



Designation: **D5537—18** **D5537 – 23**

Standard Test Method for Heat Release, Flame Spread, Smoke Obscuration, and Mass Loss Testing of Insulating Materials Contained in Electrical or Optical Fiber Cables When Burning in a Vertical Cable Tray Configuration¹

This standard is issued under the fixed designation D5537; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This is a fire-test-response standard.

1.2 This test method provides a means to measure the heat released and smoke obscuration by burning the electrical insulating materials contained in electrical or optical fiber cables when the cable specimens, excluding accessories, are subjected to a specified flaming ignition source and burn freely under well ventilated conditions. Flame propagation cable damage, by char length, and mass loss are also measured.

1.3 This test method provides two different protocols for exposing the materials, when made into cable specimens, to an ignition source (approximately 20 kW), for a 20 min test duration. Use it to determine the heat release, smoke release, flame propagation and mass loss characteristics of the materials contained in single and multiconductor electrical or optical fiber cables.

1.4 This test method does not provide information on the fire performance of materials insulating electrical or optical fiber cables in fire conditions other than the ones specifically used in this test method nor does it measure the contribution of the materials in those cables to a developing fire condition.

1.5 Data describing the burning behavior from ignition to the end of the test are obtained.

1.6 This test equipment is suitable for measuring the concentrations of certain toxic gas species in the combustion gases (see [Appendix X4](#)).

1.7 The values stated in SI units are to be regarded as standard (see [IEEE/ASTM SI-10](#)). The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.8 *This standard measures and describes the response of materials, products, or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products or assemblies under actual fire conditions*

¹ This test method is under the jurisdiction of ASTM Committee [D09](#) on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee [D09.17](#) on Fire and Thermal Properties.

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*A Summary of Changes section appears at the end of this standard

1.9 *Fire testing is inherently hazardous. Adequate safeguards for personnel and property shall be employed in conducting these tests.*

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

[D1711 Terminology Relating to Electrical Insulation](#)

[D5424 Test Method for Smoke Obscuration of Insulating Materials Contained in Electrical or Optical Fiber Cables When Burning in a Vertical Cable Tray Configuration](#)

[E84 Test Method for Surface Burning Characteristics of Building Materials](#)

[E176 Terminology of Fire Standards](#)

[E603 Guide for Room Fire Experiments](#)

[E800 Guide for Measurement of Gases Present or Generated During Fires](#)

[E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter](#)

[E1537 Test Method for Fire Testing of Upholstered Furniture](#)

[E2067 Practice for Full-Scale Oxygen Consumption Calorimetry Fire Tests](#)

[E3020 Practice for Ignition Sources](#)

[IEEE/ASTM SI-10 International System of Units \(SI\), The Modernized Metric System](#)

2.2 NFPA Standards:³

[NFPA 70 National Electrical Code](#)

[NFPA 265 Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings](#)

[NFPA 286 Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth](#)

[NFPA 289 Standard Method of Fire Test for Individual Fuel Packages](#)

2.3 Underwriters Laboratories Standards:⁴

[UL 1581 Reference Standard for Electrical Wires, Cables, and Flexible Cords, ANSI/UL-1581 Cords](#)

[UL 1685 Standard—Vertical Tray Fire Propagation and Smoke Release Test for Electrical and Optical Fiber Cables](#)

[UL 2556 Wire and Cable Test Methods](#)

2.4 Canadian Standards Association Standard:⁵

[CSA FT4, Vertical Flame Tests: Cables in Cable Trays, Section 4.11.4 in Standard C 22.2 No. 0.3, Test Methods for Electrical Wires and Cables](#)

2.5 IEEE Standard:⁶

[IEEE 1202 Standard for Flame Testing of Cables for Use in Cable Tray in Industrial and Commercial Occupancies](#)

2.6 ISO Standard:⁷

[ISO 9705 Fire Tests—Full Scale Room Test for Surface Products](#)

[ISO 13943 Fire Safety—Vocabulary](#)

3. Terminology

3.1 For definitions of terms used in this test method and associated with fire issues refer to Terminology [E176](#) and ISO 13943. In case of conflict, the terminology in Terminology [E176](#) shall prevail. For definitions of terms used in this test method and associated with electrical insulation refer to Terminology [D1711](#).

3.2 Definitions of Terms Specific to This Standard:

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

⁴ Available from Underwriters Laboratories (UL), 333 Pfingsten Rd., Northbrook, IL 60062-2096, <http://www.ul.com>.

⁵ Available from Canadian Standards Association (CSA), 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada, <http://www.csa.ca>.

⁶ Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, <http://www.ieee.org>.

⁷ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

3.2.1 *heat release rate, n*—the heat evolved from the specimen, per unit of time.

3.2.2 *sample, n*—an amount of the cable type and construction to be tested, which is representative of the product for test.

3.2.3 *smoke obscuration, n*—reduction of light transmission by smoke, as measured by light attenuation.

3.2.4 *specimen, n*—the individual length of cable, or cable bundle, to be placed in the cable tray, which is representative of the product to be tested.

4. Summary of Test Method

4.1 This fire-test-response standard determines a number of fire-test-response characteristics associated with burning the materials insulating electrical or optical fiber cables, made into cable specimens, and located in a vertical cable tray and ignited with a propane gas burner. The main fire properties measured are the rate of heat release and its amount. Associated with these measurements, the test procedure also determines flame propagation cable damage (by char length), smoke obscuration, and mass loss of specimen. The apparatus described in this test method is also suitable for measuring rates and concentrations of gaseous combustion products released.

4.2 The vertical cable tray that holds the specimen is located in an enclosure of specified dimensions.

4.3 A hood, connected to a duct is located above the fire enclosure. Heat and gas release analysis instrumentation is placed in the duct. Smoke release instrumentation (optional) is also placed in the duct.

4.4 Two different test procedures are specified, which differ in the burner used and in the electrical or optical fiber cable loading. These reflect details of four existing test methods: UL 1581 (vertical tray flammability test, protocol A) and CSA Standard C 22.2 No. 0.3 (FT4 vertical tray flammability test) or IEEE 1202 (protocol B) and UL 1685 and Test Method **D5424** (both protocols, for smoke obscuration only). Both test procedures described in detail in this test method are also identified in UL 2556.

4.5 Information specific to the individual protocols is found in [7.7](#), [7.9](#), and [11.1](#).

5. Significance and Use

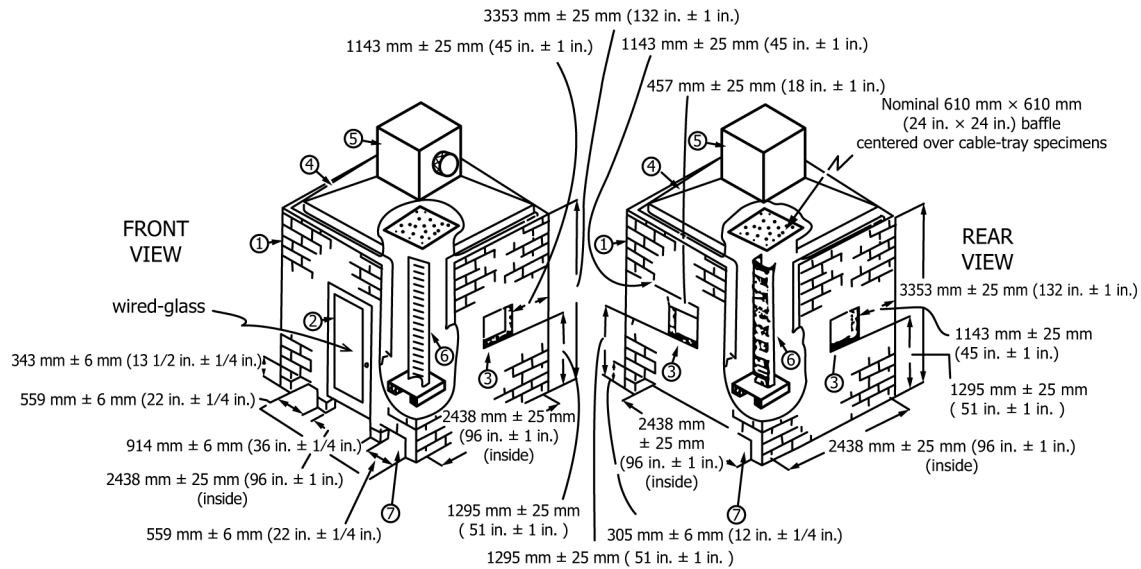
5.1 This test method provides a means to measure a variety of fire-test-response characteristics associated with heat and smoke release and resulting from burning the materials insulating electrical or optical fiber cables, when made into cables and installed on a vertical cable tray. The specimens are allowed to burn freely under well ventilated conditions after ignition by means of a propane gas burner. The ignition source used in this test method is also described as a premixed flame flaming ignition source in Practice **E3020**, which contains an exhaustive compilation of ignition sources.

5.2 The rate of heat release often serves as an indication of the intensity of the fire generated. General considerations of the importance of heat release rate are discussed in [Appendix X1](#) and considerations for heat release calculations are in [Appendix X2](#).

5.3 Other fire-test-response characteristics that are measurable by this test method are useful to make decisions on fire safety. The test method is also used for measuring smoke obscuration. The apparatus described here is also useful to measure gaseous components of smoke; the most important gaseous components of smoke are the carbon oxides, present in all fires. The carbon oxides are major indicators of the completeness of combustion and are often used as part of fire hazard assessment calculations and to improve the accuracy of heat release measurements.

5.4 Test Limitations:

5.4.1 The fire-test-response characteristics measured in this test are a representation of the manner in which the specimens tested behave under certain specific conditions. Do not assume they are representative of a generic fire performance of the materials tested when made into cables of the construction under consideration.



1. Enclosure: an acceptable construction consists of concrete masonry blocks, laid up with mortar, nominally 203 mm high by 406 mm wide by 152 mm thick (8 by 16 by 6 in.).

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(2) Wired-glass door, for access and observation. The overall size of the door is 2.1 m high and 0.9 m wide (84 in. by 36 in.).

(3) Steel-framed wired-glass observation windows, 457 mm (18 in.) per side (optional).

(4) Truncated-pyramid stainless steel hood, with each side sloped 40°.

(5) Cubical collection box, 914 mm (36 in.) per side, with exhaust duct centered on one side.

(6) Cable tray, mounted vertically in the center of the enclosure. Tray base (stand) is optional.

(7) Air intake openings.

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FIG. 1 Cable Test Enclosure

5.4.2 In particular, it is unlikely that this test is an adequate representation of the fire behavior of cables in confined spaces, without abundant circulation of air.

5.4.3 This is an intermediate-scale test, and the predictability of its results to large scale fires has not been determined. Some information exists to suggest validation with regard to some large-scale scenarios.

6. Test Specimens

6.1 Use multiple lengths of electrical or optical fiber cable as test specimens.

6.2 The mounting of the specimen on the cable tray is specified in 7.9.

7. Apparatus

7.1 Enclosure:

7.1.1 The enclosure in which the specimen is tested is shown in Fig. 1.

7.1.2 The enclosure has floor dimensions of 2.44 m ± 25 mm by 2.44 m ± 25 mm, with a height of 3.35 m ± 25 mm (8 ft ± 1 in. by 8 ft ± 1 in. by 11 ft ± 1 in. high). On top of the walls there is a pyramidal collection hood with a collection box.

7.1.2.1 Other enclosure sizes, such as $2.4 \text{ m} \times 2.4 \text{ m} \times 2.4 \text{ m}$ (8 ft by 8 ft by 8 ft) or the $3\text{-m}^3 \text{ m}$ cube are permitted, provided that the internal volume of the enclosure, exclusive of the pyramidal hood, ranges between 14.5 m^3 (512 ft³) and $36\text{-m}^3 \text{ m}^3$ (1272 ft³), the floor area ranges between 6 m^2 (64 ft²) and $9\text{-m}^2 \text{ m}^2$ (97 ft²), and the maximum air movement within the enclosure complies with 7.1.12 (Note 1).

NOTE 1—There is, as yet, not enough information as to the equivalence on smoke release between the various facilities. Further work needs to be done to confirm this.

7.1.2.2 In case of disputes, the referee method is the tests conducted using the enclosure in 7.1.2.

7.1.3 Walls—The maximum conductive heat flux loss of the walls of the structure is $6.8 \text{ W}/(\text{m}^2\text{K})$ (30 Btu/h-ft²), based upon an inside wall temperature of 38°C (100°F) and an outside air temperature of 24°C (75°F). Paint the interior surface of the walls flat black. Any materials of construction that meet the preceding requirements are acceptable. Two examples of acceptable construction materials are nominally 152 mm (6 in.) thick concrete masonry blocks (density: 1700 kg m^{-3} (106 lb ft⁻³) and thermal conductivity nominally $k = 1.75 \text{ W}/(\text{mK})$; at 21°C ; 12.13 Btu in./ft² h°F, at 70°F) or nominally 13 mm (0.5 in.) gypsum board, with $8989 \text{ mm} \pm 6 \text{ mm}$ (3.5 in. \pm 0.25 in.) of standard fiberglass insulation, with an R value of $1.94 \text{ m}^2 \text{ K}/\text{W}$ (which corresponds in practical units to an R value of 11 hft² °F/Btu). Windows for observation of the fire test are allowed in the walls; ensure that the total area of the windows does not exceed 1.86 m^2 (20 ft²).

7.1.3.1 Select materials of construction which can withstand the high temperatures and presence of open flame within the test enclosure and duct.

7.1.4 Provide air intakes at the base of two opposite walls, one of which contains the access door. Ensure that the total cross sectional area of the air intakes is $1.45 \text{ m}^2 \pm 0.03 \text{ m}^2$ (2250 in.² \pm 50 in.²), and that the intake areas are divided approximately equally. Fig. 1 shows dimensions for the air intakes installed in the walls. Air intakes are not permitted in either of the other two walls.

7.1.5 Construct a door with wired glass and locate it as shown in Fig. 1. The door is $900 \text{ mm} \pm 25 \text{ mm}$ wide and $2100 \text{ mm} \pm 25 \text{ mm}$ high (35 in. \pm 1 in. by 83.83 in. \pm 1 in.), with an overall conductive heat flux loss no greater than that of the walls, that is, $6.8 \text{ W}/(\text{m}^2 \text{ K})$ (30 Btu/h-ft²). A steel framed wired glass door will meet these requirements. Adequately seal the sides and top of the door to prevent drafts.

7.1.6 Construct a truncated pyramid stainless steel hood, formed as shown in Fig. 1, and locate it on top of the enclosure walls. Make the slope on each side of the hood 40°. Form a seal between the hood and the walls; a compressible inorganic batting as gasket is suitable.

7.1.7 Insulate the exterior of the hood to make an overall conductive heat loss no greater than that of the walls.

7.1.8 Locate a cubical stainless steel collection box, $910 \text{ mm} \pm 25 \text{ mm}$ (36 in. \pm 1 in.), on a side on top of the exhaust hood, with a nominal $410 \text{ mm} \pm 25 \text{ mm}$ (16 in. \pm 1 in.) diameter stainless steel pipe exhaust duct centered in one side.

7.1.9 Install the exhaust duct horizontally and connect it to the plenum of the hood.

7.1.10 Construct a square $610 \text{ mm} \pm 25 \text{ mm}$ (24 in. \pm 1 in.) baffle, centered over the cable tray. An acceptable height is 300 mm to 400 mm (12 in. to 15 in.) above the tray.

7.1.11 Construct a collection-exhaust system, as explained in 7.2 and Annex A2.

7.1.12 Ensure that the maximum air movement within the enclosure, with only the intake and exhaust openings open, the exhaust fan on, and the burner off, does not exceed 1 m s^{-1} (3.3 ft s⁻¹), as measured by a vane-type anemometer in the areas in 7.1.12.1 and 7.1.12.2:

7.1.12.1 At the floor level where the burner is positioned during the test, and

7.1.12.2 At $1.50 \text{ m} \pm 0.05 \text{ m}$ (4.9 ft \pm 2 in.) above the enclosure floor, where the cable tray is positioned during the test.

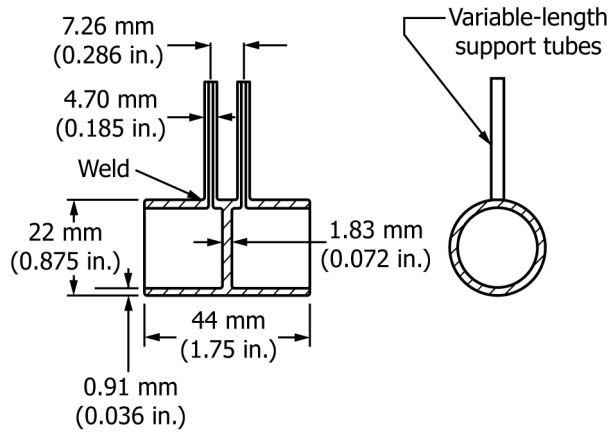


FIG. 2 Bidirectional Probe

7.2 Exhaust Collection System:

7.2.1 Construct the exhaust collection system containing, as a minimum: a blower, a steel hood, a duct, a bidirectional probe, thermocouple(s), an oxygen measurement system, and a smoke obscuration measurement system (white light photocell lamp/detector or laser). Optional components of the exhaust collection system include a system for combustion gas sampling and analysis. Construct the exhaust collection system as explained in Annex A2 and Annex A3.

7.2.2 Ensure that the system for collecting the smoke (which includes gaseous combustion products) has sufficient exhaust capacity and is designed in such a way that all of the combustion products leaving the burning specimen are collected. Design the capacity of the evacuation system such that it will exhaust minimally all combustion gases leaving the cable specimen (see also Annex A2). Make the exhaust system capacity at least $2.7 \text{ m}^3 \text{ s}^{-1}$ ($340,000 \text{ ft}^3 \text{ h}^{-1}$) at normal pressure and at a temperature of $25 \pm 2^\circ\text{C}$ ($77 \pm 4^\circ\text{F}$).

7.2.3 Place probes for sampling of combustion gas and for measurement of flow rate in accordance with 7.3.

7.2.4 Make all measurements of gas concentrations or flow rates at a position in the exhaust duct where the exhaust is uniformly mixed so that there is a nearly uniform velocity across the duct section (turbulent flow). Make the minimum straight section before the measuring system at least 8 times the inside diameter of the duct, to ensure the exhaust is uniformly mixed.

7.3 Instrumentation in Exhaust Duct:

7.3.1 The following specifications are minimum requirements for exhaust duct instrumentation. Additional information is found in Annex A1 through Annex A4.

7.3.2 Flow Rate:

7.3.2.1 Measure the volumetric flow rate in the exhaust duct by means of a bidirectional probe, or an equivalent measuring system, with an accuracy of at least $\pm 6 \%$ (see Annex A1 – Annex A4). The response time to a stepwise change of the duct flow rate shall not exceed 5 s, to reach 90 % of the final value.

7.3.2.2 Use a bidirectional probe or an equivalent measuring system to measure pressure in the duct. Locate the probe shown in Fig. 2 in the exhaust duct, at least 4.6 m (15 ft) but no more than 13.7 m (45 ft) from the centerline of the collection box.

7.3.2.3 Build a stainless steel bidirectional probe consisting of a cylinder 44 mm (1.75 in.) long and 22 mm (0.875 in.) in inside diameter with a solid diaphragm in the center. The pressure taps on either side of the diaphragm also provide support for mounting the probe. Position the long axis of the probe along the centerline of the duct. Connect the taps to a pressure transducer which can detect pressure differences as small as 0.25 Pa (0.001 in. of water).

7.3.2.4 Measure the mass flow rate as indicated in Annex A4.

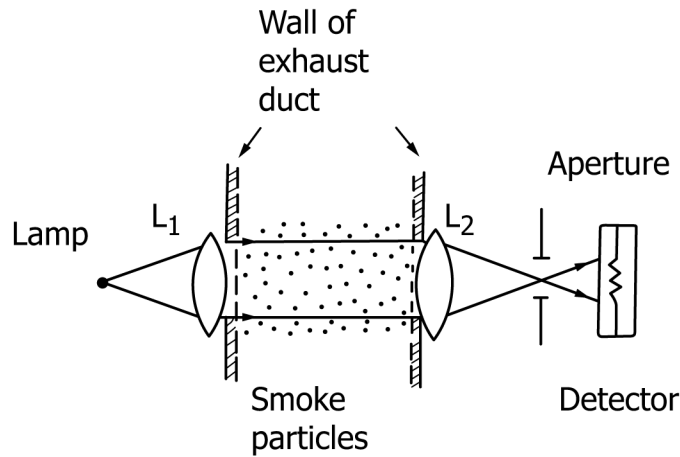


FIG. 3 Optical System

7.3.2.5 Measure gas temperatures in the vicinity of the probe with Inconel sheathed Chromel-Alumel thermocouples. Ensure that the thermocouple does not disturb the flow pattern around the bidirectional probe. Further details are discussed in A1.3.

7.4 Smoke Obscuration Measurements:

7.4.1 Install an optical system for measurement of light obscuration across the centerline of the exhaust duct. Determine the optical density of the smoke by measuring the light transmitted with a photometer system consisting of a white light source and a photocell/detector or a laser system for measurement of light obscuration across the centerline of the exhaust duct. Locate the system so that it is preceded by at least eight diameters of duct without bends, to ensure a nearly uniform velocity across the duct section. If the system is positioned at a different location, demonstrate the achievement of equivalent results.

7.4.2 One photometer system found suitable consists of a lamp, lenses, an aperture and a photocell (see Fig. 3 and Annex A3). Construct the system so that soot deposits on the optics during a test do not reduce the light transmission by more than 5 %.

7.4.2.1 Alternatively, instrumentation constructed using a 0.50.5 mW to 2.0 mW helium-neon laser, instead of a white light system is also acceptable. See Fig. 4 and Annex A3 for further details. White light and laser systems give similar results (1-5)⁸.

7.5 Combustion Gas Analysis:

7.5.1 Sampling Line:

7.5.1.1 Construct the sampling line tubes using a material which is not affected by the combustion gas species, thereby influencing the concentration of the combustion gas species to be analyzed. The recommended sequence of the gas train is: sampling probe, soot filter, cold trap, gas path pump, vent valve, plastic drying column and carbon dioxide removal columns (if used), flow controller and oxygen analyzer. Each analyzer in the gas train shall also include appropriate spanning and zeroing facilities.

7.5.1.2 Locate the sampling probe in a position where the exhaust duct flow is well mixed. Use a probe with a cylindrical cross section to minimize disturbance of the air flow in the duct. Collect the gas samples along the whole diameter of the exhaust duct.

7.5.1.3 Manufacture the sampling line, see Fig. 5, from corrosion resistant material, for example polytetrafluoroethylene. Remove the particulates contained in the combustion gases with inert filters to the degree required by the gas analysis equipment. Preferably filter the gases in more than one step. Cool the gas mixture to a maximum of $\pm 10^{\circ}\text{C}$ and dry the gas samples completely before the smoke reaches each analyzer.

7.5.1.4 Use a pump for the combustion gases which does not allow the gases to contact oil, grease or similar products, all of which can contaminate the gas mixture. A membrane pump is suitable.

⁸ The boldface numbers in parentheses refer to the list of references at the end of this test method.

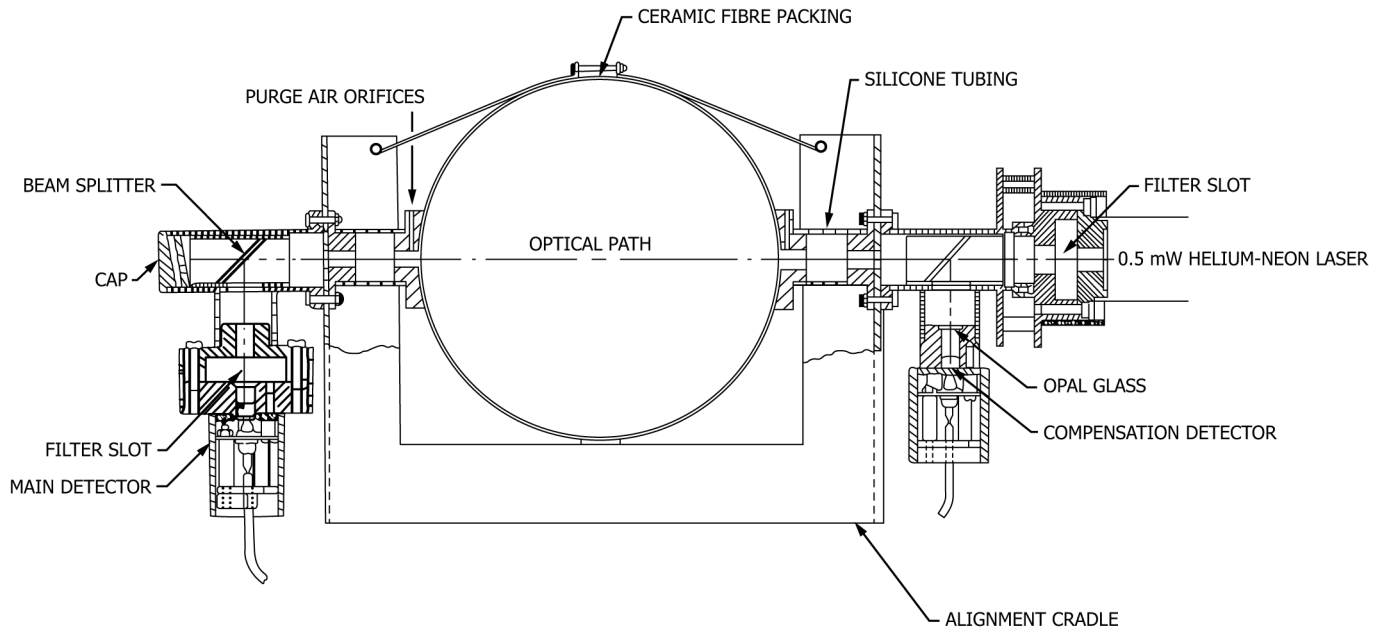


FIG. 4 Laser Extinction Beam

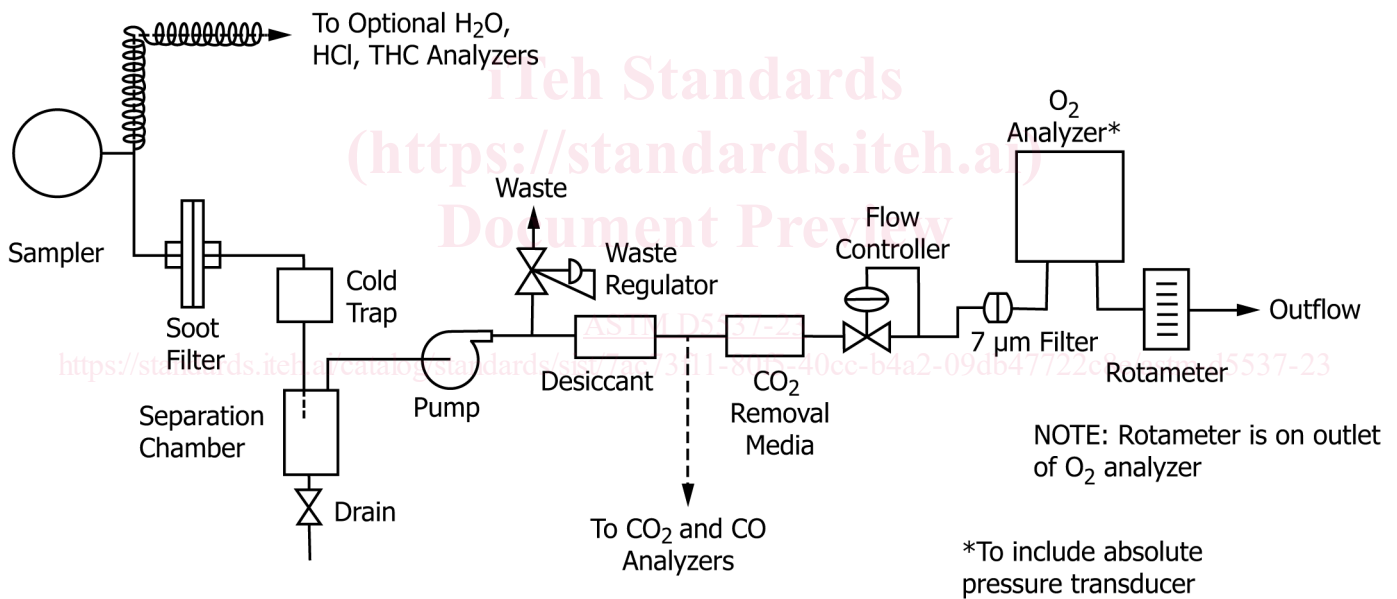


FIG. 5 Schematic Diagram of Gas Analysis System

7.5.1.5 A suitable sampling probe is shown in Fig. 6. This sampling probe is of the bar type. Ring type sampling probes are also acceptable, although they do not collect gas samples across the full diameter of the duct. The sampling line is shown in Fig. 5. A suitable pump has a capacity of $40\text{--}10\text{ L min}^{-1}$ to 50 L min^{-1} at 10 kPa (minimum), as each gas analysis instrument consumes about 1 L min^{-1} . A pressure differential of at least 10 kPa, as generated by the pump, reduces the risk of smoke clogging of the filters. Turn the intake of the sampling probe downstream to avoid soot clogging the probe.

7.5.1.6 Install a soot filter, capable of removing all particles $>25\mu\text{m}$ in size.

7.5.1.7 A refrigerated column is the most successful approach to cool and dry the gases. Provide a drain plug to remove the collected water from time to time. Alternative devices are also acceptable.

7.5.1.8 If carbon dioxide is to be removed, it is important to use carbon dioxide removal media, as indicated in Fig. 5.

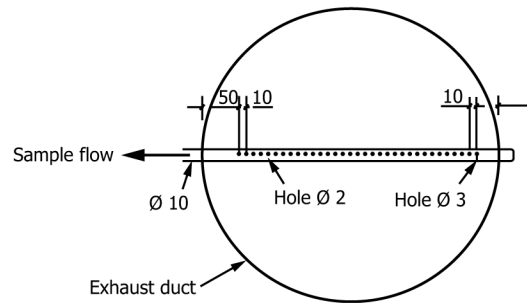


FIG. 6 Sampling Probe

7.5.2 Oxygen Measurement:

7.5.2.1 Measure the oxygen concentration with an accuracy of at least $\pm 0.04\%$ of full scale in the output range of 0 to 21 vol % oxygen, or ± 0.01 vol % oxygen, in order to have adequate measurements of rate of heat release. Take the combustion gas sample from the end of the sampling line. Calculate the time delay, including the time constant of the instrument, from the test room; it is a function of the exhaust duct flow rate. This time delay shall not exceed 60 s.

7.5.2.2 Use an oxygen analyzer, meeting the specifications of 7.5.2.1, preferably of the paramagnetic type.

7.6 Cable Tray:

7.6.1 Use a steel ladder cable tray, $300\text{ mm} \pm 25\text{ mm}$ ($12\text{ in.} \pm 1\text{ in.}$) wide, $75\text{ mm} \pm 6\text{ mm}$ ($3\text{ in.} \pm 0.25\text{ in.}$) deep, and $2440\text{ mm} \pm 25\text{ mm}$ ($8\text{ ft} \pm 1\text{ in.}$) long. Arrange the tray so that the burner flame will impinge on the cables midway between rungs.

7.6.1.1 Each rung in the tray is to measure $25\text{ mm} \pm 6\text{ mm}$ ($1\text{ in.} \pm 0.25\text{ in.}$) in the direction parallel to the length of the tray and $13\text{ mm} \pm 3\text{ mm}$ ($0.5\text{ in.} \pm 0.125\text{ in.}$) in the direction parallel to the depth of the tray.

7.6.1.2 Space the rungs $230\text{ mm} \pm 13\text{ mm}$ ($9\text{ in.} \pm 0.5\text{ in.}$) apart (measured center to center).

7.6.1.3 Attach the rungs to the side rails.

7.6.1.4 Mount the cable tray vertically in the center of the enclosure. Position the tray on a tray base (stand) which is to be no higher than $150\text{ mm} \pm 25\text{ mm}$ ($6\text{ in.} \pm 1\text{ in.}$).

7.7 Burner:

7.7.1 Use a 254 mm (10-in.) strip or ribbon type propane gas burner with an air/gas Venturi mixer.

7.7.2 The flame producing surface of the burner consists essentially of a flat metal plate that is 341 mm ($13\frac{7}{16}\text{ in.}$) long and 30 mm ($1\frac{5}{32}\text{ in.}$) wide. The plate has an array of 242 holes drilled in it. The holes are 1.35 mm (metric drill size: 1.35 mm) or 0.052 in. (No. 55 drill) in diameter, on 3.2 mm (0.125 in.) centers in three staggered rows of 81, 80, and 81 holes each, to form an array measuring 257 mm ($10\frac{1}{8}\text{ in.}$) by 5 mm ($\frac{3}{16}\text{ in.}$). Center the array of holes on the plate (see Fig. 7).

7.7.3 Protocol A:

7.7.3.1 Position the burner behind the cable tray containing the specimen, with the flame-producing surface (face) of the burner vertical and its long dimension horizontal and with the 257 mm ($10\frac{1}{8}\text{ in.}$) dimension of the array of holes spaced $76\text{ mm} \pm 5\text{ mm}$ ($3.0\text{ in.} \pm 0.2\text{ in.}$) from the specimens in the tray and centered midway between the side rails of the tray. Position the centerpoint of the array of holes at 460 mm (18 in.) above the bottom end of the tray and specimen and midway between two rungs. Support the burner in a manner that allows its quick removal and precise repositioning of the burner to the position described. The tray faces the door.

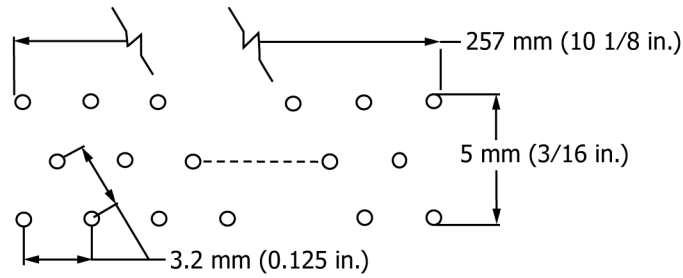


FIG. 7 Burner Holes

7.7.4 Protocol B:

7.7.4.1 Mount the burner on a stand and place it $20^{\circ} \pm 2^{\circ}$ from the horizontal with the burner ports up, in front of the cable tray. Locate the major axis of the burner ports 305 ± 25 mm (12 ± 1 in.) above the base of the cable tray and parallel to the cable tray rungs during the fire test (Fig. 8). The tray faces away from the door.

7.7.4.2 Attach a guide to the burner or stand such that the leading edge of the burner face is located quickly and accurately 75 ± 5 mm (3 ± 0.2 in.) horizontally away from the nearest surface of the cables during the burn period of the test.

7.7.5 Insert a flowmeter in both the propane and the air lines feeding the burner to measure the flow rates of these gases during the test.

7.7.6 Use a propane flowmeter capable of measuring at least $230 \text{ cm}^3 \text{ s}^{-1}$ ($29 \text{ ft}^3 \text{ h}^{-1}$) and an air flowmeter of at least $1330 \text{ cm}^3 \text{ s}^{-1}$ ($170 \text{ ft}^3 \text{ h}^{-1}$). Make flow rate measurements with an accuracy of $\pm 3\%$. Mass flow controllers with recordable outputs are permitted alternatives.

7.7.7 Supply compressed air to the burner, either bottled or from a compressed air system. Filter the air supply sufficiently so as to eliminate any contaminants that might affect the test results.

7.7.8 Use air with a dew point no greater than 0°C (32°F), as measured by a dew point measuring device.

7.7.9 Use CP grade propane (99 % pure), having a heat content of approximately 50.8 MJ kg^{-1} ($21.7 \text{ k Btu lb}^{-1}$) (93.0 MJ m^{-3} at 20°C , 101 kPa), for the burner.

7.7.10 Use a propane flow rate of $220 \pm 8 \text{ cm}^3 \text{ s}^{-1}$ ($28 \pm 1 \text{ ft}^3 \text{ h}^{-1}$) when corrected to standard temperature and pressure (20°C , 101 kPa). This propane flow will provide a theoretical heat output of 20 kW (approximately 70 000 Btu h^{-1}). The actual heat output is less, due to incomplete combustion of the propane at the burner. Accurate flow rates of propane gas are calculated using the mass flow rate equations.

7.7.11 Use an air flow rate to the burner of $1280 \pm 80 \text{ cm}^3 \text{ s}^{-1}$ ($163 \pm 10 \text{ ft}^3 \text{ h}^{-1}$) when corrected to standard temperature and pressure.

7.8 Mass Loss Measuring Device:

7.8.1 Use a mass measuring device, such as a load cell, to continuously measure the mass loss of the burning specimen.

7.8.2 The mass measuring device needs to measure the specimen mass with an accuracy of at least ± 45 g (1.6 oz) up to at least 90 kg (198 lb) of specimen mass. Install it in such a way that the heat from the burning specimen and any eccentricity of the load does not affect the accuracy. Avoid range shifts during measurements. Protect all parts of the weight measuring device by a thermal barrier.

7.8.3 There are two alternative locations for the mass measuring device, as described in 7.8.4 – 7.8.6.

7.8.4 Alternative 1—Place the mass measuring device under a platform, with a thermal barrier of dimensions 0.3 ± 0.05 m by 0.3 ± 0.05 m ($1 \text{ ft} \pm 2$ in. by $1 \text{ ft} \pm 2$ in.) $0.3 \text{ m} \pm 0.05 \text{ m}$ by $0.3 \text{ m} \pm 0.05 \text{ m}$ ($1 \text{ ft} \pm 2$ in. by $1 \text{ ft} \pm 2$ in.) and of a non-combustible

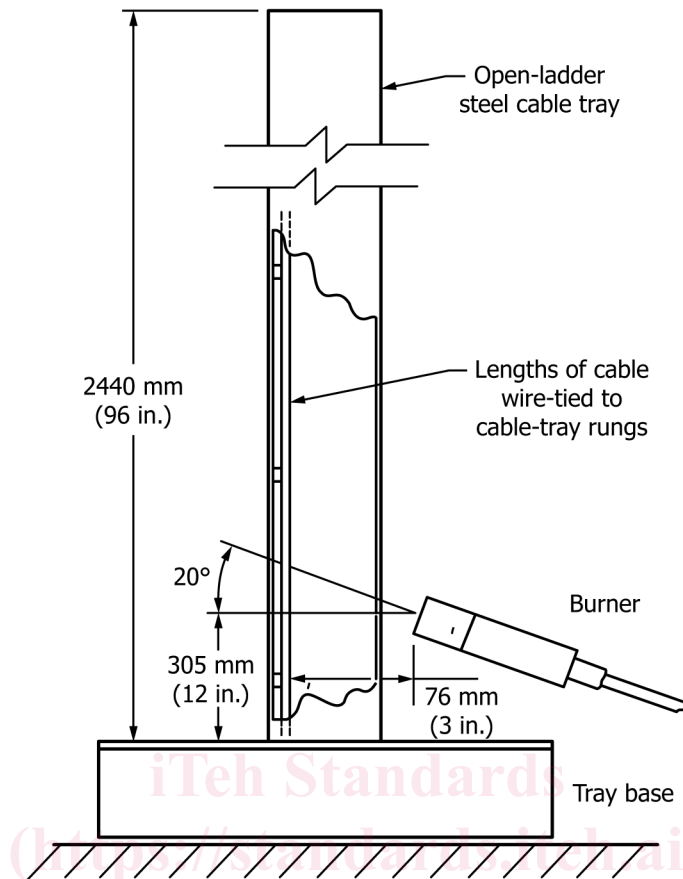


FIG. 8 Protocol B Cable Tray

material, for example calcium silicate boards. Provide the platform with sides of $0.1 \text{ m} \pm 10 \text{ mm}$ ($4 \pm 0.4 \text{ in.}$) ($4 \text{ in.} \pm 0.4 \text{ in.}$) height in order to prevent melting or falling material from the tested specimens from falling off the thermal barrier.

7.8.5 Do not exceed 0.5 m (20 in.) from the upper surface of the thermal barrier to floor level. Shield the area between the thermal barrier and the floor level to avoid lifting forces due to fire induced air flow that could influence the measurement. Ensure that there are virtually no obstructions to the air supply for the test set-up.

7.8.6 *Alternative 2*—Place the mass measuring device in the hood and hang the cable tray from it. Thermal and combustion gas protection of the mass measuring equipment is still required.

7.8.7 Place a square galvanized steel platform under the cable tray. The platform shall be constructed of nominally 1.6 mm ($\frac{1}{16}$ in.) thick steel, and have dimensions of no less than $\pm 0.1.0 \text{ m}$ by 1.0 m (approximately 39 in. by 39 in.), with a uniform raised lip, 100 mm (approximately 4 in.) high, on each side, to catch falling material. The platform shall be covered by a tight fitting sheet of standard gypsum board, of nominally 13 mm (0.5 in.) thickness. The platform shall protect the load cell, if it is placed underneath the cable tray. The gypsum board shall be clean before the start of a test. If the sheet used has been damaged it shall be replaced.

NOTE 2—A square galvanized steel platform of dimensions of up to 1.22 m by 1.22 m (approximately 44 ft by 4 ft) with a raised lip is also acceptable.

7.9 Cable Mounting:

7.9.1 *Protocol A*—Fasten ~~2440 ± 10 mm~~ $2440 \text{ mm} \pm 10 \text{ mm}$ ($96 \text{ in.} \pm 0.5 \text{ in.}$) specimen lengths of finished cable in a single layer in the tray by means of steel or copper wire, not larger than ~~2.1 mm~~ 2.1 mm^2 (14 AWG) in cross section, at their upper and lower ends and at two other equally spaced points along their lengths, with each cable vertical. Install as many specimens in the tray as will fit, spaced one half cable diameter apart, to fill the center 150 mm (6 in.) of the tray width.

7.9.1.1 Determine the number of specimen lengths for test using Eq 1:

TABLE 1 Tray Loading for Circular Cables Smaller than 13 mm (0.5 in.) in Diameter

Cable Diameter, mm		Number of Cables in Each Bundle	Number of Bundles in Tray
From	But Less Than		
11	13	3	7
9	11	3	8
6	9	3	10
5	6	7	9
3	5	19	8
0	3	19	13

$$N = [(4 \times 25.4) / D] + 0.33 \quad (1)$$

where:

N = number of cables (rounded up to the nearest whole number), and
 D = diameter of the cable, mm.

7.9.2 *Protocol B*—Fasten ~~2440~~2440 mm \pm 10 mm (~~96 \pm 0.5 in.~~) (96 in. \pm 0.5 in.) specimen lengths of finished cable in the tray. Depending upon the outside diameter of the individual cables, the test specimen is to be either an individual length or a bundle of individual lengths. Center the specimens or specimen bundles in a single layer between the side rails of the cable tray. Ensure that the lower end of each specimen is no more than 100 mm (4 in.) above the bottom end of the cable tray. Attach each individual specimen or bundle of specimens separately to each rung of the cable tray using one wrap of a copper or steel wire tie not larger than 2.1 mm² (14 AWG) in diameter.

7.9.2.1 For cables smaller in diameter than 13 mm (0.5 in.), group the specimens into untwisted bundles (nominally circular) as shown in **Table 1**. Space the bundles one-half bundle diameter apart on the cable tray as measured at the point of attachment to the cable tray.

7.9.2.2 For cables 13 mm (0.5 in.) in diameter and larger, attach the individual specimens to the cable tray with spacings of 1/2 cable diameter, except do not exceed a spacing of 15 mm (0.6 in.). **Table 2** shows the tray loading.

7.9.3 On flat cables, calculate the equivalent cable diameter using **Eq 2**

$$D = 1.128 \times \sqrt{(T \times W)} \quad (2)$$

where:

D = calculated equivalent cable diameter,
 T = minor axis of the cable, and
 W = major axis of the cable.

8. Calibration

8.1 Calibrate all instruments carefully with standard sources after initial installation. Among the instruments to be calibrated are load cells or weighing platforms, smoke meters, flow or velocity transducers, and gas analyzers. Perform recalibration tests on the entire system, for example using standard output burners.

8.2 Heat Release:

8.2.1 Perform the calibration of the heat release instrumentation in the exhaust duct by burning propane gas and comparing the heat release rates calculated from the metered gas input, and those calculated from the measured oxygen consumption. The value of net heat of combustion for propane is 46.5 MJ/kg. Position the burner in the same location that the cable tray will occupy during the test. Measure the gas flow rate at a pressure of ~~10~~101 kPa \pm 5 kPa (standard atmospheric pressure, measured at the flow gage) and a temperature of ~~20 \pm 5°C~~ 20 °C \pm 5 °C. Use **Eq A5.7** for calculation of heat release rate during calibration.

8.2.2 Obtain a minimum of two calibration points. Obtain a lower heat release rate value of 40 kW and then a higher heat release rate value of 160 kW. Approximate propane flow rates for any required heat release rate value are estimated using the following