UL 1685

STANDARD FOR SAFETY

Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

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UL Standard for Safety for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables, UL 1685

Fourth Edition, Dated July 7, 2015

SUMMARY OF TOPICS:

This new edition of ANSI/UL 1685 is being issued to reaffirm approval as an American National Standard. No changes in requirements are involved.

The new and/or revised requirements are substantially in accordance with Proposal(s) on this subject dated May 15, 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 note following the affected item. 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that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

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ANSI/UL 1685-2010 (R2015)

UL 1685

Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for

Electrical and Optical-Fiber Cables

First Edition – July, 1992
Second Edition – February, 1997
Third Edition – April, 2007

Fourth Edition

July 7, 2015

This ANSI/UL Standard for Safety consists of the Fourth Edition.

The most recent designation of ANSI/UL 1685 as an American National Standard (ANSI) occurred on July 7, 2015. ANSI approval for a standard does not include the Cover Page, Transmittal Pages and Title Page.

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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INTRODUCTION

1 Choice of Test

1.1 Limits are specified for each fire test to make the tests equally acceptable for the purpose of quantifying the smoke. The cable manufacturer is to specify, for testing each limited-smoke cable construction, either the UL vertical-tray flame exposure described in Sections 4 – 11 or the FT4/IEEE 1202 type of flame exposure described in Sections 12 – 19. The same test need not be specified for all constructions. Sections 20 – 25 provide for the collection of certain optional additional data, which may be requested by the cable manufacturer (see list in 25.1).

1.2 For cables that are subject to a vertical-tray flame test without the cable manufacturer requesting the rating for limited smoke, the end-product wire Standard specifies that smoke measurements are not applicable. In the UL or FT4/IEEE 1202 test for these cables, only the flame height and cable damage height are of interest unless the manufacturer requests that the smoke data and results also be reported.

2 Units of Measurement

2.1 If a value for measurement is followed by a value in other units either in parentheses or in square brackets [ ], the second value may be only approximate. The first-stated value is the requirement.

3 Undated References

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

UL FLAME EXPOSURE

4 Scope

4.1 The UL flame exposure is a vertical-tray fire test for determining values of cable damage height and smoke release from electrical and optical-fiber cables when the cables are subjected to a flaming ignition source. For a cable to be acceptable under the UL test procedure, each of the following is to be exhibited (see 10.1 and 10.2):

a) The cable char height is to be less than 8 ft, 0 inch (244 cm) when measured from the bottom of the cable tray in accordance with Section 8.

b) The total smoke released is to be 95 m^2 or less.

c) The peak smoke release rate is to be 0.25 m^2/s or less.

4.2 The purpose of this test is to determine flame propagation and smoke characteristics of these cables to qualify the cables for the limited smoke marking.

4.3 This test does not investigate the toxicity of the products of combustion or decomposition.

4.4 This test does not cover the constructional requirements for the cable or any electrical, optical, or other performance requirements for the cable.

5 Apparatus

5.1 General

5.1.1 The test apparatus is to include the following main components:

a) Ignition source.

b) Collection hood and exhaust duct.

c) Velocity-measuring instrumentation.

d) Smoke-measuring instruments.

e) Data-acquisition system.

5.1.2 The cable test enclosure is to be located in a test building that has vents for the discharge of the combustion products and also has provisions for fresh-air intake.

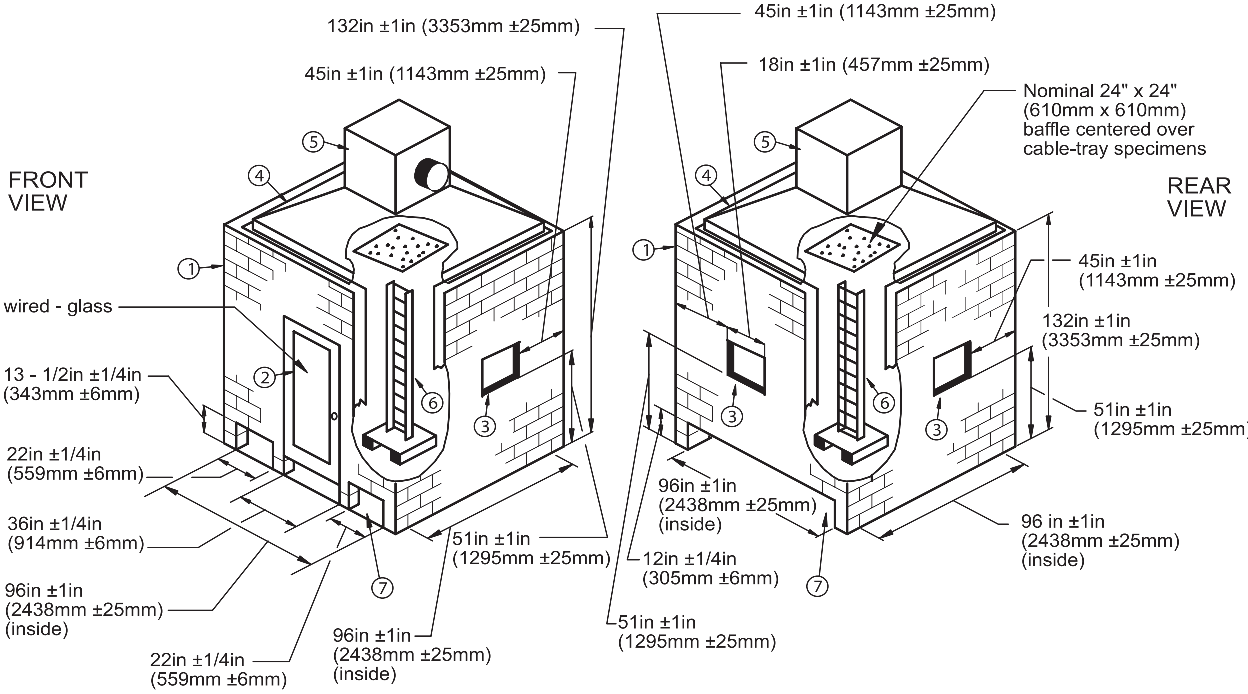
5.2 Cable test enclosure and exhaust duct

5.2.1 The enclosure in which the cables are tested is to be as shown in Figure 5.1. Other enclosures may be used if they are shown to provide equivalent results and are of a size [such as an 8-ft cube (2.4-m cube) or the 3-m 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) or greater than 36 m^3 (1272 ft^3), the floor area is not smaller than 6 m^2 (64 ft^2) or larger than 9 m^2 (97 ft^2), and the maximum air movement within the enclosure complies with 5.3.4.

5.2.2 The walls of the enclosure shall be constructed of concrete masonry units complying with ASTM C90, Standard Specification for Loadbearing Concrete Masonry Units. The interior surface of the walls shall be painted flat black. The walls are to contain window(s) as shown in Figure 5.1 for observation of the fire test. Alternate construction materials are acceptable for the enclosure walls provided the construction materials are capable of withstanding the high temperatures and open flame in the test enclosure.

5.2.3 The enclosure is to contain an access door, typically constructed of steel. The door is to be provided with a wired-glass window and is to be located as shown in Figure 5.1.

Figure 5.1
Cable test enclosure



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1) Enclosure constructed of concrete blocks laid up with mortar. The blocks are to be nominally 8 inches high by 16 inches long by 6 inches thick (203 mm × 406 mm × 152 mm).

2) Steel-framed wired-glass door for access and observation. The overall size of the door is to be nominally 36 inches wide by 84 inches high (0.9 m × 2.1 m).

3) Square steel-framed wired-glass observation window(s) nominally 18 inches (457 mm) on a side.

4) Truncated-pyramid stainless-steel hood. Each side is to be sloped 40°.

5) Collection box with exhaust duct centered in one side. The box is to be a cube with each face a 36-inches (914-mm) square.

6) Cable tray mounted vertically in the center of the enclosure. The tray base (stand) is optional and is not to be higher than 6 inches (152 mm).

7) Air-intake openings.

5.2.4 A truncated-pyramid steel hood and a collection box, each formed as shown in Figure 5.1, are to be located on top of the enclosure walls. Compressible, inorganic batting is to be used as a gasket between the hood and the walls.

5.2.5 The exhaust duct connected to the plenum on the hood is to consist of a nominal 16-inch (406-mm) steel pipe installed horizontally as shown in Figure 5.1.

5.3 Velocity-measuring instruments

5.3.1 The velocity in the exhaust duct is to be determined by measuring the differential pressure in the flow path with a bi-directional probe. The probe is to be connected to an electronic pressure gauge or to an equivalent measuring system. The probe is to 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 1.0 in (25.4 mm) and a maximum length of 2.0 in (51 mm). The pressure taps (tubes) on either side of the diaphragm are to support the probe.

5.3.2 The axis of the probe is to be located on the centerline of the duct a minimum of 13 ft, 4 inches (4.0 m) downstream from the last turn in the duct to ensure a nearly uniform velocity of flow across the duct cross section. The probe may be positioned at another location if it is shown that equivalent results are provided. The pressure taps are to be connected to a pressure transducer having a minimum resolution of 0.001 in H_2O (0.025 Pa).

5.3.3 The temperature of the exhaust gas is to be measured approximately 6 inches (152 mm) upstream from the probe on the centerline of the duct using a 28 AWG (0.08 mm^2) Type K thermocouple having an inconel sheath.

5.3.4 The maximum air movement within the enclosure, with only the intake and exhaust openings open, the exhaust fan on (if applicable), 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 vane type of anemometer:

a) On the floor of the enclosure at the position occupied by the burner during the test.

b) 1.5 m (4.9 ft) above the floor of the enclosure at the position occupied by the cable tray during the test.

5.4 Cable tray

5.4.1 A steel ladder type of cable tray that is clean and free of residue and debris is to be securely mounted in a vertical position. The tray is to be 12 inches wide, 3 inches deep, about 96 inches long (300 mm by 76 mm by 2400 mm) and is to have channel rungs as follows:

a) Each rung is to measure approximately 1 inch (25 mm) in the direction parallel to the length of the tray and approximately 1/2 inch (13 mm) in the direction of the depth of the tray.

b) The rungs are to be spaced approximately 9 inches (230 mm) apart (measured center to center).

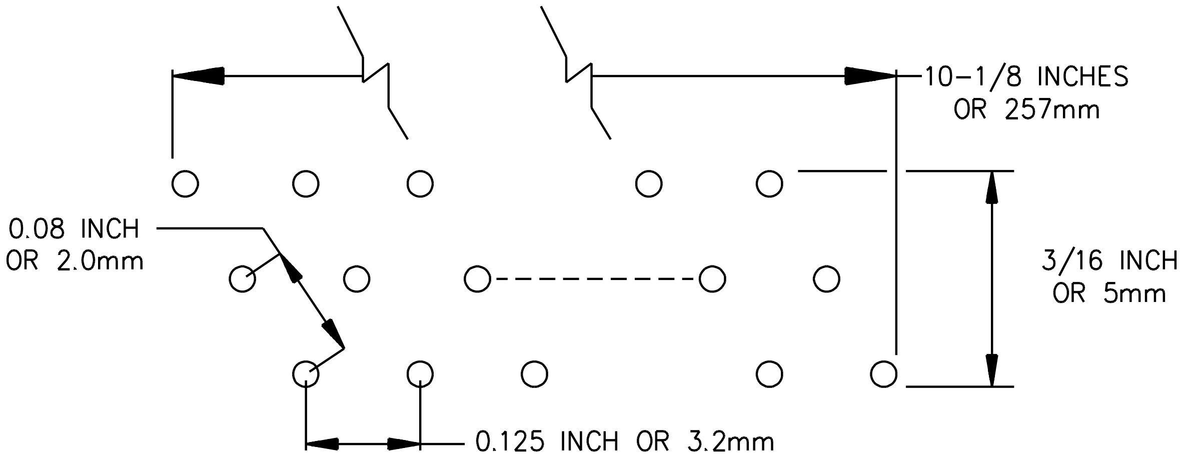
c) The rungs are to be tack welded to the side rails.

5.5 Burner

5.5.1 The test flame is to be supplied by means of a strip or ribbon type of propane-gas burner[a]. The flame-producing surface (face) of the burner is to consist essentially of a flat metal plate that is 13-7/16 inches long and 1-5/32 inches wide (341 mm by 30 mm). The plate is to have an array of 242 holes in three staggered rows of 81, 80, and 81 holes each to form an array measuring 10-1/8 inches by 3/16 inch (257 mm by 5 mm). The holes are to be 0.052 inch (No. 55 drill) or 1.35 mm (1.35 mm metric drill size) in diameter. The array of holes is to be centered on the plate. See Figure 5.2, which is not to scale.

[a] A burner (catalog No. 55AGF001-0098)) and venturi mixer (catalog No. 55AGF001-0113), or a kit that includes both a burner and mixer (catalog No. 55AGF001-0091) that can be used to effect compliance with the requirements in 5.6.1 and 13.6.1 are available from Carlisle Machine Works, Inc., 412 S. Wade Blvd., Milville, NJ 08332.

Figure 5.2
Burner holes



NOTE –

See 5.5.1.

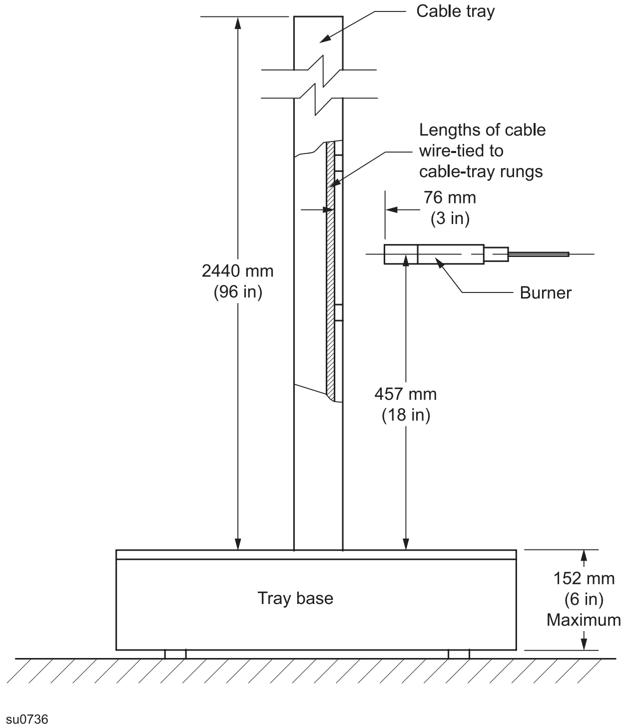
5.5.2 The burner is to be mounted on a stand and positioned on the side of the tray in which the tray rungs are attached (see Figure 5.3). The burner is to have its flame-producing surface (face) vertical and its long dimension horizontal. The 10-1/8-inch (257-mm) dimension of the array of holes is to be spaced 3 inches (76 mm) from the cables in the tray and is to be centered midway between the side rails of the tray. The centerpoint of the burner face is to be positioned 18 inches (457 mm) above the bottom end of the tray and cables and midway between two tray rungs.

5.6 Flowmeters

5.6.1 A flowmeter is to be inserted in each of the propane and air lines feeding the burner, to measure the flow rates of these gases during the test.

5.6.2 The propane flowmeter is to be capable of measuring a flow rate of 29 standard cubic feet per hour (2.3×10^{-4} m^3/s), and the air flowmeter 170 standard cubic feet per hour (13.3×10^{-4} m^3/s). Measurements are to be accurate within 3 percent. A mass flow controller with an output that can be recorded may be used.

Figure 5.3
Cable tray, specimen, and burner details for UL Flame exposure



5.7 Air

5.7.1 The air supplied to the burner is to be compressed air, either bottled or supplied through a compressed-air system.

5.8 Propane

5.8.1 The gas supplied to the burner is to be Special Duty Propane as defined in ASTM D 1835, Standard Specification for Liquefied Petroleum (LP) Gases or HD-5 Propane as defined in GPA Standard 2140, Liquefied Petroleum Gas Specifications and Test Methods . This gas has a nominal heating value of 2500 Btu (thermochemical) per cubic foot [93.0 MJ/m^3 or 22.2 kilocalories (thermochemical) per cubic meter].

5.9 Gas flows

5.9.1 The propane flow is to be 28 ±1 standard cubic feet per hour (220 ±8 cm^3/s) when corrected to standard temperature and pressure (20°C, 101 kPa).

5.9.2 The airflow is to be 163 ±10 standard cubic feet per hour (1280 ±80 cm^3/s) when corrected to standard temperature and pressure.

5.10 Smoke-measuring instruments

5.10.1 The photometer system is to consist of a light source[b] and photoelectric cell[c] 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 16 ft (4.9 m) long to ensure a nearly uniform velocity of flow across the duct cross section. The light beam is to be directed horizontally along a diameter of the duct. A photoelectric cell whose output is directly proportional to the amount of light received is to be mounted over the light source and is to be connected to a recording device having an accuracy within ±1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke (particulate matter) and other effluents. The distance between the light-source lens and the photo-cell lens is to be 36 ±2 inches (910 ±50 mm). The cylindrical light beam is to pass through round openings 3 inches (76 mm) in diameter at the top and bottom of the 16-inch (406-mm) duct, with the resultant light beam centered on the photocell.

[b] A General Electric Model 4405 12-V sealed-beam clear auto spot lamp (Part Number 4405) has been found suitable for this purpose. The light source may be procured from any electrical supplies vendor.

[c] A photoelectric cell suitable for this purpose is a Weston Instruments No. 856-9901013BB photronic cell.

5.10.2 The output signal from the photoelectric cell is to be processed into a continuous record of smoke obscuration, from which the optical density is to be calculated.

5.11 Data acquisition

5.11.1 A digital data-acquisition system is to be used to collect and record smoke and pressure measurements. The speed and capacity of the data system are to result in the collection of data every 5 seconds.

6 Smoke System Calibration

6.1 Prior to the start of each day of testing, the linearity of the photometer system is to be verified by interrupting the light beam with multiple calibrated neutral-density filters to cover the range of the recording instrument.

6.2 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[d]. Each filter is to be positioned in front of the photoelectric cell to cover the entire width of the light path. The attenuation of incident light using the neutral-density filters shall be used to calibrate the optical density as follows:

$$OD = \log_{10} (I_0/I)$$

in which:

OD is the optical density,

I_0 is the clear-beam photoelectric cell signal, and

I is the photoelectric cell signal with the neutral-density filter.

[d] Wratten filters from Kodak Company have been found to be suitable for the purpose. The filters may be purchased from a professional photography supplies vendor. Filters must be calibrated to a set of calibrated filters traceable to national standards.

6.3 The calculated values of OD for each filter shall agree within ±3 percent of the calculated neutral-density values.

7 Test Specimens

7.1 Cable mounting

7.1.1 Two sets of specimens of each cable construction are to be tested. Each set is to consist of multiple 96-inch (244-cm) lengths of the finished cable.

7.1.2 The specimen lengths of cable are to be fastened in a single layer in the tray by means of steel or copper wire not larger than 14 AWG (2.1 mm^2) at their upper and lower ends and at two other equally spaced points along their lengths, with each cable vertical. As many cables are to be installed in the tray as will fit spaced one-half cable diameter apart filling the center 6 inches or 150 mm of the tray width. The number of specimen lengths to be tested is to be determined as

$$N = (4/D) + 0.33$$

in which:

N is the number of cables (rounded up to the next whole number) and

D is the diameter of the cable in inches.

For a flat cable, the cable diameter is to be an equivalent diameter calculated as

$$1.1284 \times (TW)^{1/2}$$

in which:

T is the length of the minor axis of the flat cable and

W is the length of the major axis of the flat cable.

7.2 Conditioning

7.2.1. Before the test is started, the test specimens are to be conditioned for at least 3 hours in air whose temperature is 73 ±9°F (23 ±5°C).

8 Test Procedure

8.1 Initial preparation

8.1.1 At the start of the test, the cables, apparatus, and the air in the test area are to be in thermal equilibrium with one another at a temperature of at least 41°F (5°C).

8.1.2 The pretest calibration procedure described in 6.1 is to be performed if smoke measurements are being reported.

8.1.3 Power is to be applied to the digital data-acquisition equipment and to the computer.

8.1.4 A nominal exhaust flow rate of 0.65 ±0.05 m^3/s (23.0 ±1.8 ft^3/s) is to be established in the duct.

8.2 Procedure

8.2.1 The prepared cable tray is to be positioned vertically inside the enclosure, with the open front of the cable tray facing the front of the enclosure. The cable tray is to be firmly secured in position.

8.2.2 The burner is to be ignited and the gas flows are to be adjusted to the values indicated in 5.9.1 and 5.9.2. The burner is to be positioned 3.0 inches ±0.2 inch (75 mm ±5 mm) from the nearest cable surface.

8.2.3 The burner flame is to impinge on the specimens for a continuous period of 20 min.

8.2.4 At the end of the 20-min burn, the burner flame is to be extinguished and the cable fire (if any) is to be allowed to burn itself out.

8.2.5 Note is to be taken and a record kept of the flame height during the 20-min test as well as the time in seconds that the cables continue to flame following removal of the burner flame.

8.2.6 The test procedure is to be conducted on the number of sets of cable specimens specified. Each procedure (burn) is to be conducted on previously untested specimens.

8.3 Evaluation of damage

8.3.1 After burning has ceased, the cables shall be wiped clean, and the maximum extent of char determined. In addition, for informational purposes, other damage, such as melt, is also to be recorded. Soot that can be removed with a cloth shall be ignored.

8.3.2 Cable char and other damage shall be determined by measuring the distance of char and other damage measured from the bottom of the cable tray to the nearest 1 in (25 mm).

8.3.3 The limit of charring shall be determined by pressing against the cable surface with a sharp object. Where the surface of the cable changes from a resilient surface to a brittle or crumbling surface, the limit of charring has been determined.

8.3.4 Certain cable constructions may not char upon exposure to flame due to the characteristics of the compounds used. For those cables, other significant damage in the vicinity of the maximum, visible flame height, that results in the overall cable diameter being visibly reduced or increased, shall be considered “char” for assessing pass/fail.

9 Calculations

9.1 Smoke release rate

9.1.1 The smoke release rate (SRR) is to be calculated using the optical density per linear path length in the duct and the volumetric flow rate. The following equation is to be used to determine the SRR

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

in which:

SRR is the smoke release rate in meters squared per second,

OD is the optical density,

M_1 is the volumetric flow rate (in cubic meters per second) in the exhaust duct referred to 298K, and

0.4064 is the path length in the duct in meters.

10 Report

10.1 The test report is to contain the following summary information:

a) A description of each set of specimens tested – that is, the cable type letters and component makeup and the number of cable lengths in the set.

b) The number of burns.

c) The date on which the test was conducted.

10.2 The following information is to be included for each set of specimens tested (see Report of Supplemental Data, Section 25 for optional additional data):

a) A graph of flame height (in feet and inches) versus time, with the maximum flame height identified.

b) The maximum cable damage (in feet and inches) measured after the test in terms of melt, char, ash, and conductor damage. See 8.3.1 – 8.3.4.

c) The peak SRR in meters squared per second.

d) The total smoke released in 20 min, expressed in meters squared.

e) A graph of SRR versus time.

f) Observations recorded during and after the test.

11 Acceptance Criteria

11.1 Each cable specimen shall have the following properties when tested as described in 8.1.1 – 9.1.1 (UL test):

a) The cable char height for each specimen shall be less than 8 ft, 0 inch (244 cm) when measured from the bottom of the cable tray.

b) The total smoke released in 20 min for each specimen shall not exceed 95 m^2.

c) The peak smoke release rate for each specimen shall not exceed 0.25 m^2/s.

FT4/IEEE 1202 TYPE OF FLAME EXPOSURE

12 Scope

12.1 The FT4/IEEE 1202 type of flame exposure is a vertical-tray fire test for determining values of cable damage height and smoke release from electrical and optical-fiber cables when the cables are subjected to a flaming ignition source. For a cable to be acceptable under the FT4/IEEE 1202 type of test procedure, each of the following is to be exhibited (see 19.1):

a) The cable char height is to be less than 4 ft, 11 inches (1.5 m) when measured from the lower edge of the burner face in accordance with Section 13.

b) The total smoke released is to be 150 m^2 or less.

c) The peak smoke release rate is to be 0.40 m^2/s or less.

12.2 The purpose of this test is to determine flame propagation and smoke characteristics of these cables to qualify the cables for the limited smoke marking.

12.3 This test does not investigate the toxicity of the products of combustion or decomposition.

12.4 This test does not cover the constructional requirements for the cable or any electrical, optical, or other performance requirements for the cable.

13 Apparatus

13.1 General

13.1.1 The test apparatus is to include the following main components:

a) Ignition source.

b) Collection hood and exhaust duct.

c) Velocity-measuring instrumentation.

d) Smoke-measuring instruments.

e) Data-acquisition system.

13.1.2 The cable test enclosure is to be located in a test building that has vents for the discharge of the combustion products and also has provisions for fresh-air intake.

13.2 Cable test enclosure and exhaust duct

13.2.1 The enclosure in which the cables are tested is to be as shown in Figure 5.1. Other enclosures may be used if they are shown to provide equivalent results and are of a size [such as an 8-ft cube (2.4-m cube) or the 3-m 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) or greater than 36 m^3 (1272 ft^3), the floor area is not smaller than 6 m^2 (64 ft^2) or larger than 9 m^2 (97 ft^2), and the maximum air movement within the enclosure complies with 5.3.4.

13.2.2 The walls of the enclosure shall be constructed of concrete masonry units complying with ASTM C90, Standard Specification for Loadbearing Concrete Masonry Units. The interior surface of the walls shall be painted flat black. The walls are to contain window(s) as shown in Figure 5.1 for observation of the fire test. Alternate construction materials are acceptable for the enclosure walls provided the construction materials are capable of withstanding the high temperatures and open flame in the test enclosure.

13.2.3 The enclosure is to contain an access door, typically constructed of steel. The door is to be provided with a wired-glass window and is to be located as shown in Figure 5.1.

13.2.4 A truncated-pyramid steel hood and a collection box, each formed as shown in Figure 5.1, are to be located on top of the enclosure walls. Compressible, inorganic batting is to be used as a gasket between the hood and the walls.

13.2.5 The exhaust duct connected to the plenum on the hood is to consist of a nominal 16-inch (406-mm) steel pipe installed horizontally as shown in Figure 5.1.

13.3 Velocity-measuring instruments

13.3.1 The velocity in the exhaust duct is to be determined by measuring the differential pressure in the flow path with a bi-directional probe. The probe is to 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 are to support the probe.

13.3.2 The axis of the probe is to be located on the centerline of the duct a minimum of 13 ft, 4 inches (4.0 m) downstream from the last turn in the duct to ensure a nearly uniform velocity of flow across the duct cross section. The probe may be positioned at another location if it is shown that equivalent results are provided. The pressure taps are to be connected to a pressure transducer having a minimum resolution of 0.001 in H_2O (0.025 Pa).

13.3.3 The temperature of the exhaust gas is to be measured approximately 6 inches (152 mm) upstream from the probe on the centerline of the duct using a 28 AWG (0.08 mm^2) Type K thermocouple having an inconel sheath.

13.3.4 The maximum air movement in the inlets at the floor of the enclosure, with the exhaust fan on, is not to exceed 1 m/s (3.28 ft/s).

13.3.5 The maximum air movement within the enclosure, with only the intake and exhaust openings open, the exhaust fan on (if applicable), 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 vane type of anemometer:

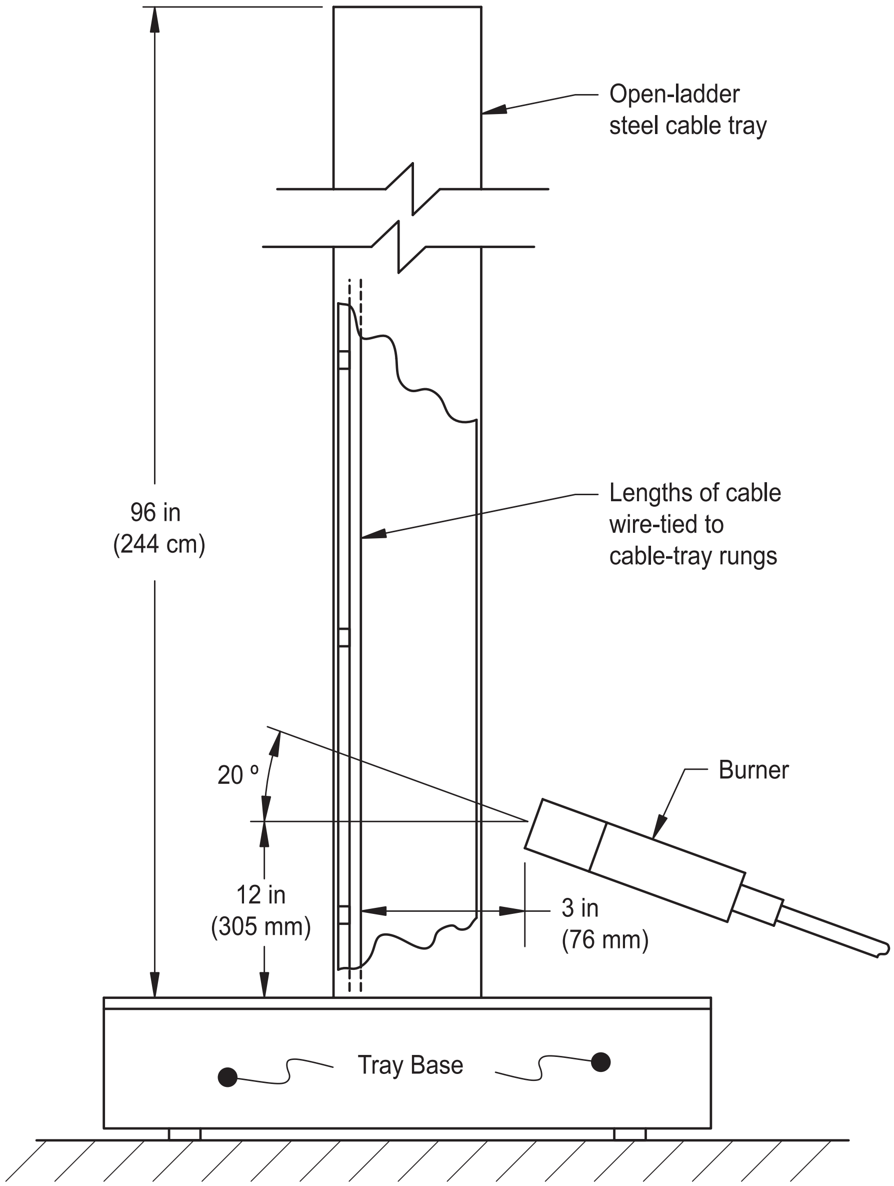
a) On the floor of the enclosure at the position occupied by the burner during the test.

b) 1.5 m (4.9 ft) above the floor of the enclosure at the position occupied by the cable tray during the test.

13.4 Cable tray

13.4.1 A steel ladder type of cable tray that is as shown in Figure 13.1 and is clean and free of residue and debris is to be used. The rungs are to be attached to the inside of the side channels. The tray is to be arranged so that the burner flame impinges on the cables midway between rungs.

Figure 13.1
Cable tray, specimen, and burner details for FT4/IEEE 1202 type flame exposure



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NOTES –

Cable tray – Nominally 12 inches wide by 3 inches deep by 96 inches long (305 mm × 76 mm × 244 cm) with steel rungs nominally 1 ±1/4 inches wide (25 ±6 mm) and spaced 9 inches (229 mm) on centers.

Burner – 10-inches wide (254-mm) ribbon-type burner with an air/gas venturi mixer.

Tray Base – Optional. 6 inches (152 mm) maximum height.

13.5 Burner

13.5.1 The test flame is to be supplied by means of a strip or ribbon type of propane-gas burner. The flame-producing surface (face) of the burner is to consist essentially of a flat metal plate that is 13-7/16 inches long and 1-5/32 inches wide (341 mm by 30 mm). The plate is to have an array of 242 holes in three staggered rows of 81, 80, and 81 holes each to form an array measuring 10–1/8 inches by 3/16 inch (257 mm by 5 mm). The holes are to be 0.052 in (No. 55 drill) or 1.35 mm (1.35 mm metric drill size) in diameter. The array of holes is to be centered on the plate. See Figure 5.2 and note (a) to 5.5.1.

13.5.2 The burner is to be mounted on a stand and positioned on the open side of the tray (side opposite the tray rungs). The burner is to be angled 20° ±2° from the horizontal with the burner ports up (see Figure 13.1). The top of the burner is to be located 305 ±25 mm (12 ±1 inch) above the base of the cable tray and parallel to the cable-tray rungs. A guide is to be attached to the burner or stand so that the leading edge of the burner face can be accurately placed 76 ±5 mm (3.0 ±0.2 inch) horizontally from the nearest surface of the cables.

13.6 Flowmeters

13.6.1 A flowmeter is to be inserted in each of the propane and air lines feeding the burner, to measure the flow rates of these gases during the test.

13.6.2 The propane flowmeter is to be capable of measuring a flow rate of 29 standard cubic feet per hour (2.3×10^{-4} m^3/s), and the air flowmeter 170 standard cubic feet per hour (13.3×10^{-4} m^3/s). Measurements are to be accurate within 3 percent. A mass flow controller with an output that can be recorded may be used.

13.7 Air

13.7.1 The air supplied to the burner is to be compressed air, either bottled or supplied through a compressed-air system.

13.8 Propane

13.8.1 The gas supplied to the burner is to be Special Duty Propane as defined in ASTM D 1835 or HD-5 Propane as defined in GPA Standard 2140. This gas has a nominal heating value of 2500 Btu (thermochemical) per cubic foot [93.0 MJ/m^3 or 22.2 kilocalories (thermochemical) per cubic meter].

13.9 Gas flows

13.9.1 The propane flow is to be 28 ±1 standard cubic feet per hour (220 ±8 cm^3/s) when corrected to standard temperature and pressure (20°C, 101 kPa).

13.9.2 The airflow is to be 163 ±10 standard cubic feet per hour (1280 ±80 cm^3/s) when corrected to standard temperature and pressure.

13.10 Smoke-measuring instruments

13.10.1 The photometer system is to consist of a light source[b] and photoelectric cell[c] 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 16 ft (4.9 m) long to ensure a nearly uniform velocity of flow across the duct cross section. The light beam is to be directed horizontally along a diameter of the duct. A photoelectric cell whose output is directly proportional to the amount of light received is to be mounted over the light source and is to be connected to a recording device having an accuracy within ±1 percent of full scale for indicating changes in the attenuation of incident light resulting from the passage of smoke (particulate matter) and other effluents. The distance between the light-source lens and the photo-cell lens is to be 36 ±2 inches (910 ±50 mm). The cylindrical light beam is to pass through round openings 3 inches (76 mm) in diameter at the top and bottom of the 16-inch (406-mm) duct, with the resultant light beam centered on the photocell.

[b] A General Electric Model 4405 12-V sealed-beam clear auto spot lamp (Part Number 4405) has been found suitable for this purpose. The light source may be procured from any electrical supplies vendor.

[c] A photoelectric cell suitable for this purpose is a Weston Instruments No. 856-9901013BB photronic cell.

13.10.2 The output signal from the photoelectric cell is to be processed into a continuous record of smoke obscuration, from which the optical density is to be calculated.

13.11 Data acquisition

13.11.1 A digital data-acquisition system is to be used to collect and record smoke and pressure measurements. The speed and capacity of the data system are to result in the collection of data every 5 s.

14 Smoke System Calibration

14.1 Prior to the start of each day of testing, the linearity of the photometer system is to be verified by interrupting the light beam with multiple calibrated neutral-density filters to cover the range of the recording instrument.

15 Test Specimens

15.1 Cable mounting

15.1.1 Two sets of specimens of each cable construction are to be tested. Each set is to consist of multiple 96-inch (244-cm) lengths of the finished cable. Depending upon the outside diameter of the individual cable, the test specimens are to be either separate, individual lengths or a bundle of individual lengths. The specimens or specimen bundles are to be centered between the side rails in a single layer. The lower end of each specimen or specimen bundle is to be located not more than 4 inches (100 mm) above the bottom end of the cable tray. Each specimen or specimen bundle is to be separately attached to each rung of the cable tray using one wrap of copper or steel wire not larger than 14 AWG (2.1 mm^2).

15.1.2 CABLES SMALLER THAN 13 mm – For cables smaller in diameter than 13 mm (0.51 inch), the specimens are to be grouped into untwisted bundles (nominally circular) as indicated in Table 15.1. The bundles are to be spaced one-half bundle diameter apart on the cable tray as measured at the point of attachment to the cable tray.

Table 15.1
Tray loading for circular cables smaller than 13 mm (0.5 inch) in diameter

Cable diameter, mm (inch)		Number of cables 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

15.1.3 CABLES 13 mm and LARGER – For cables 13 mm (0.51 inch) and larger in diameter, each specimen is to be individually attached to the cable tray with a separation of one-half cable diameter or 15 mm (0.59 inch) (whichever is less) between specimens. The tray loading is to comply with Table 15.2.

Table 15.2
Tray loading for circular cables 13 mm (0.5 inch) in diameter and larger

Cable diameter, mm (inch)		Number of cables 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 (1.0)	7
26 (1.0)	28 (1.1)	6
28 (1.1)	39 (1.5)	5
39 (1.5)	52 (2.0)	4
52 (2.0)	73 (2.9)	3
73 (2.9)	120 (4.7)	2

15.1.4 FLAT CABLES – For a flat cable, the equivalent cable diameter is to be calculated using the following formula

$$D = 1.128 \times (TW)^{1/2}$$

in which:

D is the calculated cable diameter,

T is the length of the minor axis of the cable, and

W is the length of the major axis of the cable.

15.2 Conditioning

15.2.1 Before the test is started, the test specimens are to be conditioned for at least 3 hours in air whose temperature is 73 ±9°F (23 ±5°C).

15.3 Smoke measurement system calibration

15.3.1 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[d]. Each filter is to be positioned in front of the photoelectric cell to cover the entire width of the light path. The attenuation of incident light using the neutral-density filters shall be used to calibrate the optical density as follows:

$$OD = \log_{10} (I_0/I)$$

in which:

OD is the optical density,

I_0 is the clear-beam photoelectric cell signal, and

I is the photoelectric cell signal with the neutral-density filter.

[d] Wratten filters from Kodak Company have been found to be suitable for the purpose. The filters may be purchased from a professional photography supplies vendor. Filters must be calibrated to a set of calibrated filters traceable to national standards.

15.3.2 The calculated values of OD for each filter shall agree within ±3 percent of the calculated neutral-density values.

16 Test Procedure

16.1 Initial preparation

16.1.1 At the start of the test, the lengths of cable in the tray, the apparatus, and the air in the test area are to be in thermal equilibrium with one another at a temperature of at least 41°F (5°C).

16.1.2 The pretest calibration procedure described in 14.1 is to be performed if smoke measurements are to be reported.

16.1.3 Power is to be applied to the digital data-acquisition equipment and to the computer.

16.1.4 A nominal exhaust flow rate of 0.65 ±0.05 m^3/s (23.0 ±1.8 ft^3/s) is to be established in the duct.

16.2 Procedure

16.2.1 The prepared cable tray is to be positioned vertically inside the enclosure. The cable tray is to be firmly secured in position.

16.2.2 The burner is to be ignited and the gas flows are to be adjusted to the values indicated in 13.9.1 and 13.9.2. The burner is to be positioned at an angle of 20° and 3.0 ±0.2 inches (75 ±5 mm) from the nearest cable surface. See Figures 5.3 or 13.1, as applicable, for the relative positions of the cable tray and burner in the room.

16.2.3 The burner flame is to impinge on the specimens for a continuous period of 20 min.

16.2.4 At the end of the 20-min burn, the burner flame is to be extinguished and the cable fire (if any) is to be allowed to burn itself out.

16.2.5 Note is to be taken and a record kept of the flame height during the 20-min test as well as the time in seconds that the cables continue to flame following removal of the burner flame.

16.2.6 The test procedure is to be conducted on the number of sets of cable specimens specified. Each procedure (burn) is to be conducted on previously untested specimens.

16.3 Evaluation of damage

16.3.1 After burning has ceased, the cables shall be wiped clean, and the maximum extent of char determined. In addition, for informational purposes, other damage, such as melt, is also to be recorded. Soot that can be removed with a cloth shall be ignored.

16.3.2 Cable char and other damage shall be determined by measuring the distance of char and other damage above the horizontal line from the lower edge of the burner face to the nearest 25 mm (1 in.).

16.3.3 The limit of charring shall be determined by pressing against the cable surface with a sharp object. Where the surface of the cable changes from a resilient surface to a brittle or crumbling surface, the limit of charring has been determined.

16.3.4 Certain cable constructions may not char upon exposure to flame due to the characteristics of the compounds used. For those cables, other significant damage in the vicinity of the maximum, visible flame height, that results in the overall cable diameter being visibly reduced or increased, shall be considered “char” for assessing pass/fail.

17 Calculations

17.1 Smoke release rate

17.1.1 The smoke release rate (SRR) is to be calculated using the optical density per linear path length in the duct and the volumetric flow rate. The following equation is to be used to determine the SRR

$$SRR = \frac{(OD \times M_1)}{0.4064}$$

in which:

SRR is the smoke release rate in meters squared per second,

OD is the optical density,

M_1 is the volumetric flow rate (in cubic meters per second) in the exhaust duct referred to 298K, and

0.4064 is the path length in the duct in meters.

18 Report

18.1 The test report is to contain the following summary information:

a) A description of each set of specimens tested – that is, the cable type letters and component makeup and the number of cable lengths in the set.

b) The number of burns.

c) The date on which the test was conducted.

18.2 The following information is to be included for each set of specimens tested (see Report of Supplemental Data, Section 25 for optional additional data):

a) A graph of flame height (in feet and inches) versus time, with the maximum flame height identified.

b) The maximum cable damage (in feet and inches) measured after the test in terms of melt, char, ash, and conductor damage. See 16.3.1 – 16.3.4.

c) The peak SRR in meters squared per second.

d) The total smoke released in 20 min, expressed in meters squared.

e) A graph of SRR versus time.

f) Observations recorded during and after the test.

19 Acceptance Criteria

19.1 Each individual representative cable construction shall have the following properties when tested as described in 16.1.1 – 17.1.1 (FT4/IEEE 1202 type of test):

a) The cable char height for each specimen shall be less than 4 ft, 11 inches (1.5 m) when measured from the lower edge of the burner face.

b) The total smoke released in 20 min for each specimen shall not exceed 150 m^2.

c) The peak smoke release rate for each specimen shall not exceed 0.40 m^2/s.

OPTIONAL MEASUREMENTS

20 Introduction

20.1 If the supplemental performance data itemized in 25.1 is requested by the cable manufacturer, the use of additional equipment and procedures as described in Sections 21 – 25 will be necessary during the cable fire tests described in Sections 1 – 19 of this Standard. Such data is not required to qualify a cable for the limited smoke marking.

21 Weight-Measuring System

21.1 A weight-measuring system is to be used to continuously record the weight of the set of specimens during a test. The system is to consist of the weight-measuring device described in 21.2 and a noncombustible platform on which the set of specimens is to be mounted.

21.2 The weight-measuring device is to consist of a steel frame and load cells. The device is to have the capacity to handle the weight of a set of specimens and the precision to record the weight to the nearest 0.1 lb (45 g).

22 Oxygen-Concentration Analysis Equipment

22.1 A stainless-steel gas-sampling tube is to be located 13-1/4 ft (4.0 m) downstream from the last turn in the duct to ensure a nearly uniform velocity of flow across the duct cross section. The gas-sampling tube may be positioned at another location if it is shown that equivalent results are provided. The sampling tube is to obtain a continuously flowing amount of gas from which the oxygen content of the exhaust can be determined as a function of time. A suitable filter and cold trap are to be placed in the line ahead of the analyzer to remove particulates and water. The oxygen analyzer[a] is to be of the paramagnetic type and is to be capable of measuring the oxygen concentration in the range of 0 – 21 percent having an accuracy within ±0.2 percent of full scale. The signal from the oxygen analyzer is to attain 90 percent of the calibration value within 30 s after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

[a] An analyzer found acceptable for this purpose is Beckman Instrument Model 755 Paramagnetic Type Oxygen Analyzer.

23 Pretest Calibration

23.1 Load cell

23.1.1 The load cell is to be calibrated with known weights appropriate for the capacity of the load cell and the set of specimens being tested.

23.2 Oxygen analyzer

23.2.1 The oxygen analyzer is to be zeroed and spanned. The analyzer is to be zeroed by introducing 100 percent nitrogen gas to the instrument at the same pressure and flow rate as set for the sampling of gases. The analyzer is to be spanned by introducing ambient duct air via the sampling probe and adjusting the span to 20.95 percent oxygen. The spanning-and-zeroing process is to be continued until adjustment-free accuracy is obtained.

23.2.2 Following zeroing and spanning, linearity of the analyzer response curve is to be verified by introducing bottled gas of a known oxygen concentration (for example, 19 percent oxygen) to the analyzer.

23.2.3 The delay time of the oxygen analyzer is to be determined at a nominal exhaust flow rate of 0.65 ±0.05 m^3/s (23.0 ±0.8 ft^3/s) in the duct. The burner is to be ignited, is to reach steady state, and then is to be turned off. The delay time of the analyzer is to be determined as the difference between the time at which the burner reaches steady state and the time at which the analyzer readings reach 90 percent of the final reading. The final delay time is to be used to time-shift all subsequent readings.

23.3 Heat release rate

23.3.1 Calibration of the heat-release instrumentation is to be conducted at least every 3 months by burning propane gas using a calibration burner. The heat release calculated from the metered gas input is to be compared to the heat release as measured by calculating the amount of oxygen consumed. The burner is to be positioned in the center of the test enclosure.

23.3.2 The calibration burner is to consist of a rectangle measuring 43 inches by 31 inches (1.09 m by 0.79 m) formed of 1-1/4-inch-diameter (31.8-mm) pipe. Holes are to be provided in the top of the formed pipe. The holes are to be spaced on 1-inch (25.4-mm) centers and are to be arranged in a repeated pattern of one 13/16-inch-diameter (20.6-mm) hole and two 1/8-inch-diameter (3.2-mm) holes. The propane gas is to be supplied to the burner through a calibrated flowmeter.

23.3.3 A nominal exhaust flow rate of 0.65 ±0.05 m^3/s (23.0 ±0.8 ft^3/s) is to be established in the duct. The gas supply to the calibration burner is to be CP-grade propane (99 percent pure) having a nominal heating value of 2500 Btu (thermochemical) per cubic foot [93.0 MJ/m^3 or 22.2 kilocalories (thermochemical) per cubic meter]. The flow rate of propane is to be metered and kept constant throughout the calibration test. A heat-release value of 100 kW is to be used for calibration. This is equivalent to approximately 136 standard cubic feet per hour (1.075 m^3/s) of propane. The test is to be conducted for 10 min.

23.3.4 Oxygen consumption measurements are to be made at 5-s intervals starting 60 s prior to burner ignition. A calibration constant (C) is to be obtained as described in 24.1.1. A calibration constant that deviates more than 5 percent from the previous constant is not normal and suggests instrument malfunction.

24 Calculations

24.1 Calibration constant

24.1.1 The calibration constant (C) is to be calculated using the following equation

$$C = \frac{100 \times 600}{\int_0^{600} HRR \, dt}$$

in which:

HRR is the heat release rate calculated using the oxygen-concentration and flow-rate data obtained by the oxygen-consumption technique.

The following equation is to be used to determine the HRR

$$HRR = (16.55 \times 10^3) \times M_1 \times \frac{(0.2095 - Y)}{(1.084 - 1.4Y)}$$

in which:

HRR is the heat release rate in kW,

M_1 is the volumetric flow rate (in cubic meters per second) in the duct referred to 298K, and

Y is the oxygen concentration.

24.2 Heat release rate

24.2.1 The heat release rate is to be calculated using the following equation

$$HRR = (17.08 \times 10^3) \times M_1 \times \frac{(0.2095 - Y)}{(A - BY)}$$

in which:

HRR is the heat release rate,

M_1 is the volumetric flow rate (in cubic meters per second) in the exhaust duct referred to 298K,

Y is the oxygen concentration,

A is the chemical expansion factor, and

B is the ratio of moles of combustion products to the moles of oxygen consumed.

If A and B are not known, use A = 1.084 and B = 1.4.

24.2.2 The calculated HRR for test specimens is to be adjusted based on the calibration constant determined using the following equation

$$HRR_c = C \times HRR$$

in which:

HRR_c is the corrected HRR in kilowatts,

C is the calibration constant, and

HRR is the calculated HRR in kilowatts from the measured data.

25 Report of Supplemental Data

25.1 The following information may be added to the report outlined in Report, Section 10 or Report, Section 18:

a) A table showing the specimen weight loss in pounds versus time.

b) A graph of weight loss versus time.

c) A graph of the tabulated heat release rate (HRR_c) in kilowatts versus time.

d) The peak HRR_c in kilowatts.

e) The heat released (area under the curve of HRR_c) in megajoules for selected time intervals after the start of the test.