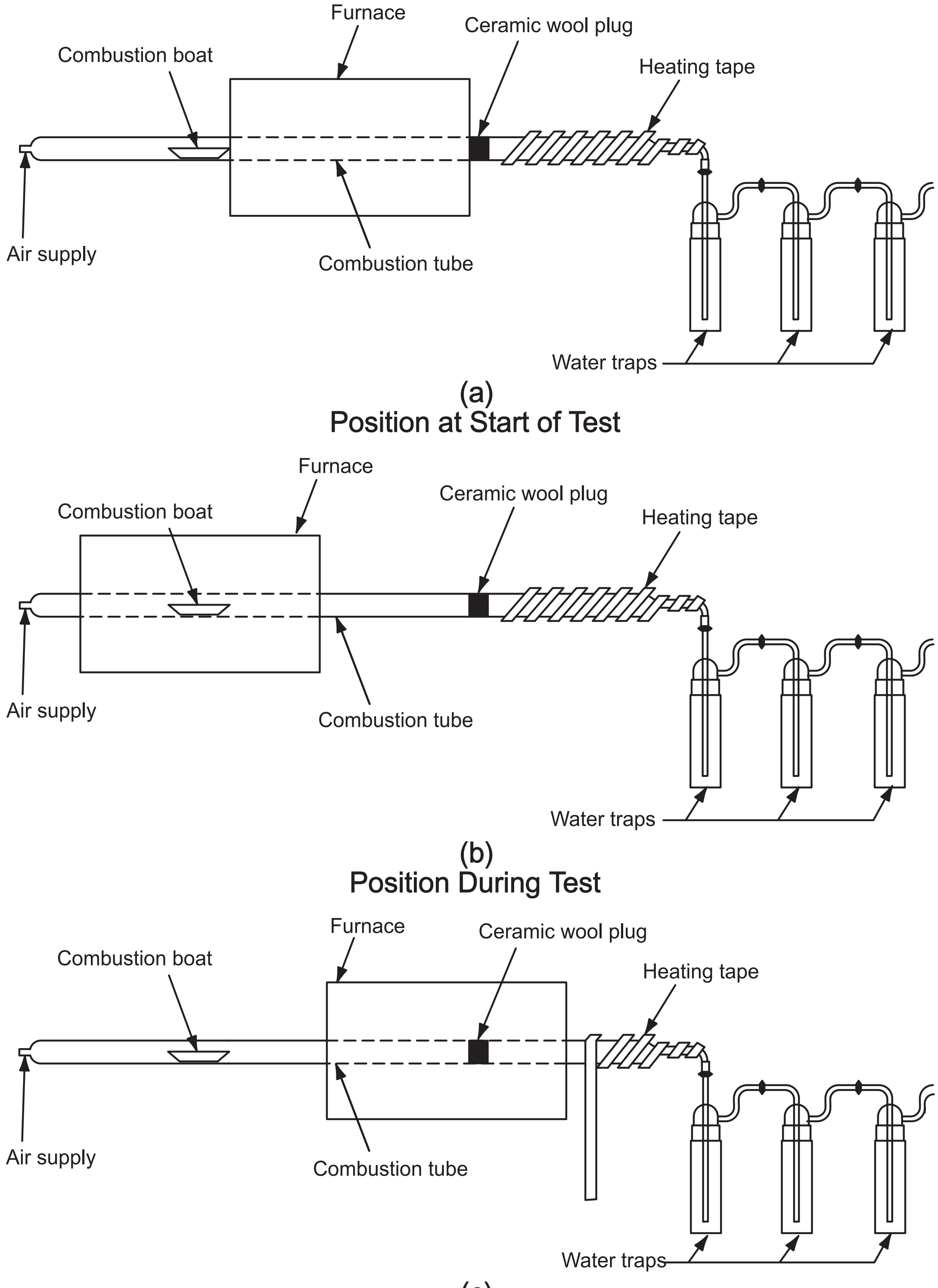
(b)
Position During Test

(c)
Position to Burn Off Residue

S5404

Figure 43
Acid Gas Evolution Test Apparatus – Method 2

(See 9.11.5.2.3, 9.11.5.2.5, 9.11.5.2.7, 9.11.5.2.8, and 9.11.5.2.10)



(c)
Position to Burn Off Residue

S5405

Annex A (informative)
Conductor removal from insulation for tubular specimens

(See 4.2.4.2.2)

Note: *This annex is not a mandatory part of this standard, but is written in mandatory language to accommodate its adoption by anyone wishing to do so.*

A.1 Method 1: Stranded conductors

The individual strands of the conductor shall be removed from the insulation by means of a pair of pliers without damaging the specimen.

A.2 Method 2: Stranded or solid conductors

A.2.1 A 150 mm (6 in) sample of insulated conductor shall be cut and 12.7 mm (0.5 in) of its insulation shall be removed from both ends.

A.2.2 To avoid nicks in the specimen, any rough conductor strand(s) shall be filed down at one end of the insulated conductor.

A.2.3 The other end of the insulated conductor shall be inserted in the hole of a drill gage metal plate (or equivalent) while ensuring the hole is of a sufficient size to allow the conductor strand(s) to move freely, yet not allow the insulation to pass through.

A.2.4 The insulated conductor strand(s) inserted in the metal plate shall be secured in a vice, and the insulation shall be removed from the conductor by slowly pulling the plate along with the insulation away from the vice. Care shall be taken to go slowly enough to prevent the insulation from ″bunching up″.

A.2.5 After the conductor removal, the insulation specimen shall be allowed to rest for 30 minutes before any testing takes place, to ensure any heat developed in the specimen has had time to dissipate and any stress in the specimen has relaxed.

A.2.6 To facilitate removal, the conductor may be stretched prior to removing the insulation.

Annex B (informative)
Determination of density

(See 4.2.5.1.2)

Note: *This annex is not a mandatory part of this standard, but is written in mandatory language to accommodate its adoption by anyone wishing to do so.*

B.1 The density of a specimen shall be determined to two decimal places by the displacement method using a precision balance of a type that either yields the density by direct reading (a Young's gravitometer) or requires calculation. All of the equipment, the fluid, the ethyl alcohol, and the specimen shall be at the same temperature (any convenient ROOM TEMPERATURE) throughout the procedure.

B.2 A clean 250 mm (10 in) length adjacent to that used for preparation of the physical-properties specimens shall be cut from the finished sample and the conductor(s), any covering(s), and any separator shall be removed. To reduce the likelihood of air being trapped in the hollows, the length shall be cut parallel to its longitudinal axis. All of the cut surfaces of the sample shall be smooth.

B.3 The specimens shall be cut into lengths of 50 mm (2 in). A single length shall be used as the specimen where it weighs 5 g or more. Several lengths shall be used as the specimen where one length weighs less than 5 g. The single length or the bundle of lengths shall be tied at its center with wire that is not larger in diameter than 0.127 mm (0.0050 in, No. 36 AWG) and shall be suspended by the wire from the weighing arm of the balance.

B.4 Where a Young's gravitometer is used, the beam weights shall be adjusted to bring the pointer to rest at the infinity mark on the scale. A beaker or other wide-mouth container shall be filled with ethyl alcohol and placed on the platform in the instrument. The specimen shall be lifted by the wire and fully immersed in the alcohol and then removed from the alcohol and rinsed with distilled or demineralized water or other fluid that is virtually free of air. The container of alcohol shall be removed and replaced with a similar container filled with virtually air-free distilled or demineralized water or other fluid. The specimen again shall be lifted by the wire and then fully immersed in the fluid. The ethyl alcohol acts as a wetting agent and thereby helps to keep air bubbles from clinging to the specimen or wire while the specimen and wire are in the fluid. However, any bubbles that do remain shall be removed by rubbing the bubbles with a fine wire or by agitation of the specimen. Neither the suspending wire nor the specimen shall touch the container. The vibrator in the instrument shall be activated to assist the balance in reaching equilibrium. After equilibrium is reached, the density shall be read to two decimal places directly from the scale.

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

$$D = \frac{W_1}{W_1 - W_2 + W_3} x$$

where

X = the density of the fluid in which the specimen is immersed at ROOM TEMPERATURE.

Annex C (informative)

Sample calculation for the determination of ultimate elongation or tensile strength at 300 d

(See 4.3.5.2)

C.1 Elongation

Example: Elongation after 90 days = 200%, after 120 = 150%, after 150 days = 100%.

Building the x/y plot using the above values and the need to subtract 90 days from the start gives

$$x_1 = 90 - 90 = 0$$

$$x_2 = 120 - 90 = 30$$

$$x_3 = 150 - 90 = 60$$

$$y_1 = \ln(200) = 5.29832$$

$$y_2 = \ln(150) = 5.01064$$

$$y_3 = \ln(100) = 4.60517$$

Using least squares linear regression analysis, and converting to a linear equation (Y = B + RT) gives

$$R = -0.0115525 \text{ and } B = 5.31795$$

Using this equation and solving for the elongation at 300 days, (Y_{300} = 2.8919), gives 18.03% elongation (failure).

C.2 Tensile strength

Example: Tensile strength after 90 days = 13.79 MPa (2000 lbf/in^2), after 120 = 12.41 MPa (1800 lbf/in^2), after 150 days = 11.03 MPa (1600 lbf/in^2).

Building the x/y plot using the above values and the need to subtract 90 days from the start gives

$$x_1 = 90 - 90 = 0$$

$$x_2 = 120 - 90 = 30$$

$$x_3 = 150 - 90 = 60$$

$$y_1 = \ln(13.79) = 2.62355\ (\ln(2000) = 7.6009)$$

$$y_2 = \ln(12.41) = 2.51820\ (\ln(1800) = 7.4955)$$

$$y_3 = \ln(11.03) = 2.40041\ (\ln(1600) = 7.3778)$$

Using least squares linear regression analysis, and converting to a linear equation (Y = B + RT) gives

$$R = -0.00372 \text{ and } B = 2.62563\ (R = -0.003719 \text{ and } B = 7.60297)$$

Using this equation and solving for the tensile strength at 300 days (Y_{300} = 1.84442) gives 6.32 MPa (pass).

Annex D (normative)

Establishment of parameters and requirements for short-term air oven aging test

(See 4.3.5.6)

D.1 After the temperature rating of a new material has been established, a short-term air oven aging test shall be developed. When sufficient data have been collected, the material shall be added to the appropriate standard, including a short-term air oven aging test, common to that family of materials, and the evaluation of temperature rating shall no longer be necessary for that material. The guidelines for determining the parameters and requirements of the short-term air oven aging test shall be in accordance with D.2 – D.4. The unaged tensile strength and ultimate elongation values of the material shall be specified in the product standard and based on the conditions of use.

D.2 Choose the temperature and duration for the test from the test parameters listed in the Table D.1 below for the temperature rating of the material.

D.3 Using specimens from the same source (reel, carton, etc.) as those used to determine the temperature rating of the material, determine the retention of ultimate elongation and tensile strength under the conditions chosen in Table D.1. Subtract 15% from the retention values obtained and round to the nearest 5%. If the values are 35% or greater, set these values as the requirements for this material.

D.4 If either of the values is less than 35%, the value shall be considered to be too low for reliable testing. In this case, choose the aging temperature and duration associated with the next lowest temperature rating, as shown in Table D.1, then determine the ultimate elongation and tensile strength requirements as described in D.3.

D.5 If either of the values is greater than 85%, the value shall be considered to be too high for reliable testing. In this case, choose the aging temperature and duration associated with the next highest temperature rating, as shown in Table D.1, then determine the ultimate elongation and tensile strength requirements as described in D.3.

D.6 If after choosing the conditions in Table D.1, in accordance with D.4 or D.5 either of the retained values are not between 35% and 85%, an alternate aging temperature shall be used.

Table D.1
Parameters for short-term air oven aging tests

(See D.2 – D.4)

Established temperature rating (°C)	60	75	80	90	105	125	150	180	200	250
Aging temperature (°C)	100	110	113	121	136	158	180	220	232	287
Aging time (d)	7	7	7	7	7	7	7	7	7	7
Note: Alternate aging temperatures other than those in this table may be applied in accordance with D.4 and D.5.										

Annex E (normative)

Determination of temperature correction factor

(See 6.4.5)

E.1 If the test for IR at 15°C is performed in water or air having a temperature differing from 15°C (see 6.4.1), the temperature correction factor (F) referred to in the formula of 6.4.5 shall be determined using the coefficient for 1°C, as determined in accordance with the method in E.2.

E.2 The coefficient for 1°C shall be determined for a given insulating material as follows:

a) Three samples shall be selected as representative of the insulation under consideration. The samples shall be of sufficient length to yield insulation resistance values within the calibrated range of the measuring equipment at the lowest water bath temperature.

b) The three samples shall be immersed in a water bath equipped with heating, cooling, and circulating facilities, with the ends of the samples extended at least 0.6 m (2 ft) above the surface of the water and properly prepared for minimum leakage. The samples shall be left in the water at ROOM TEMPERATURE for 16 hours before adjusting the bath temperature to 10°C or before transferring the samples to a 10°C test temperature bath.

c) After the temperature of the water bath, measured within 50 mm (2 in) of the specimen and at least 50 mm (2 in) away from the edge of the water bath, does not fluctuate more than ±1°C, the specimen shall be conditioned for a minimum additional 2 hours. Alternatively, the sample shall be immersed in the water bath for a minimum of 6 hours without requiring the use of an additional temperature measuring device near the specimen. The insulation will then be at the temperature of the bath as read on the bath thermometer. Insulation resistance shall then be measured using one of the methods in 6.4.1.

d) Each of the three samples shall be exposed to successive water temperatures of 10°C, 16°C, 22°C, 28°C, and 35°C and, returning, 28°C, 22°C, 16°C, and 10°C. Insulation resistance readings shall be taken at each temperature after equilibrium has been established in accordance with Item (c).

e) The two sets of readings taken at the same temperature shall be averaged and, together with the reading at 35°C, plotted on a semi-log scale.

If the resultant curve is a straight line, the 1°C coefficient is calculated as follows:

$$\text{Coefficient for } 1°\text{C} = \text{Antilog}_{\alpha} [(\log_{\alpha} [IR_{10}/IR_{35}])/25]$$

where

α = base of the logarithm

The temperature correction factor shall be read from Table E.1 under the appropriate ″Coefficient for 1°″ heading.

The IR at 15°C for a particular material is then calculated as follows:

$$IR_{15} = IR_x \text{ x Temperature Correction Factor}$$

where

IR_x = insulation resistance at X °C

f) If the resultant curve is not a straight line, the temperature correction factors shall be calculated by dividing the insulation resistance at 15°C by the insulation resistance values read from the IR curve at 0.5°C intervals, and these temperature correction factors plotted.

The IR at 15°C for a particular material is then calculated as follows:

$$IR_{15} = IR_x \text{ x temperature correction factor}$$

where

IR_x = insulation resistance at X °C

The temperature correction factor shall be read directly from the plotted values.

Table E.1
Insulation resistance temperature correction factor
(See E.2)

Temperature	Coefficient for 1°C									
°C	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
5.0	0.68	0.56	0.46	0.39	0.32	0.27	0.23	0.19	0.16	0.14
5.5	0.69	0.57	0.48	0.40	0.34	0.29	0.24	0.21	0.18	0.15
6.0	0.70	0.59	0.50	0.42	0.36	0.31	0.26	0.23	0.19	0.17
6.5	0.72	0.61	0.54	0.44	0.38	0.33	0.28	0.24	0.21	0.18
7.0	0.73	0.63	0.56	0.47	0.40	0.35	0.31	0.27	0.23	0.20
7.5	0.75	0.65	0.58	0.49	0.43	0.37	0.33	0.29	0.25	0.23
8.0	0.76	0.67	0.61	0.51	0.45	0.40	0.35	0.31	0.28	0.25
8.5	0.77	0.68	0.62	0.54	0.48	0.43	0.38	0.34	0.31	0.27
9.0	0.79	0.70	0.63	0.56	0.51	0.46	0.41	0.37	0.33	0.30
9.5	0.81	0.73	0.65	0.59	0.54	0.49	0.44	0.40	0.37	0.33
10.0	0.82	0.75	0.68	0.62	0.57	0.52	0.48	0.44	0.40	0.37
10.5	0.84	0.77	0.71	0.65	0.60	0.55	0.51	0.47	0.44	0.41
11.0	0.85	0.79	0.74	0.68	0.64	0.59	0.55	0.52	0.48	0.45
11.5	0.87	0.82	0.76	0.72	0.67	0.63	0.59	0.56	0.53	0.50
12.0	0.89	0.84	0.79	0.75	0.71	0.67	0.64	0.61	0.58	0.55
12.5	0.91	0.86	0.82	0.79	0.75	0.72	0.69	0.66	0.63	0.61
13.0	0.92	0.89	0.86	0.83	0.80	0.77	0.74	0.72	0.69	0.67
13.5	0.94	0.92	0.89	0.87	0.84	0.82	0.80	0.78	0.76	0.74
14.0	0.96	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.83	0.82
14.5	0.98	0.97	0.96	0.95	0.94	0.94	0.93	0.92	0.91	0.91
15.0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
15.5	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.10
16.0	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
16.5	1.06	1.09	1.12	1.15	1.19	1.22	1.25	1.28	1.31	1.35

Table E.1 Continued on Next Page

Table E.1 Continued

Temperature	Coefficient for 1°C									
°C	1.04	1.06	1.08	1.10	1.12	1.14	1.16	1.18	1.20	1.22
17.0	1.08	1.12	1.17	1.21	1.25	1.30	1.35	1.39	1.44	1.49
17.5	1.10	1.16	1.21	1.27	1.33	1.39	1.45	1.51	1.58	1.64
18.0	1.12	1.19	1.26	1.33	1.40	1.48	1.56	1.64	1.73	1.82
18.5	1.15	1.23	1.31	1.40	1.49	1.58	1.68	1.78	1.89	2.01
19.0	1.17	1.26	1.36	1.46	1.57	1.69	1.81	1.94	2.07	2.22
19.5	1.19	1.30	1.41	1.54	1.67	1.80	1.95	2.11	2.27	2.45
20.0	1.22	1.34	1.47	1.61	1.76	1.93	2.10	2.29	2.49	2.70
20.5	1.24	1.38	1.53	1.69	1.87	2.06	2.26	2.49	2.73	2.99
21.0	1.27	1.42	1.59	1.77	1.97	2.19	2.44	2.70	2.99	3.30
21.5	1.29	1.46	1.65	1.86	2.09	2.34	2.62	2.93	3.27	3.64
22.0	1.32	1.50	1.71	1.95	2.21	2.50	2.83	3.19	3.58	4.02
22.5	1.34	1.55	1.78	2.04	2.34	2.67	3.04	3.46	3.93	4.44
23.0	1.37	1.59	1.85	2.14	2.48	2.85	3.28	3.76	4.30	4.91
23.5	1.40	1.64	1.92	2.25	2.62	3.05	3.53	4.08	4,71	5.42
24.0	1.42	1.69	2.00	2.36	2.77	3.35	3.80	4.44	5.16	5.99
24.5	1.45	1.74	2.08	2.47	2.93	3.47	4.10	4.82	5.65	6.61
25.0	1.48	1.79	2.16	2.59	3.11	3.71	4.41	5.23	6.19	7.30
25.5	1.51	1.84	2.24	2.72	3.29	3.96	4.75	5.69	6.78	8.07
26.0	1.54	1.90	2.33	2.85	3.48	4.23	5.12	6.18	7.43	8.91
26.5	1.57	1.95	2.42	2.99	3.68	4.51	5.51	6.71	8.14	9.84
27.0	1.60	2.01	2.52	3.14	3.90	4.82	5.94	7.29	8.92	10.87
27.5	1.63	2.07	2.62	3.29	4.12	5.14	6.39	7.92	9.77	12.01
28.0	1.67	2.13	2.72	3.45	4.36	5.49	6.89	8.60	10.70	13.26
28.5	1.70	2.20	2.83	3.62	4.62	5.86	7.42	9.34	11.72	14.65
29.0	1.73	2.26	2.94	3.80	4.89	6.26	7.99	10.15	12.84	16.18
29.5	1.77	2.33	3.05	3.98	5.17	6.69	8.60	11.02	14.06	17.87
30.0	1.80	2.40	3.17	4.18	5.47	7.14	9.27	11.97	15.41	19.74
30.5	1.84	2.47	3.30	4.38	5.79	7.62	9.98	13.01	16.88	21.81
31.0	1.87	2.54	3.43	4.59	6.13	8.14	10.75	14.13	18.49	24.09
31.5	1.91	2.62	3.56	4.82	6.49	8.69	11.58	15.35	20.25	26.60
32.0	1.95	2.69	3.70	5.05	6.87	9.28	12.47	16.67	22.19	29.38
32.5	1.99	2.77	3.85	5.30	7.27	9.90	13.43	18.11	24.30	32.46
33.0	2.03	2.85	4.00	5.56	7.69	10.58	14.46	19.67	26.62	35.85
33.5	2.07	2.94	4.15	5.83	8.14	11.29	15.58	21.37	29.16	39.60
34.0	2.11	3.03	4.32	6.12	8.61	12.06	16.78	23.21	31.95	43.74
34.5	2.15	3.12	4.49	6.41	9.11	12.87	18.07	25.22	35.00	48.31
35.0	2.19	3.21	4.66	6.73	9.65	13.74	19.46	27.39	38.34	53.36

Annex F (normative)

Procedure and calculations for determining the degree of coverage of fibrous coverings

(See 5.1.4 and 5.1.5)

F.1 The number of picks per mm (in) N shall be measured at three places that are at least 50 mm (2 in) apart in any 300 mm (12 in) section in the center 1 m (3 ft) of a 1.5 m (5 ft) specimen of the braid-covered wire. The average of the three determinations shall be taken as the number of picks per mm (in) for that specimen. Values of yarn diameter T are shown in Table F.1 below.

Table F.1
Yarn diameter

(See F.1)

Size and ply of yarn			Yarn diameter T, mm	Yarn diameter T, in
12/1	25/2	26/2	0.28	0.011
14/1	30/2		0.25	0.010
36/2			0.23	0.009
20/1	40/2		0.20	0.008
25/1	26/1	50/2	0.18	0.007
30/1	60/2		0.18	0.007
36/1			0.15	0.006

The lay angle shall be determined by means of whichever of the following formulas is applicable:

$$\tan A = \frac{\pi N(2T_{mm} + D_{mm})}{25.4 K}$$

or

$$\tan A = \frac{\pi N(2T_{in} + D_{in})}{K}$$

where

A = lay angle

N = number of picks per mm (in)

T = diameter of one end of yarn, mm (in),

D = nominal (calculated) diameter, mm (in), over the insulation for single conductors as indicated in Table F.2; in computing the diameter, D, under the overall braid on multiple-conductor cables, the average of the diameters of the finished individual conductors shall be multiplied by the following factors:

Twisted pair assemblies without fillers:	1.64
Twisted pair assemblies with fillers:	2.00
Three-conductor assemblies:	2.15
Four-conductor assemblies:	2.41

K = number of carriers in one direction

Table F.2
Nominal diameter over the insulation

(See F.2)

AWG size of conductor	Stranding	Insulation thickness		Nominal diameter D	
		mm	in	mm	in
20	stranded	0.58	0.023	2.18	0.086
18	solid	0.38	0.015	1.78	0.070
18	stranded	0.38	0.015	1.98	0.078
18	stranded	0.51	0.020	2.34	0.092
18	stranded	0.58	0.023	2.39	0.094
18	solid	0.76	0.030	2.54	0.100
18	stranded	0.76	0.030	2.74	0.108
16	stranded	0.51	0.020	2.57	0.101
16	solid	0.76	0.030	2.82	0.111
16	stranded	0.76	0.030	3.05	0.120
14	stranded	1.14	0.045	4.27	0.168

F.2 The formula for determining the minimum acceptable number of picks per unit width for the most commonly used braids that are woven on a 16-carrier braider is as follows:

$$\text{Picks per cm} = N = 10\sqrt{\left(\left[\frac{Q}{100\,ET_{mm}}\right]^2 - \left[\frac{K}{\pi(2T_{mm} + D_{mm})}\right]^2\right)}$$

or

$$\text{Picks per inch} = N = \sqrt{\left[\frac{Q}{100\,ET_{in}}\right]^2 - \left[\frac{K}{\pi(2T_{in} + D_{in})}\right]^2}$$

where

N = number of picks per unit length

E = number of ends per pick

Q = percent coverage

F.3 If the formula in F.2 produces a value resulting in a braid angle less than the acceptable minimum, the value shall be recomputed by means of whichever of the following formulas is applicable:

$$\text{Picks per centimeter} = N = \frac{25.4\,K \tan A}{\pi(2T_{mm} + D_{mm})}$$

or

$$\text{Picks per inch} = N = \frac{K \tan A}{\pi(2T_{in} + D_{in})}$$

Annex G (normative)

Calculation of coverage of shielding (wraps and braids)

(See 5.2.4)

G.1 The coverage shall be determined by using the following formulas, as applicable:

a) For braids

$$\% \text{ coverage} = 100\ (2F - F^2)$$

where

F = NCd/(2Lsin a)

where

N = number of wires per carrier

C = number of carriers

d = diameter of individual wires

L = lay of wires

a = angle of braid with axis of underlying core, having a tangent of angle equal to:

Note: *Dimensions can be in mm or inches, provided that they are consistent throughout the calculation.*

$$\tan(a) = \pi(D + 2d)/L$$

where

D = diameter of core under shield

Note: *Dimensions can be in mm or inches, provided that they are consistent throughout the calculation.*

b) For wraps

$$\% \text{ coverage} = 100F$$

where

F = NCd/(Lsin a)

where

N = number of wires per carrier

C = number of carriers

d = diameter of individual wrap wires

L = lay of wires

a = angle of wrap with axis of underlying core, having a tangent of angle equal to:

Note: *Dimensions can be in mm or inches, provided that they are consistent throughout the calculation.*

$$\tan(a) = \pi(D + 2d)/L$$

where

D = diameter of core under wrap

Note: *Dimensions can be in mm or inches, provided that they are consistent throughout the calculations.*

Note: *For a cable having flat parallel conductors, the expression π(D+2d) may be taken directly by measuring the circumference of the cable over the braid.*

G.2 In computing D (the diameter of the conductor assembly under the braid or wrap having insulated conductors of the same size), the diameter of one of the insulated conductors shall be multiplied by the factor given in Table G.1. The diameter of an individual insulated conductor shall be determined by using the nominal diameter of the conductor and the average thickness of the insulation and the covering over the insulation, if one is used, as specified in this standard.

Table G.1
Multiplying factors for the calculation of the diameter of the conductor assembly under the braid

(See G.2)

Number of conductors	Multiplying factor	Number of conductors	Multiplying factor
2 (without fillers)	1.64	11	4.00
2 (with fillers)	2.00	12	4.15
3	2.15	13	4.24
4	2.41	14	4.41
5	2.70	15	4.55
6	3.00	16	4.70
7	3.00	17	4.86
8	3.31	18	5.00
9	3.62	19	5.00
10	3.93	–	–

Annex H (normative)
Test enclosure and exhaust duct

(See 9.6.3)

H.1 Test enclosure

The enclosure in which the cables are tested shall be as shown in Figure H.1. Other enclosures shall be allowed if they are shown to provide equivalent results and are of a size (e.g., a 2.4 m (8 ft) cube) such that the internal volume of the enclosure, exclusive of the pyramidal hood, is not less than 14.5 m^3 (512 ft^3) nor greater than 36 m^3 (1272 ft^3), the floor area is not smaller than 6 m^2 (64 ft^2) nor larger than 9 m^2 (97 ft^2), and the maximum air movement within the enclosure complies with H.4.2.

The walls of the structure shall be of concrete having a density of 1700 kg/m^3 (106 lb/ft^3) ±5% and a thermal conductivity *k* at 21.1°C (70.0°F) of 0.055 W/(m·K) (0.38 Btu·in/(h·ft^2·°F)) ±5%, with the interior surface painted flat black. Alternative construction materials shall meet the intent of this requirement if both of the following conditions are met:

a) The overall thermal conductivity, based on an inside wall temperature of 37.8 °C (100.0°F) and an outside air temperature of 23.9°C (75°F), shall be 0.072 ±0.043 W/(m·K) (0.50 ±0.30 Btu ·in/(h·ft^2·°F)).

b) The construction materials shall withstand the high temperatures and open flame in the test enclosure.

The enclosure shall contain an access door, typically constructed of steel, located as shown in Figure H.1. The door shall be provided with a wired-glass window.

A truncated-pyramid stainless steel hood and a collection box, each formed as shown in Figure H.1, shall be located on top of the enclosure walls. Compressible inorganic batting shall be used as a gasket between the hood and walls.

The cable test enclosure shall be located in a test building that has vents for the discharge of the combustion products and also has provisions for fresh-air intake.

H.2 Exhaust duct

H.2.1 The exhaust connected to the plenum on the hood shall consist of a nominal 405 mm (trade size 16 in) duct as shown in Figure H.1.

H.2.2 A baffle constructed of 3.2 mm (0.125 in) nominal thick steel plate shall be horizontally suspended 2.95 m (116 in) ±3% above the floor over the center of the tray by chains or cable attached to the corners of the baffle and connected to the hood (see Figure H.1).

H.3 Exhaust fan

An exhaust fan shall be connected to the exhaust duct for maintaining the flow rates as described in 9.6.3(b) (see Figure H.2).

H.4 Air velocity measurements

H.4.1 Within the exhaust duct

The velocity shall be calculated in the following manner:

$$V = 0.806 \text{ x } \Delta P \text{ x } T_K \text{ (m/s)}$$

or

$$V = 2.644 \text{ x } \Delta P \text{ x } T_K \text{ (ft/s)}$$

where

ΔP = pressure drop measured by the pressure transducer (manometer), mm Hg

T_K = temperature in the duct measured by a thermocouple, K

The velocity in the exhaust duct shall be determined by measuring the differential pressure in the flow path with the bi-directional probe shown in Figure H.3. The probe shall be connected to an electronic pressure gauge or to an equivalent measuring system. The probe shall consist of a stainless steel cylinder with a solid diaphragm in the center that divides the probe into two chambers. The probe shall have a length nominally two times the outside diameter of the cylinder with a minimum length of 25.4 mm (1.0 in) and a maximum length of 51 mm (2.0 in). The pressure taps (tubes) on either side of the diaphragm shall support the probe within the duct and are connected to the pressure transducer via flexible tubing.

Note: *Means for removing the probe for periodic cleaning are recommended.*

The axis of the probe shall be located on the centerline of the duct a minimum of 4 m (13.3 ft) downstream from the last turn in the duct (see Figure H.1), to ensure a nearly uniform velocity of flow across the duct cross-section. Positioning of the probe at another location shall be allowed if it is shown that equivalent results are obtained.

The temperature of the exhaust gas shall be measured approximately 152 mm (6 in) upstream from the probe on the centerline of the duct using the thermocouple.

H.4.2 Within the enclosure

The maximum air movement within the enclosure, with only the enclosure intake and exhaust open, the exhaust fan on, and the burner off, shall not exceed 1 m/s (3.3 ft/s), as measured in each of the following areas by means of a hand-held vane anemometer:

a) on the floor of the enclosure at the position occupied by the burner during the test; and

b) 1.5 m (4.9 ft) above the floor of the enclosure at the position occupied by the cable tray during the test.

H.5 Smoke measuring equipment

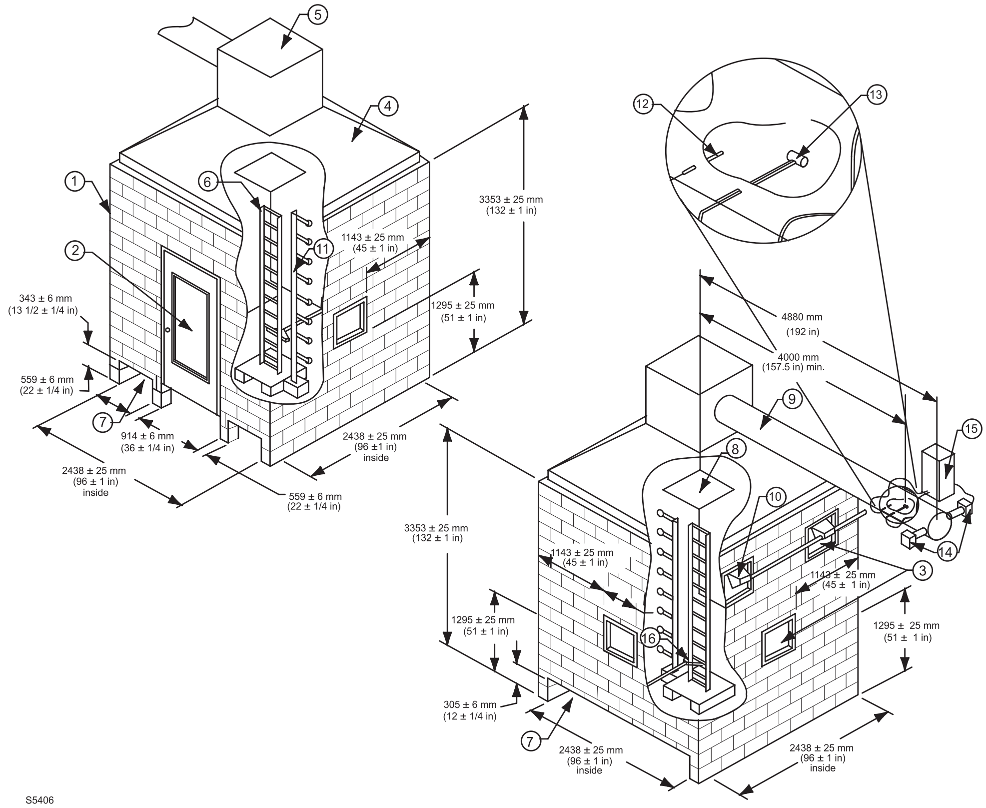
The measuring equipment (photometer) shall consist of a light source and photoelectric cell mounted on a horizontal section of the exhaust duct at a point at which the system is preceded by a straight run of duct that is at least twelve duct diameters or 4.88 m (16 ft) long. This is to ensure a nearly uniform velocity of flow across the duct cross-section. The light beam shall be directed horizontally across the diameter of the duct. A photoelectric cell whose output is directly proportional to the amount of light received shall be mounted opposite the light source. The light beam shall pass through round openings 76 mm (3 in) in diameter on opposite sides of the duct. The resultant light beam shall be centered on the photoelectric cell. The distance between the light source lens and the photoelectric cell lens shall be 914 ±51 mm (36 ±2 in). The photoelectric cell shall be connected to a digital data acquisition system having accuracy within ±1 percent. Light and pressure measurements shall be collected every 5 seconds. Data shall be processed into a continuous record of smoke obscuration values, from which the optical density shall be calculated.

Note 1: *A General Electric Model 4405* **12 V** *sealed-beam clear automotive head lamp (Part No. 4405) has been found suitable for this purpose. Equivalent apparatus is also acceptable.*

Note 2: *A photoelectric cell from Weston Instruments, the No. 856-9901013BB photronic cell, has been found suitable for this purpose. Equivalent apparatus is also acceptable.*

Figure H.1
Flame test enclosure and exhaust duct

(See 9.6.3, 9.6.5.2, 9.6.5.3, H.1, H.2.1, H.2.2, and H.4.1)

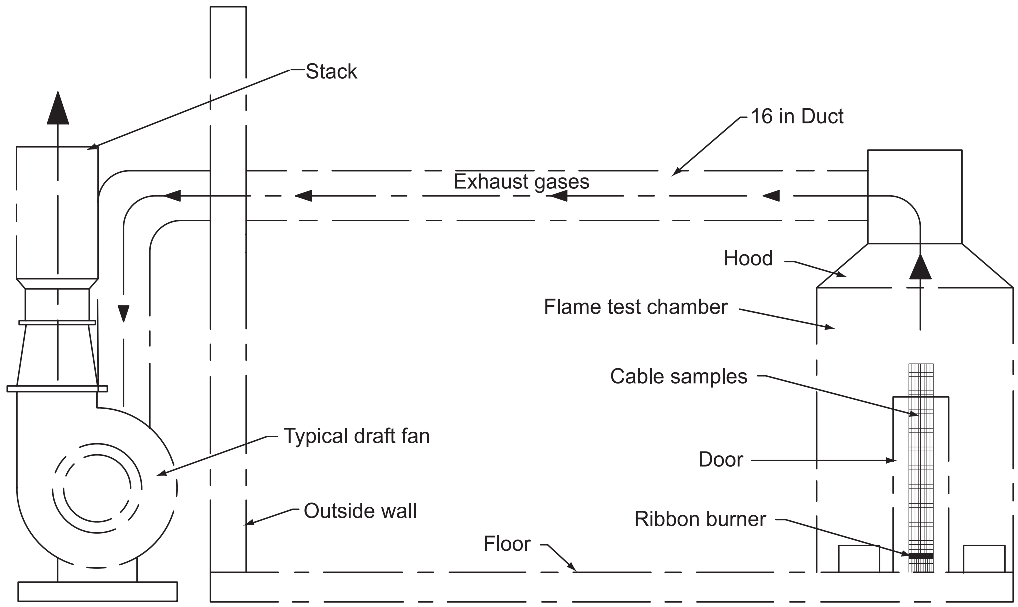


Legend:

1	Enclosure. Concrete blocks, if used, shall be nominally 203 mm high x 406 mm long x 152 mm thick (8 x 16 x 6 in)
2	Steel-framed door with wired-glass window for access and observation. The size of the door shall be nominally 0.9 x 2.1 m (36 x 84 in)
3	Steel-framed wired-glass observation window(s) nominally 457 mm (18 in) square, located on a side wall of the chamber
4	Truncated-pyramid stainless-steel hood, each side sloped 40°
5	Collection box with exhaust duct centered on one side. The box shall be a cube with each face a 914 mm (36 in) square
6	Tray mounted vertically in the center of the enclosure
7	Air-intake openings
8	Steel baffle that is nominally 610 x 610 mm (24 x 24 in) and 3.2 mm (0.125 in) thick
9	Duct that is 405 mm (16 in) inside diameter
10	Optional lighting
11	Flame height gauge (optional)
12	Temperature probe (Type K with inconel sheath)
13	Bi-directional velocity probe
14	Photoelectric cell and light source (for smoke density measurement)
15	Control cabinet(s) (for bi-directional velocity probe, thermocouple, light source and photoelectric cell)
16	Ribbon burner

Figure H.2
Typical draft fan arrangement

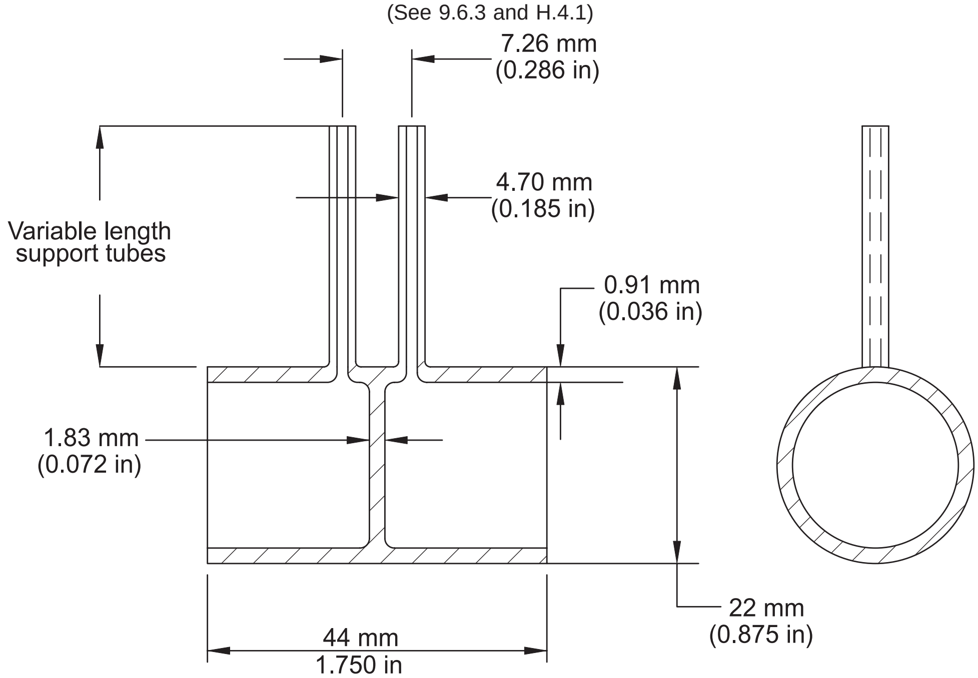
(See 9.6.3 and H.3)



s5413

Figure H.3
Bi-directional probe

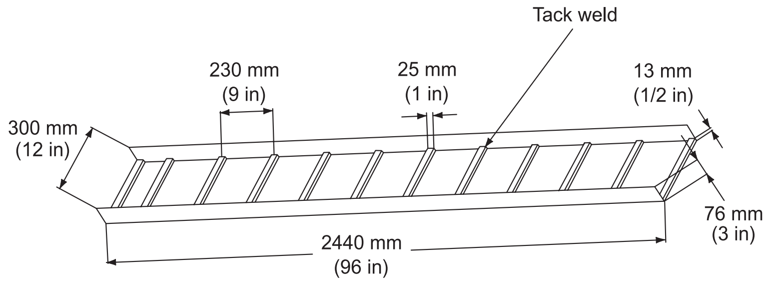
(See 9.6.3 and H.4.1)



S3355B

Figure H.4
Steel cable tray

(See 9.6.3)



s5414

Note: A steel ladder type tray in accordance with CSA C22.2 No. 126.1 or NEMA VE 1 or NMX-J-498-ANCE that is clean and free of residue and debris shall be securely mounted in a vertical position. The tray shall be 300 mm (12 in) wide by 76 mm (3 in) deep by 2440 mm (96 in) long and shall have channel rungs as follows and as shown in this Figure:

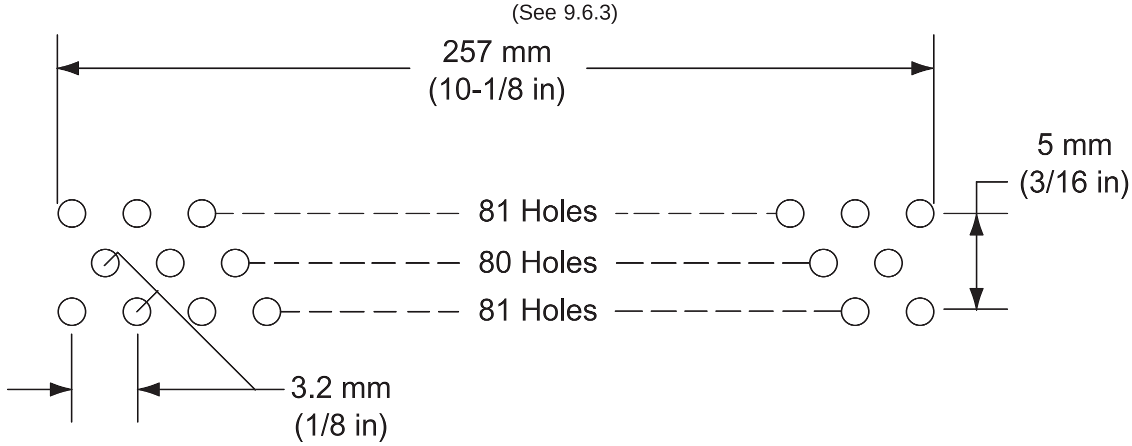
a) Each rung shall measure approximately 25 mm (1 in) in the direction parallel to the length of the tray and approximately 13 mm (1/2 in) in the direction of the depth of the tray.

b) The rungs shall be spaced approximately 230 mm (9 in) apart (measured center to center).

c) The rungs shall be tack-welded to the side rails.

Figure H.5
Burner holes

(See 9.6.3)



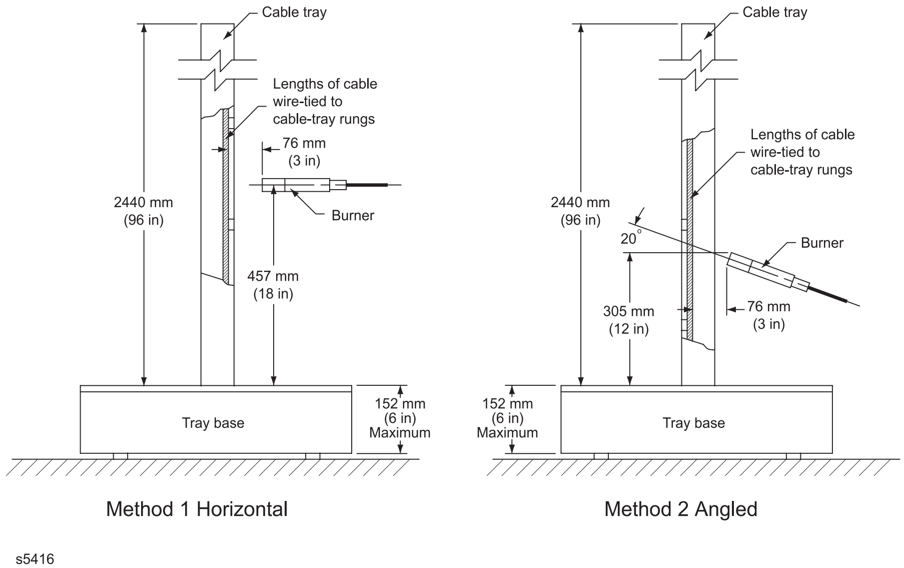
s5415

Note 1: All dimensions are nominal.

Note 2: Holes shall be centered on the plate and 1.35 mm (0.052 in (No. 55 drill)) in diameter.

Figure H.6
Burner placement details

(See 9.6.5.2 and 9.6.5.3)



Note: Tray base (optional) is 152 mm (6 in) maximum height.

Figure H.7
Schematic of gas train

(See 9.6.3)

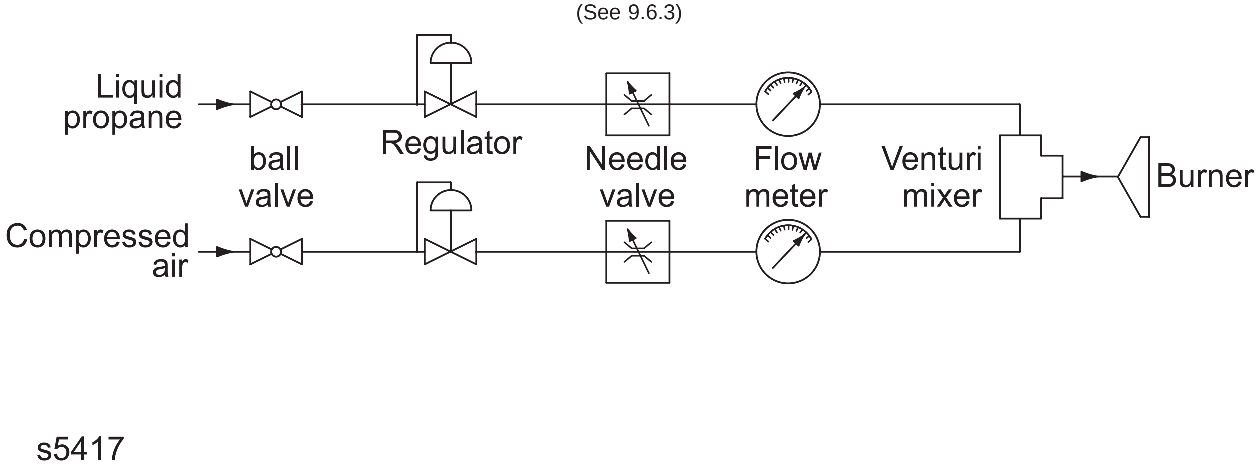
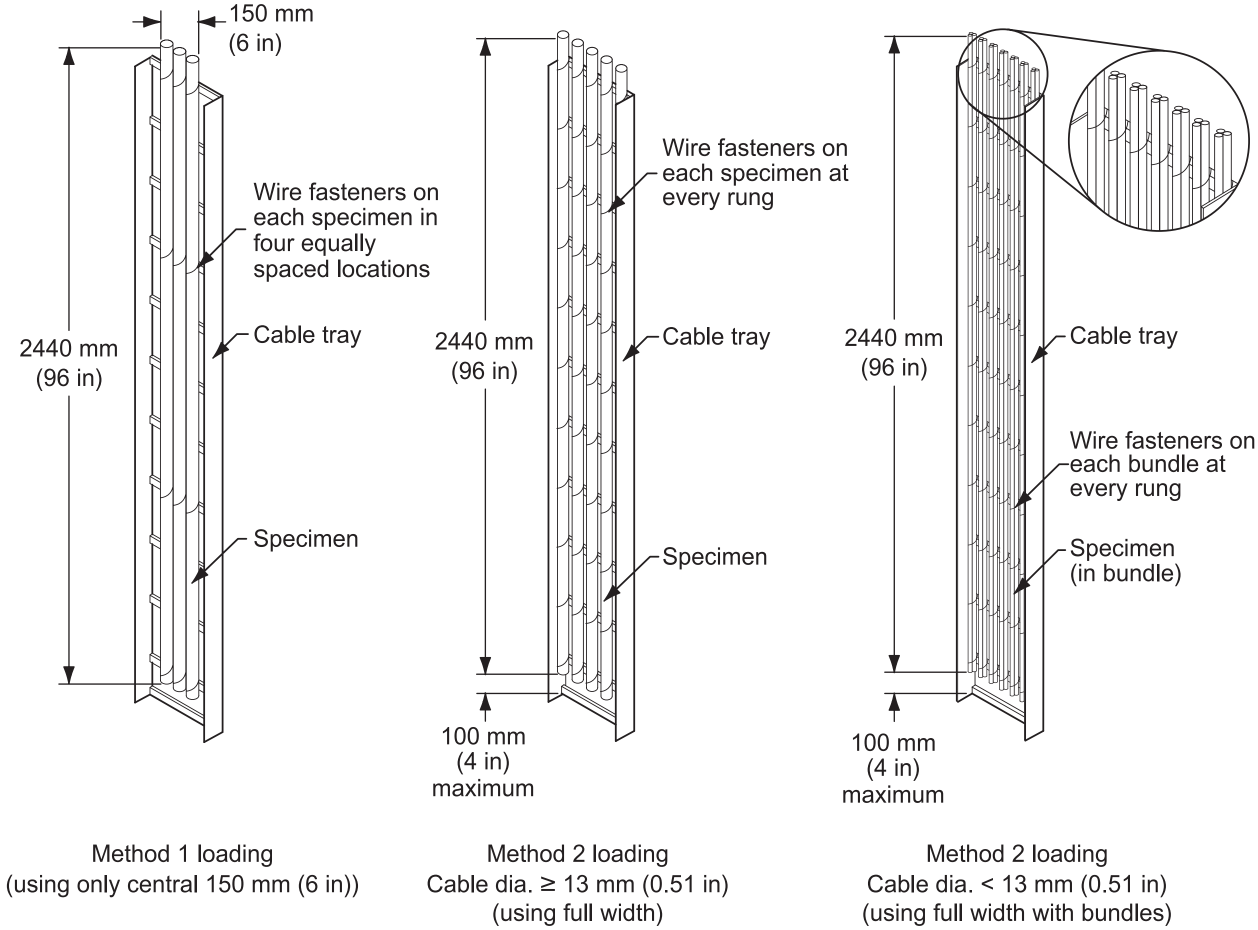


Figure H.8
Cable tray

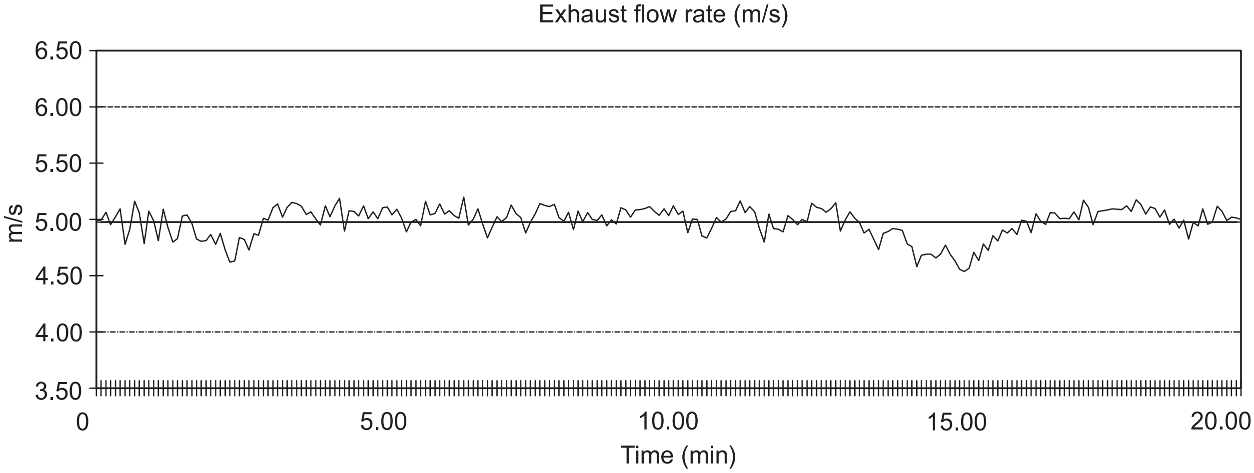
(See 9.6.4.2 and 9.6.4.3)



S5418

Figure H.9
Typical exhaust velocity graph

(See 9.6.6.1)



Annex I (informative)

Conversion of pH to acid gas (as % HCl) and acid gas (as % HCl) to pH

Table I.1
Conversion of pH to acid gas (as % HCl) and acid gas (as % HCl) to pH

pH to Acid gas		pH to Acid gas		Acid gas to pH		Acid gas to pH	
pH	% Acid gas	pH	% Acid gas	% Acid gas	pH	% Acid gas	pH
0.1	5792.2	3.6	1.8	0.1	4.86	3.5	3.32
0.2	4600.9	3.7	1.5	0.2	4.56	3.6	3.31
0.3	3654.7	3.8	1.2	0.3	4.39	3.7	3.29
0.4	2903.0	3.9	0.9	0.4	4.26	3.8	3.28
0.5	2305.9	4.0	0.73	0.5	4.16	3.9	3.27
0.6	1831.7	4.1	0.58	0.6	4.08	4.0	3.26
0.7	1454.9	4.2	0.46	0.7	4.02	4.1	3.25
0.8	1155.7	4.3	0.37	0.8	3.96	4.2	3.24
0.9	918.0	4.4	0.29	0.9	3.91	4.3	3.23
1.0	729.2	4.5	0.23	1.0	3.86	4.4	3.22
1.1	579.2	4.6	0.18	1.1	3.82	4.5	3.21
1.2	460.1	4.7	0.15	1.2	3.78	4.6	3.20
1.3	365.5	4.5	0.12	1.3	3.75	4.7	3.19
1.4	290.3	4.9	0.09	1.4	3.72	4.5	3.18
1.5	230.6	5.0	0.07	1.5	3.69	4.9	3.17
1.6	183.2	5.1	0.08	1.6	3.66	5.0	3.16
1.7	145.5	5.2	0.05	1.7	3.63	5.1	3.16
1.8	115.6	5.3	0.04	1.8	3.61	5.2	3.15
1.9	91.8	5.4	0.03	1.9	3.58	5.3	3.14
2.0	72.9	5.5	0.02	2.0	3.56	5.4	3.13
2.1	57.9	5.6	0.018	2.1	3.54	5.5	3.12
2.2	46.0	5.7	0.015	2.2	3.52	5.6	3.11
2.3	38.5	5.8	0.012	2.3	3.50	5.7	3.11
2.4	29.0	5.9	0.009	2.4	3.48	5.8	3.10
2.5	23.1	6.0	0.007	2.5	3.46	5.9	3.09
2.6	18.3	6.1	0.008	2.6	3.45	6.0	3.06
2.7	14.5	6.2	0.005	2.7	3.43	6.1	3.06
2.8	11.6	6.3	0.004	2.8	3.42	6.2	3.07
2.9	9.2	6.4	0.0029	2.9	3.40	6.3	3.06
3.0	7.3	6.5	0.0023	3.0	3.39	6.4	3.06
3.1	5.8	6.6	0.0018	3.1	3.37	6.5	3.05
3.2	4.6	6.7	0.0015	3.2	3.36	6.6	3.04
3.3	3.7	6.8	0.0012	3.3	3.34	6.7	3.04
3.4	2.9	6.9	0.0009	3.4	3.33	6.8	3.03
3.5	2.3	7.0	0.0007	3.5	3.32	6.9	3.02
Note: The following equations give guidance on how to do the calculations:							

$$pH = -\log \frac{[\%\ \text{Acid Gas}] \times m_{polymer}\ [g]}{Mw_{HCL}\ [36.46g/mol] \times 100}$$

$$[\%\ \text{Acid Gas}] = \frac{10^{-pH} \times Mw_{HCL}\ [36.46g/mol] \times 100}{m_{polymer}\ [g]}$$

Annex J (informative)
Correlation of NMX wire and cable test method standards with UL 2556/CSA C22.2 No. 2556

Table J.1
Test correlation - UL 2556/CSA C22.2 No. 2556 vs. NMX Standards

Test method	UL 2556/CSA C22.2 No. 2556 Clause	NMX Standard
Conductor diameter	3.1	NMX-J-066-ANCE
Cross-sectional area by mass (weight) method	3.2	NMX-J-129-ANCE
Cross-sectional area by diameter method	3.3	NMX-J-066-ANCE
DC resistance	3.4	NMX-J-212-ANCE
Physical properties of conductors	3.5	NMX-J-312-ANCE
Maximum tensile strength and elongation at break	3.5.1	NMX-J-312-ANCE
Ultimate strength	3.5.2	NMX-J-556-ANCE
Bending fatigue	3.5.3	NMX-J-556-ANCE
High-current heat cycling for aluminum conductors	3.6	NMX-J-556-ANCE
Thickness	4.1	NMX-J-177-ANCE
Physical properties (ultimate elongation and tensile strength)	4.2	NMX-J-556-ANCE*
Short-term air-oven aging	4.2.8.2	NMX-J-186-ANCE
Oil resistance	4.2.8.3	NMX-J-194-ANCE
Gasoline resistance	4.2.8.4	NMX-J-556-ANCE
Weather (sunlight resistance)	4.2.8.5	NMX-J-553-ANCE
Dry temperature rating of new materials (long-term aging test)	4.3	NMX-J-556-ANCE
Carbon black content	4.4	NMX-J-437-ANCE
Coverage of fibrous braids	5.1	NMX-J-556-ANCE
Coverage of shielding (wraps and braids)	5.2	NMX-J-556-ANCE
Saturation	5.3	NMX-J-556-ANCE
Continuity	6.1	NMX-J-556-ANCE
Dielectric voltage-withstand	6.2	NMX-J-293-ANCE
Dielectric breakdown	6.3	NMX-J-556-ANCE
Insulation resistance	6.4	NMX-J-294-ANCE
Capacitance and relative permittivity	6.5	NMX-J-040-ANCE
Stability factor	6.6	NMX-J-205-ANCE
Spark	6.7	NMX-J-473-ANCE
Standard arcing test	6.8	NMX-J-556-ANCE
Flex arcing test	6.9	NMX-J-556-ANCE
Jacket resistance	6.10	NMX-J-556-ANCE
AC leakage current test	6.11	NMX-J-556-ANCE
Fall-in of extruded materials	7.1	NMX-J-556-ANCE
Heat shock	7.2	NMX-J-190-ANCE
Heat shock resistance	7.3	NMX-J-556-ANCE
Shrinkback	7.4	NMX-J-556-ANCE
Cold bend	7.6	NMX-J-193-ANCE
Cold impact	7.6	NMX-J-556-ANCE
Deformation	7.8	NMX-J-191-ANCE
Hot creep elongation and hot creep set	7.9	NMX-J-432-ANCE
Abrasion resistance	7.10	NMX-J-556-ANCE
Crush resistance	7.11	NMX-J-556-ANCE
Impact resistance	7.13	NMX-J-556-ANCE

Table J.1 Continued on Next Page

Table J.1 Continued

Test method	UL 2556/CSA C22.2 No. 2556 Clause	NMX Standard
Dielectric breakdown alter glancing impact	7.14	NMX-J-556-ANCE
Flexibility at room temperature alter aging	7.15	NMX-J-189-ANCE
Flexibility of separator tape under jacket	7.16	NMX-J-556-ANCE
Swelling and blistering when immersed in liquid	7.18	NMX-J-556-ANCE
Durability of ink printing	7.19	NMX-J-556-ANCE
Color coating	7.20	NMX-J-556-ANCE
Mechanical strength	7.21	NMX-J-556-ANCE
Bend test on nylon covered conductors	7.23	NMX-J-556-ANCE
Tightness of insulation	7.24	NMX-J-556-ANCE
Flexing of shielded cables	7.26	NMX-J-556-ANCE
Copper corrosion	8.1	NMX-J-556-ANCE
FT2/FH/Horizontal flame	9.1	NMX-J- 192-ANCE
Burning particles (dropping)	9.2	NMX-J-556-ANCE
FT1	9.3	NMX-J-556-ANCE
FV-2/VW-1	9.4	NMX-J- 192-ANCE
FV-1/Vertical flame	9.5	NMX-J- 192-ANCE
Vertical tray flame Method 1 – Vertical tray	9.6.4.2	NMX-J-556-ANCE
Vertical tray flame Method 2 – FT4	9.6.4.3	NMX-J-498-ANCE
ST1 limited smoke	9.7	NMX-J-556-ANCE
Fire propagation/RPI	9.8	NMX-J-093-ANCE
Smoke emission	9.9	NMX-J-474-ANCE
Halogen acid gas emission	9.10	NMX-J-472-ANCE
Acid gas emission	9.11	NMX-J-556-ANCE
Conductor removal from insulation for tubular specimens	Annex A	NMX-J-178-ANCE
Determination of density	Annex B	NMX-J-178-ANCE
Calculation for determination of ultimate elongation or tensile strength at 300 d	Annex C	NMX-J-556-ANCE
Parameters and requirements for short-term air oven aging test	Annex D	NMX-J-556-ANCE
Determination of temperature correction factor	Annex E	NMX-J-294-ANCE
Procedure and calculations for determining the degree of coverage of fibrous coverings	Annex F	NMX-J-556-ANCE
Calculation of coverage of shielding	Annex G	NMX-J-556-ANCE
*Clauses 4.2.1 – 4.2.3 and reference to NMX-J-178-ANCE		