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

## 2000 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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**NFPA 286**

**Standard Methods of**

# Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth

**2000 Edition**

This edition of NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Walls and Ceiling Interior Finish to Room Fire Growth*, was prepared by the Technical Committee on Fire Tests and acted on by the National Fire Protection Association, Inc., at its November Meeting held November 14–17, 1999, in New Orleans, LA. It was issued by the Standards Council on January 14, 2000, with an effective date of February 11, 2000, and supersedes all previous editions.

This edition of NFPA 286 was approved as an American National Standard on February 11, 2000.

## Origin and Development of NFPA 286

This is the first edition of this standard. This document was developed in response to activities associated with the regulation of interior finishes in NFPA *101*®, *Life Safety Code*®. The Fire Safety Technical Committee on Furnishings and Contents had proposed modifications to NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, for the 1997 edition of NFPA *101*. These modifications would have established a test protocol that was not appropriate to the scope of NFPA 265. The NFPA 286 standard addresses those concerns associated with interior finishes that do not remain in place during testing to NFPA 255 test protocols.

The provisions and application of NFPA 265 will be reviewed in the near future, with the possible intention of incorporating in NFPA 286 those materials currently being tested to NFPA 265. The reason is that there are differences in burner placement and fuel flow.

## Technical Committee on Fire Tests

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Rep. Society of the Plastics Industry Inc.
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**Alfred J. Hogan,** Reedy Creek Improvement District, FL [E]
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**Peter J. Gore Willse,** HSB Industrial Risk Insurers, CT [I]

### Alternates

**Kenneth G. Adams,** The Society of the Plastics Industry, DC [M]
(Alt. to J. A. Blair)
**Robert G. Bill, Jr.,** Factory Mutual Research Corp., MA [I]
(Alt. to D. K. Tanaka)
**Delbert F. Boring, Jr.,** American Iron & Steel Inst., OH [M]
(Alt. to R. J. Wills)
**Tony Crimi,** Underwriters Laboratories of Canada, ON, Canada [RT]
(Alt. to J. Roberts)
**Philip J. DiNenno,** Hughes Assoc., Inc., MD [SE]
(Alt. to J. J. Beitel)
**Sam W. Francis,** American Forest & Paper Assn., PA [M]
(Alt. to K. Sumathipala)
**Richard G. Gann,** U.S. Nat'l Inst. of Standards & Technology, MD [RT]
(Alt. to J. R. Lawson)
**Marc L. Janssens,** Southwest Research Inst., TX [RT]
(Alt. to J. R. Griffith)
**John W. Michener,** Milliken Research Corp., SC [M]
(Alt. to P. K. Adair)
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(Alt. to J. A. Milke)
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(Alt. to G. E. Lingenfelter)
**William A. Thornberg,** HSB Industrial Risk Insurers, CT [I]
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(Alt. to T. H. Talley)

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Rep. American Fiber Mfrs. Assn.
**Rohit Khanna,** U.S. Consumer Product Safety Commission, MD [C]
(Alt. to J. F. Hoebel)
**James C. Norris,** Couance Laboratories Ltd, UK [SE]
**Herman H. Spaeth,** Novato, CA
(Member Emeritus)

**Walter P. Sterling,** NFPA Staff Liaison

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## Contents

# NFPA 286

## Standard Method of

# Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth

## 2000 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Appendix A.

Information on referenced publications can be found in Chapter 10 and Appendix B.

## Chapter 1 General

### 1-1 Scope.

**1-1.1*** This standard describes a method for determining the contribution of interior finish materials to room fire growth during specified fire exposure conditions. This method shall be used to evaluate the flammability characteristics of wall and ceiling interior finish, other than textile wall coverings, where such materials constitute the exposed interior surfaces of buildings.

**1-1.2** This fire test method shall not be intended to evaluate the fire endurance of assemblies, nor shall it be able to evaluate the effect of fires that originate within a wall assembly.

**1-1.3** This standard specifies three types of specimen mounting, depending on the application of the interior finish material, as follows:

(1) Three walls (for interior finish to be used on walls only)
(2) Three walls and the ceiling (for interior finish to be used on walls and ceilings)
(3) The ceiling alone (for interior finish to be used on ceilings only)

### 1-2 Purpose.

**1-2.1** This method of test measures certain fire performance characteristics of interior finish materials in an enclosure under specified fire exposure conditions. It determines the potential extent to which the interior finish materials contribute to fire growth in a room, including the heat and smoke released, the combustion products released, and the potential for fire spread beyond the room, under the particular conditions simulated.

The method of test shall provide the following:

(1) Extent of fire growth in the fire test room
(2) Rate of heat release by the specimen
(3) Total heat released by the specimen
(4) Time to flashover in the fire test room if flashover occurs
(5) Time to flame extension beyond the doorway of the fire test room if flame extension occurs
(6) Total heat flux incident to the floor of the fire test room
(7) Upper level gas temperature in the fire test room
(8) Smoke obscuration, as determined in the exhaust duct
(9) Production of carbon monoxide, as determined in the exhaust duct
(10) Emissions of other combustion gases, as determined in the exhaust duct

**1-2.2** This method does not provide data that can be generalized to apply to rooms or spaces of different shapes, sizes, and ventilation. This method provides a general ranking of interior finish materials. The performance observed in the test shall be based on the test conditions. If a test specimen is exposed to a different environment, as in an actual fire, the performance of the specimen can be different.

**1-2.3** The method of test does not provide the following:

(1) Full information concerning toxicity of combustion gases
(2) Fire resistance of wall–ceiling systems

### 1-3 Summary of Method.

**1-3.1** The specimen shall be tested by using the ignition source described in 1-3.3. Ceiling finish materials shall be tested mounted on the ceiling only. For materials intended for use only as interior wall finish, the specimen shall be mounted on three walls of the fire test room. For materials intended for use as interior wall and ceiling finish, the specimen shall be mounted on three walls and on the ceiling of the fire test room.

**1-3.2** These methods shall use a gas burner to produce a diffusion flame to expose the walls in the corner of a fire test room 2.44 m × 3.66 m × 2.44 m (8 ft × 12 ft × 8 ft). The burner shall produce a prescribed rate of heat output, as described in 1-3.3. The contribution of the interior finish material to fire growth shall be measured by constant monitoring of the incident heat flux on the center of the floor, the temperature of the gases in the upper part of the fire test room, the rate of heat release, the smoke release, and the time to flashover. The test shall be conducted with natural ventilation to the fire test room provided through a single doorway that is 0.78 m × 2.02 m (30.75 in. × 79.50 in.). The combustion products shall be collected in a hood that feeds into a plenum connected to an exhaust duct in which measurements of the gas velocity, temperature, smoke obscuration, and concentrations of selected gases are made.

**1-3.3*** The ignition source shall be a gas burner that is capable of supplying a net rate of heat output of 40 kW for 5 minutes followed by 160 kW for 10 minutes, for a total exposure period of 15 minutes.

**1-3.4** Flashover is determined to have occurred when any two of the following conditions have been attained:

(1) The heat release rate exceeds 1 MW.
(2) Heat flux at the floor exceeds 20 kW/m$^2$.
(3) The average upper layer temperature exceeds 600°C (1112°F).
(4) Flames exit the doorway.
(5) Autoignition of a paper target on the floor occurs.

### 1-4 Definitions.

**1-4.1 Average Upper Gas Layer Temperature.** The temperature based on the average of the four ceiling quadrant thermocouples and the center of the fire test room ceiling thermocouple.

**1-4.2 Shall.** Indicates a mandatory requirement.

**1-4.3 Should.** Indicates a recommendation or that which is advised but not required.

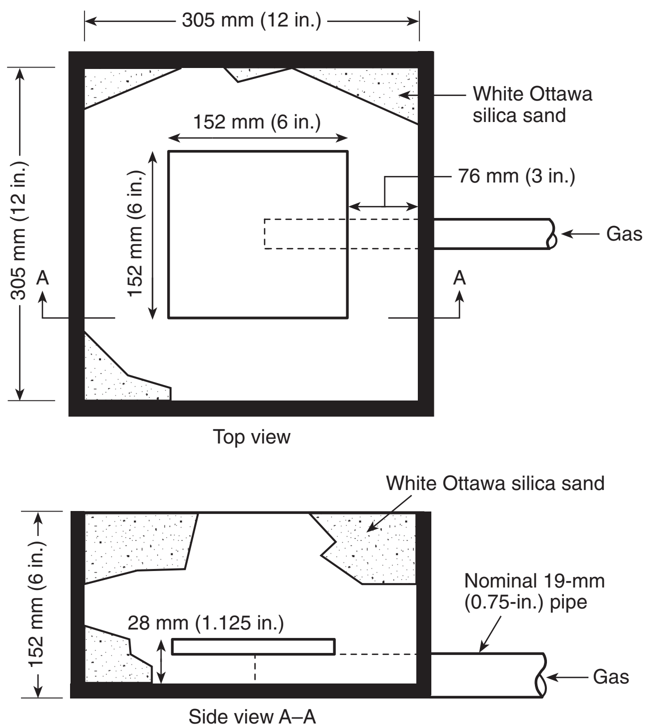
**1-4.4 Standard.** A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

## Chapter 2 Test Equipment

**2-1 Ignition Source.**

**2-1.1*** The ignition source for the test shall be a gas burner with a nominal 305 mm × 305 mm (nominal 12 in. × 12 in.) porous top surface of a refractory material, as shown in Figure 2-1.1. This refractory material, through which the gas is supplied, shall be a nominal 25 mm (nominal 1 in.) thick porous ceramic fiberboard over a 152 mm ± 5 mm (6 in. ± 0.2 in.) plenum. Alternatively, a minimum 102-mm (4-in.) layer of Ottawa sand shall be permitted to be used to provide the horizontal surface through which the gas is supplied. The burner with a layer of sand shall be used for samples with a potential for dripping.

**FIGURE 2-1.1 Gas burner.**




**2-1.2** The top surface of the burner through which the gas is applied shall be located horizontally 300 mm ± 50 mm (12 in. ± 2 in.) above the floor. The burner enclosure shall be in contact with both walls in a corner of the fire test room, opposite from the door. The edge of the diffusion surface shall be located 25 mm ± 0.3 mm (1.0 in. ± 0.1 in.) from the wall.

**2-1.3** The gas supply to the burner shall be of C.P. grade propane (99 percent purity). Flow rates of gas shall be calculated using a net heat of combustion of propane of 85 $MJ/m^3$ (2280 $Btu/ft^3$) at standard conditions of 101 kPa (14.7 psia) pressure and 20°C (68°F) temperature. The gas flow rate shall be metered throughout the test, with an accuracy of at least ±3 percent. The heat output to the burner shall be controlled within ±5 percent of the prescribed value.

**2-1.4*** The gas supply to the burner shall produce a net heat output of 40 kW ± 1 kW for the first 5 minutes, followed by a net heat output of 160 kW ± 5 kW for the next 10 minutes.

**2-1.5** The burner design shall allow switching from the first fixed net heat output to the second fixed net heat output within 10 seconds. The gas flow rate shall be switched from a net heat output of 40 kW to one of 160 kW.

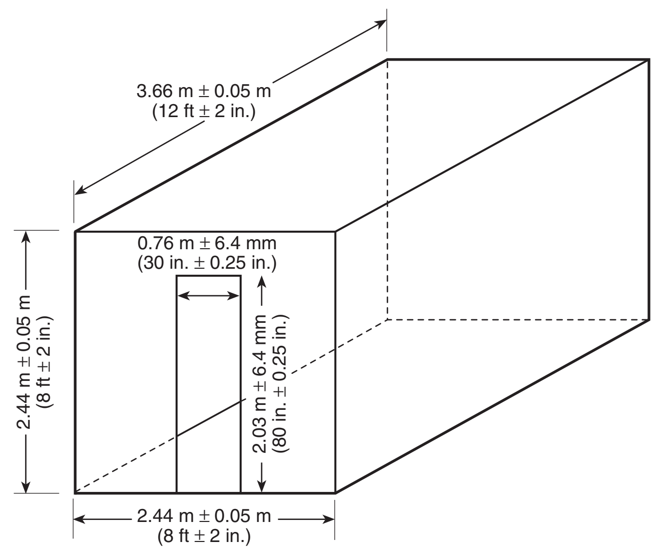
**2-1.6** Burner controls shall be provided for automatic shutoff of the gas supply if flameout occurs.

**2-1.7** The burner shall be ignited by a pilot burner or a remotely controlled spark igniter.

**2-2 Geometry and Construction of the Fire Test Room.**

**2-2.1*** The interior dimensions of the floor of the fire test room, when the specimens are in place, shall be as shown in Figure 2-2.1 and shall measure 2.44 m ± 0.05 m × 3.66 m ± 0.05 m (8 ft ± 2 in. × 12 ft ± 2 in.). The finished ceiling shall be 2.44 m ± 0.05 m (8 ft ± 2 in.) above the floor. There shall be four walls at right angles defining the fire test room.

**FIGURE 2-2.1 Interior fire test room dimensions and interior doorway dimensions.**




**2-2.2*** The fire test room shall be placed indoors in a draft-free, heated space that is large enough to ensure that the surroundings do not influence the test fire.

**2-2.3** There shall be a 0.78 m ± 0.02 m × 2.02 m ± 0.02 m (30.75 in. ± 0.75 in. × 79.50 in. ± 0.75 in.) doorway in the center of one of the 2.44 m × 2.44 m (8 ft × 8 ft) walls, and there shall be no other wall, floor, or ceiling openings that allow ventilation.

**2-2.4*** The fire test room shall be a framed (with wood or metal studs) or concrete block structure. The inside surface of the walls, ceiling, and floor shall be of calcium silicate board of 500–800 $kg/m^3$ (31–50 $lb/ft^3$) density and shall be at least 12 mm (nominally 0.5 in.) in nominal thickness or shall be of fire-rated (type X) gypsum wallboard that is at least 12 mm (nominally 0.5 in.) in nominal thickness.

**2-2.5** The door frame shall be constructed such that it remains unchanged during the test period to a tolerance of ±1 percent in height and width.

## Chapter 3 Specimen Mounting

### 3-1 Specimen Mounting.

**3-1.1*** Test specimens shall be mounted on a framing or support system that is comparable to that intended for their actual field use, using substrates, backing materials, insulation, or air gaps as appropriate to the intended application, and representing a typical value of thermal resistance for the wall system. If a manufacturer specifies the use of an adhesive, then specimens shall be mounted using the adhesive and the application rate specified by the manufacturer and shall be comparable to actual field installations.

**3-1.2*** Mounting methods shall be grouped according to materials to be tested, which are described either by usage or by form of the material. These mountings shall be described for test method uniformity and for good laboratory practice. They shall not imply restriction in the specific details of field installation. The mountings shall be used for general material testing for which the specific details of the field installation either have not been established or are so broad that any single installation method is not representative of the full range of installation possibilities.

**3-1.3** Where an interior finish material exhibits a distinct direction, the sample shall be mounted such that the distinct direction is vertical, unless the manufacturer indicates that a different method of mounting will be used in actual installations.

**3-1.4** If the product to be tested is in panel form, the standard dimensions (width, length, and thickness) of the panels shall be used. If panels are tested in a different fashion, the rationale for the change shall be stated in the report.

**3-1.5** A detailed description of the mounting method used shall be given in the test report. If a special mounting technique is used in order to improve the physical behavior of the specimen during the test, it shall be clearly stated in the report.

### 3-2 Materials Using Substrates.

**3-2.1** Thin surface materials, thermoplastic products that melt, paints, and varnishes shall be applied, depending on their end use, to one of the substrates identified in 3-2.1.1 through 3-2.1.2. When mounted on substrates described in 3-2.1.1 and 3-2.1.2, materials that use studs for support in an actual installation shall not be required to incorporate studs and the associated airspace in the test specimen.

**3-2.1.1** The following substitutes shall be acceptable:

(1) Noncombustible fiber-reinforced silicate board with a dry density of 680 kg/m$^3$ ± 50 kg/m$^3$ (42 lb/ft$^3$ ± 3 lb/ft$^3$), at a thickness of between 9 mm and 13 mm ($^3/_8$ in. and $^1/_2$ in.)
(2) Noncombustible board with a dry density of 1650 kg/m$^3$ ± 150 kg/m$^3$ (103 lb/ft$^3$ ± 9 lb/ft$^3$), at a thickness between 9 mm and 13 mm ($^3/_8$ in. and $^1/_2$ in.)
(3) Ordinary particle board with a density of 680 kg/m$^3$ ± 50 kg/m$^3$ (42 lb/ft$^3$ ± 3 lb/ft$^3$) at normal conditioning atmosphere of 50 ± 5 percent relative humidity and 23°C ± 2°C (73°F ± 4°F) temperature, at a thickness of between 9 mm and 13 mm ($^3/_8$ in. and $^1/_2$ in.)
(4) *Gypsum wallboard, complying with ASTM C 36, *Standard Specification for Gypsum Wallboard*, at a thickness between 12.7 mm and 15.9 mm ($^1/_2$ in. and $^5/_8$ in.)

**3-2.1.2*** Other substrates shall be acceptable if the end use of the product requires them. The use of such an alternative substrate shall be justified in the report.

**3-2.2** Paints and varnishes shall be applied to the appropriate substrate with the application rate specified by the sponsor.

**3-2.3** Coating materials, such as cementitious mixtures, mastic coatings, sprayed fibers, or similar materials, shall be mixed and applied to the substrate board as specified in the manufacturer's instructions at the thickness, coverage rate, or density recommended by the manufacturer.

**3-2.4** Coating intended for application to a wood surface shall be applied to a substrate as specified in 3-2.1.1(2).

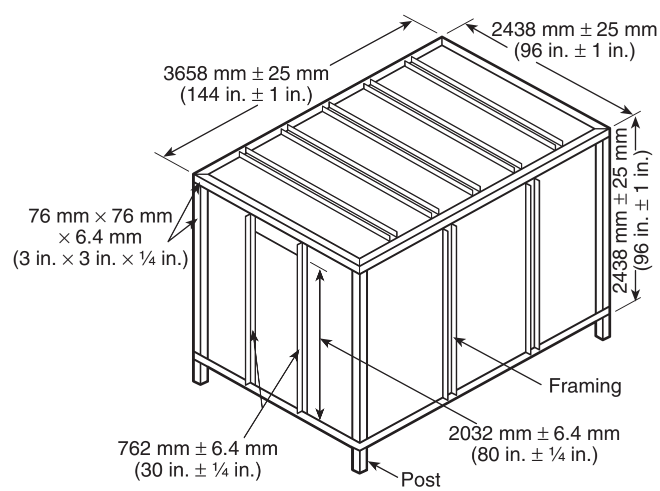
**3-2.5** Coating materials intended for application to specific combustible surfaces other than wood shall be applied to the specific surface for which they are intended. The coating material and combustible material shall be attached to the substrate board as specified in 3-2.1.

**3-2.6** Coating materials intended for application only to noncombustible surfaces shall be applied to a substrate as specified in section 3-2.1.1(1) or 3-2.1.1(2).

### 3-3 Backing Materials.

**3-3.1** All backing materials, when used, shall be supported on a framed support system as shown in Figure 3-3.1.

**FIGURE 3-3.1 Steel frame support system.**




**3-3.2** Whenever calcium silicate board or gypsum wallboard is specified as a backing substrate in subsequent paragraphs, the material shall be as described in 3-2.1. When metal screws in combination with washers and wing nuts are specified for fastening, they shall be standard 6.35 mm ($^1/_4$ in.) by 0.8 threads per mm [20 threads per in. (TPI)]; round-head steel machine screws, 6.35 mm ($^1/_4$ in.) by 0.8 threads per mm (20 TPI) steel wing nuts; and 50.8-mm (2-in.) outside diameter by 1.1 mm (0.044 in.) thick flat steel washers with a 7.1-mm ($^9/_{32}$-in.) inside diameter hole.

Fastening screws shall be installed as shown in Figure 3-3.2(a). The fastening pattern shall be as shown in Figure 3-3.2(b) for rigid wall materials, and in Figure 3-3.2(c) for flexible wall materials. The fastening pattern for all ceiling materials shall be as shown in Figure 3-3.2(d).

**FIGURE 3-3.2(a) Material fastening technique.**

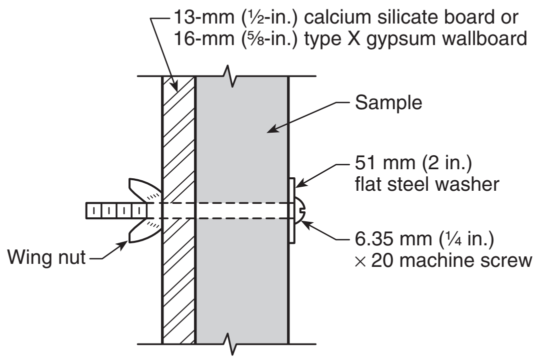



**FIGURE 3-3.2(b) Attachment details for rigid wall materials.**

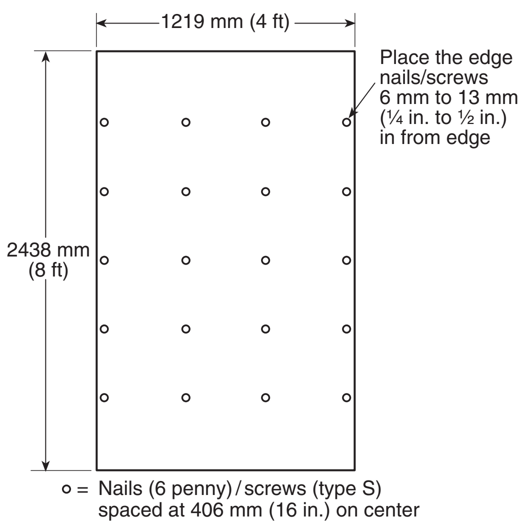



**FIGURE 3-3.2(c) Attachment details for flexible wall materials.**

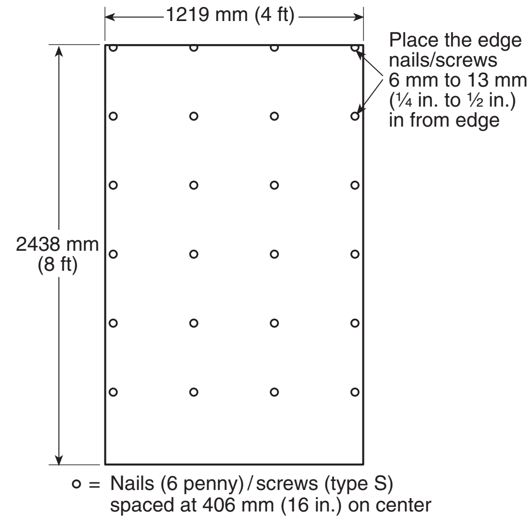
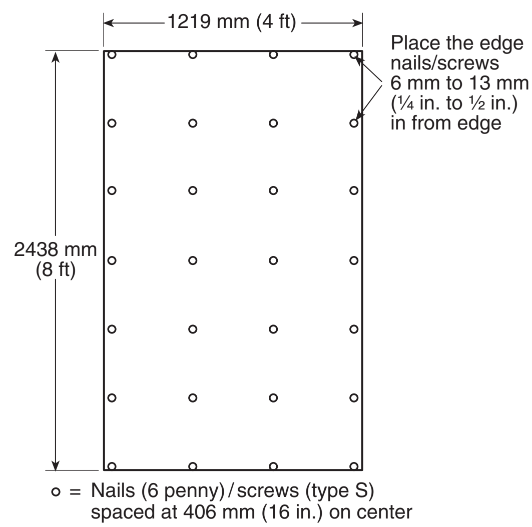



**FIGURE 3-3.2(d) Attachment details for ceiling materials.**




**3-4 Acoustical Materials and Other Board Materials.**

**3-4.1** Depending on the type of field mounting required by the acoustical product, either wood furring strips or metal runners shall be used to support acoustical material.

**3-4.2** Metal runners for mounting shall be attached to the substrate to replicate the field suspension systems application.

**3-4.3** Wood furring strips for mounting acoustical materials and other board materials shall be nominal 25 mm × 50 mm (1 in. × 2 in.) wood furring strips and attached to a substrate to replicate the field installation.

**3-5 Batt- or Blanket-Type Insulating and Other Flexible Materials.** Batt- or blanket-type and other flexible materials that do not have sufficient rigidity or strength to support themselves shall be supported by round-head machine screws in combination with wing nuts and flat washers, as specified in 3-3.2, which are inserted through the material in such a way as to fasten the material to a substrate board.

**3-6* Building Units.** If building units have sufficient structural integrity to support themselves, no additional mounting to a substrate board support shall be required. If the building units are of such construction that they require individual components that are not self-supporting, the component shall be fastened to the substrate board as specified in 3-3.2.

**3-7 Wall Covering Materials.** Wall coverings, such as vinyl coatings and wallpaper, shall be mounted on gypsum wallboard, as specified in 3-2.1.1(4), or shall be mounted on the actual substrate to which they shall be applied using the adhesive and application technique specified by the manufacturer. Where a wall covering has a distinct directionality, the sample shall be mounted such that the machine direction is vertical, unless the manufacturer indicates that a different method of mounting will be used in actual installations.

**3-8 Ceiling Lining Materials.** Materials intended only for lining ceilings shall be mounted only on the ceiling.

**3-9 Specimen Installation.**

**3-9.1** For materials intended for use only as interior wall finish, the specimen shall be mounted to cover three walls completely but shall not be mounted on the wall containing the door. The specimens shall be mounted to cover fully both 2.44 m × 3.66 m (8 ft × 12 ft) walls and the 2.44 m × 2.44 m (8 ft × 8 ft) wall that does not contain the door.

**3-9.2** For materials intended for use as interior wall and ceiling finish, the specimen shall be mounted on all three walls, as stated in 3-9.1, and it shall also be mounted to cover the entire ceiling.

**3-9.3** For materials intended for use only as an interior ceiling finish and not to be installed on any of the walls of the fire test room, the specimen shall be mounted to cover the entire ceiling.

**3-10* Conditioning.** Prior to testing, the mounted specimen shall be conditioned to equilibrium in an atmosphere at a temperature of 21°C ± 3°C (70°F ± 5°F) and a relative humidity of 50 percent ± 5 percent. Equilibrium shall be considered to be reached when a representative piece of the specimen has achieved constant mass. Constant mass shall be considered to be reached when two successive weighing operations, carried out at an interval of 24 hours, do not differ by more than 0.1 percent of the mass of the test piece or by more than 0.1 g, whichever is greater.

Specimens shall be tested as soon as possible after removal from such conditions if test room conditions differ from those required in the first paragraph of this section *(see 4-1.3)*. The time between removal from the conditioning room and start of testing shall be reported.

## Chapter 4 Environmental Conditions

**4-1 Fire Test Room Environment.**

**4-1.1** The test building in which the fire test room is located shall have vents for the discharge of combustion products and shall have provisions for fresh air intake so that no oxygen-deficient air is introduced into the fire room during the test. Prior to the start of the test, the ambient air at the mid-height entrance to the fire test room shall have a velocity of less than 0.5 m/sec (100 ft/min) in any direction, as measured at a horizontal distance of 1 m ± 0.1 m (3.3 ft ± 0.3 ft) from the center of the doorway. The building shall be of adequate size so that there shall be no smoke accumulation in the building below the level of the top of the fire test room.

**4-1.2** The ambient temperature in the test building at locations around the fire test room shall be in the range of 20°C ± 10°C (68°F ± 18°F), and the relative humidity shall be less than 75 percent for the duration of the test.

**4-1.3** If test specimens are installed within the fire test room for two or more hours prior to test, the following ambient conditions shall be maintained:

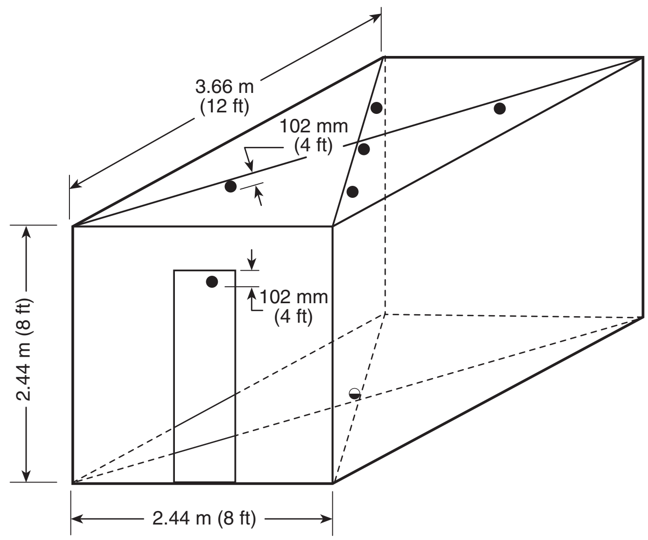
(1) The ambient temperature in the fire test room, measured by one of the thermocouples in 5-1.2.2, shall be in the range of 18°C–24°C (64°F– 75°F).
(2) The ambient relative humidity in the fire test room shall be 50 percent ± 5 percent.

## Chapter 5 Instrumentation

**5-1 Fire Test Room Instrumentation.** The instrumentation described in 5-1.1 through 5-1.4 shall be provided for this test.

**5-1.1* Heat Flux.** A total heat flux gauge (calorimeter) shall be mounted at a height of 26 mm ± 25 mm (1.1 in. ± 0.9 in.) above the floor surface, facing upward, in the geometric center of the fire test room, as shown in Figure 5-1.1.

**FIGURE 5-1.1 Thermocouple and calorimeter placement.**




● = Thermocouples — each 102 mm (4 in.) below ceiling, with one additional thermocouple over the burner, and 102 mm (4 in.) below the ceiling.

◒ = Calorimeter on floor — 26 mm (1.1 in.) above floor.

**5-1.1.1*** The gauge shall be of the Schmidt–Boelter (thermopile) type, with a full-scale design range of 50 kW/m$^2$. The gauge target shall be a circular flat surface that is not more than 15 mm (0.6 in.) in diameter and is coated with a durable matte black finish, having a view angle of 180 degrees. The target shall be contained within a water-cooled body in which the front face shall be of highly polished metal, flat, coinciding with the plane of the target, and circular, with a diameter of not more than 50 mm ± 2 mm (2 in. ± 0.1 in.). The heat flux gauge shall have an accuracy of at least ±3 percent and a repeatability within 0.5 percent. In operation, the heat flux gauge shall be maintained at a constant temperature, within 3°C (5°F) above the dew point, by water supplied at a temperature of 50°C–65°C (122°F–149°F).

**5-1.1.2** The calibration of the heat flux gauge shall be checked whenever required by comparison with two similar instruments held as reference standards and shall not be used for any other purpose. One of the reference standards shall be fully calibrated at yearly intervals.

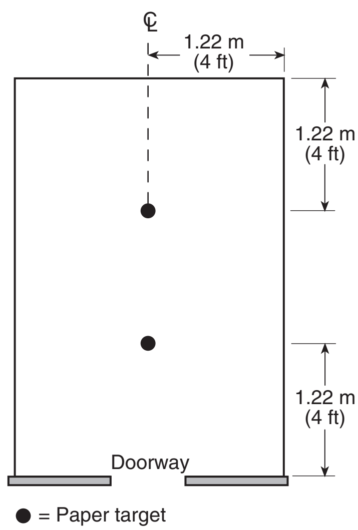
**5-1.2* Thermocouples.** Bare Type K Chromel–Alumel thermocouples, 0.50 mm ± 0.05 mm (20 mil ± 2 mil) in diameter, shall be used at each required location. The thermocouple wire, within 13 mm (0.5 in.) of the bead, shall be run along expected isotherms to minimize conduction errors. The insulation between the Chromel–Alumel wires shall be stable to at least 1100°C (2000°F), or the wires shall be separated.

**5-1.2.1** A thermocouple shall be located in the interior plane of the door opening on the door centerline, 10 mm ± 2 mm (4.0 in. ± 0.8 in.) below the top of the door opening, as shown in Figure 5-1.1.

**5-1.2.2** Thermocouples shall be located at six positions 10 mm ± 2 mm (4.0 in. ± 0.8 in.) below the ceiling. They shall be located at the center of the ceiling, at the center of each of the four ceiling quadrants, and directly over the center of the ignition burner. The thermocouples shall be mounted on supports or shall penetrate through the ceiling with their junctions 10 mm ± 2 mm (4.0 in. ± 0.8 in.) away from a solid surface as shown in Figure 5-1.1. There shall be no attachments to the test specimens. Any ceiling penetration shall be just large enough to permit passage of the thermocouples. Spackling compound or ceramic fiber insulation shall be used to backfill the holes around the thermocouple wire.

**5-1.3 Target Flashover Indicators.** Two paper target flashover indicators shall be placed on the floor of the test room, as shown in Figure 5-1.3. The targets shall consist of a single piece of newsprint crumpled into a ball approximately 150 mm (6 in.) in diameter.

**FIGURE 5-1.3 View of paper target arrangement.**




**5-1.4* Photographic Equipment.** Photographic equipment shall be used to record the spread of fire in the fire test room and the fire projection from the door of the fire test room. The location of the camera shall avoid interference with airflow. The interior wall surfaces of the fire test room adjacent to the corner in which the burner is located shall be clearly marked with a 0.3-m (12-in.) grid. A clock shall appear in all photographic records, showing the time to at least the nearest 1 second from the start of the test. This clock shall be synchronized with all other measurements, or other provision shall be made to correlate the photographic record with time. Color slides or photographs shall be taken at 15-second intervals for the first 3 minutes of the test and at least at 30-second intervals thereafter for the duration of the test. A continuous video recording shall also be made.

**5-2 Canopy Hood and Exhaust Duct.**

**5-2.1** A hood shall be installed immediately adjacent to the door of the fire test room, as shown in Figure 5-2.1(a). The bottom of the hood shall be level with the top surface of the fire test room. The face dimensions of the hood shall be at least 2.44 m × 2.44 m (8 ft × 8 ft), and the depth shall be 1.1 m ± 0.1 m (3.5 ft ± 4 in.). The hood shall feed into a plenum that has a 0.92 m ± 0.10 m × 0.92 m ± 0.1 m (3 ft ± 4 in. × 3 ft ± 4 in.) cross section, as shown in Figure 5-2.1(b). The plenum shall have a minimum height of 0.92 m (3 ft). This height shall be permitted to be increased to a maximum of 1.8 m (5 ft 11 in.) to satisfy building constraints. The exhaust duct connected to the plenum shall be horizontal and at least 406 mm (16 in.) in diameter, and it shall be permitted to have a circular aperture of at least 306 mm (12 in.) at its entrance or at mixing vanes in the duct.

**5-2.2*** The hood shall have the capability to collect all the combustion products leaving the fire test room.

**5-2.3*** An alternative exhaust system design shall be permitted to be used if it has been shown to produce equivalent results. The alternative draft system shall have shown equivalency by meeting the calibration requirements outlined in Chapter 6.

**5-3 Instrumentation in Exhaust Duct.**

**5-3.1 Exhaust Collection System.** The exhaust collection system shall be constructed with the following minimal requirements: blower, steel hood, duct, bidirectional probe, thermocouple(s), oxygen measurement system, smoke obscuration measurement system (white light photocell lamp/detector or laser), and combustion gas sampling and analysis system.

**5-3.2* Bidirectional Probe.** A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. A typical probe, shown in Figure 5-3.2, shall consist of a short, stainless steel cylinder that is 44 mm ± 1 mm long and of 22 mm ± 1 mm inside diameter (0.75 in. ± 0.625 in. long and 0.875 in. ± 0.625 in. inside diameter) with a solid diaphragm in the center. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall run along the centerline of the duct 3.35 m ± 0.1 m (11 ft ± 4 in.) (or at least 8 duct diameters for larger diameter ducts) downstream from the entrance.

**FIGURE 5-2.1(a) Canopy hood and exhaust duct.**

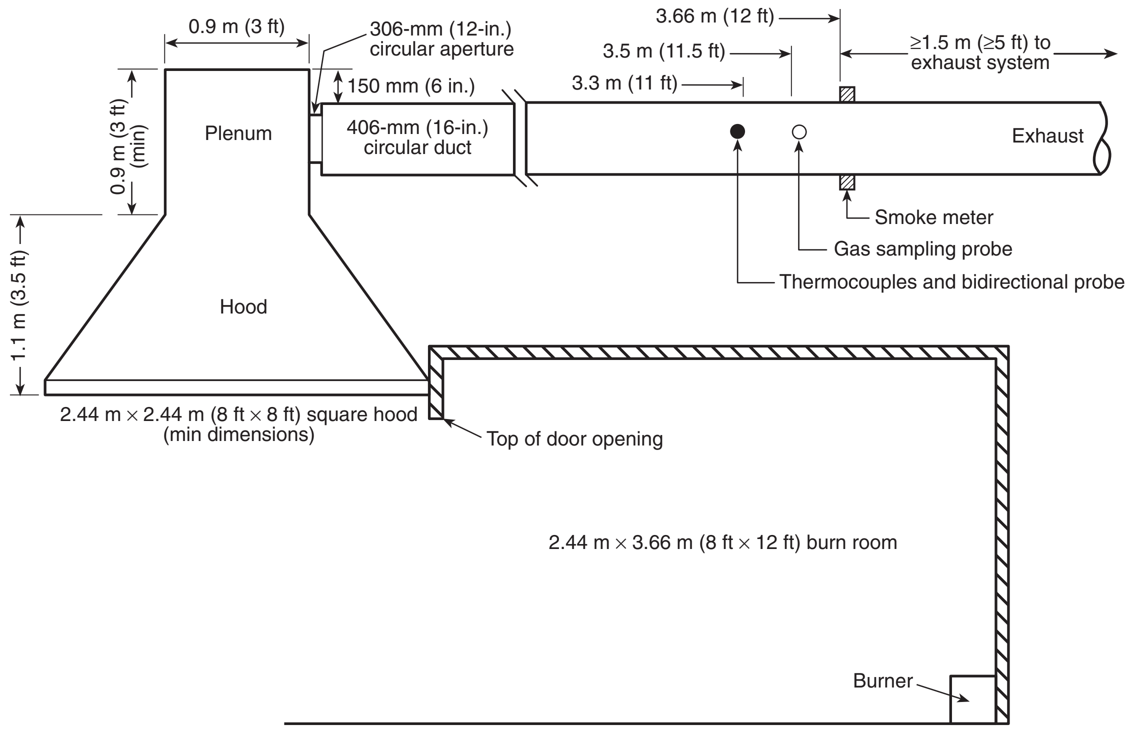
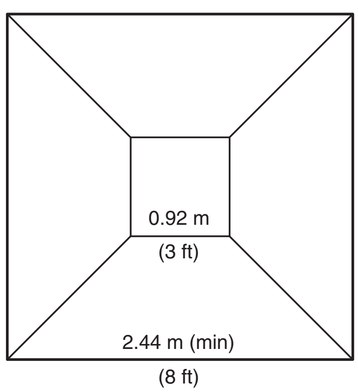


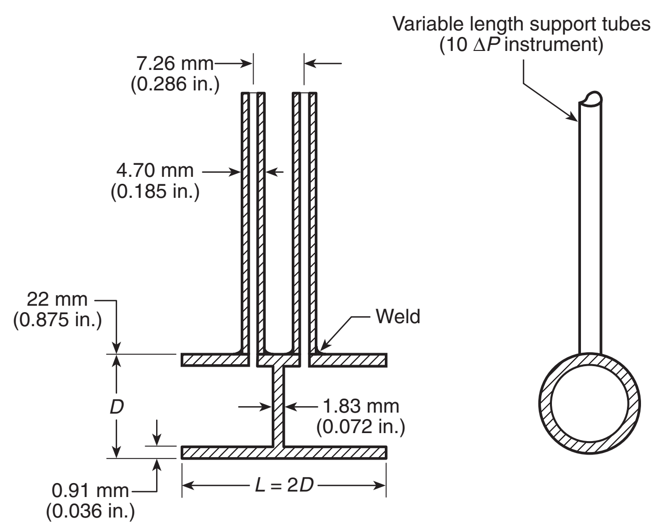

**FIGURE 5-2.1(b) Plan view of canopy head.**




**5-3.2.1*** The taps shall be connected to a pressure transducer that is able to resolve pressure differences of 0.25 Pa (0.001 psi $H_2O$). The response time to a stepwise change of the duct flow rate shall not exceed 5 seconds to reach 90 percent of the final value.

**5-3.2.2** One pair of thermocouples shall be placed 3.40 m ± 0.1 m (11 ft 2 in. ± 4 in.) (or at least 8 duct diameters for larger-diameter ducts) downstream of the entrance to the horizontal duct and 50 mm ± 5 mm (2.0 in. ± 0.2 in.) downstream from the axis of the probe. The pair of thermocouples shall straddle the center of the duct and be separated by 50 mm ± 5 mm (2 in. ± 0.2 in.) from each other *[see Figure 5-2.1(a).]*

**FIGURE 5-3.2 Bidirectional probe.**




**5-3.3* Sampling Line.** The sampling line tubes shall be constructed of a material not influencing the concentration of the combustion gas species to be analyzed. The following sequence of the gas train, as shown in Figure 5-3.3, shall be used: 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. The gas train shall also include appropriate spanning and zeroing facilities.

**5-3.3.1*** The cold trap, or cooling column, in the gas train shall be used to remove water from the combustion gases.

**5-3.3.2*** For each gas analyzer used, the system delay time (or time shift) for the analyzer to reach a 90 percent response to a step change in the gas concentration shall be determined before testing.

**5-3.4* Oxygen Concentration.** A gas sampling tube shall be located 3.5 m ± 0.1 m (11.5 ft ± 3 in.) (or at least 8 duct diameters for larger-diameter ducts) downstream from the entrance to the duct at the geometric center of the duct [to within 10 mm (0.4 in.) of the center] and 150 mm ± 5 mm (6 in. ± 0.2 in.) downstream from the axis of the probe. This gas sampling tube shall be used to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water.

The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring oxygen concentration in a range of 21 percent to 15 percent, with a relative accuracy of 100 ppm in this concentration range. The signal from the oxygen analyzer shall be within 5 percent of its final value and occur within 30 seconds of introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube. The oxygen analyzer shall include an absolute pressure transducer for gas pressure variations. There shall also be a rotameter on the outlet of the oxygen analyzer.

**5-3.5 Carbon Dioxide Concentration.** The gas sampling tube described in 5-3.4 or an alternative tube at the same location shall be used to provide a continuous sample for measuring the carbon dioxide concentration, using an analyzer with a range of 0 to 10 percent and a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds to reach a value within 5 percent of the final value, after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

**5-3.6 Carbon Monoxide Concentration.** The gas sampling tube described in 5-3.4 or an alternative tube at the same location shall be used to provide a continuous sample for measuring the carbon monoxide concentration, using an analyzer with a range of 0 to 1 percent and a maximum relative error of 2 percent of full scale. The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds to reach a value within 5 percent of the final value, after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

**5-3.7 Smoke Obscuration Measurement.**

**5-3.7.1*** An optical system shall be installed for measuring light obscuration across the centerline of the exhaust duct. The optical density of the smoke shall be determined by measuring the light transmitted with a photometer system consisting of a white light source and a photocell/detector or a laser system.

**5-3.7.2** The light beam used to measure smoke obscuration shall be horizontal.

**5-3.7.3*** A white light system shall consist of a lamp, lenses, an aperture, and a photocell, as shown in Figure 5-3.7.3. The system shall be constructed so that soot deposits on the optics during a test do not reduce the light transmission by more than 5 percent.

**5-3.7.4*** A helium–neon laser system shall consist of a helium–neon laser, silicon photodiodes as main beam and reference detectors, and electronics to derive an extinction and to set a zero reading, as shown in Figure 5-3.7.4(a). The system shall be designed for split yoke mounting in two pieces that are rigidly coupled together but resiliently attached to the exhaust duct by means of refractory gasketing. A 0.5 mW to 2.0 mW helium–neon laser beam shall be projected horizontally across the exhaust duct, as illustrated in Figure 5-3.7.4(b).

**FIGURE 5-3.3 Schematic of gas train.**

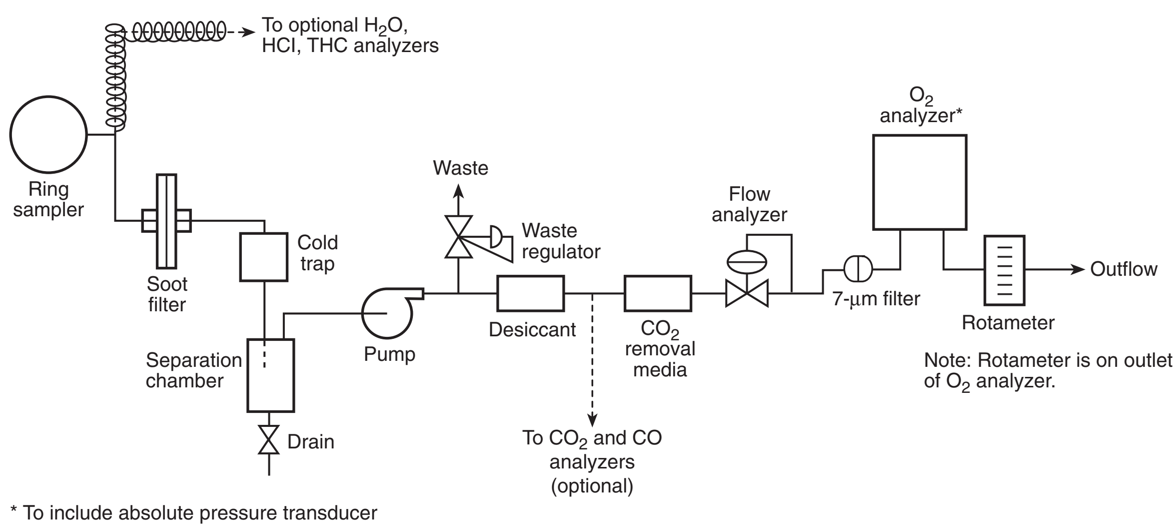


**FIGURE 5-3.7.3 Optical system, using a white light.**

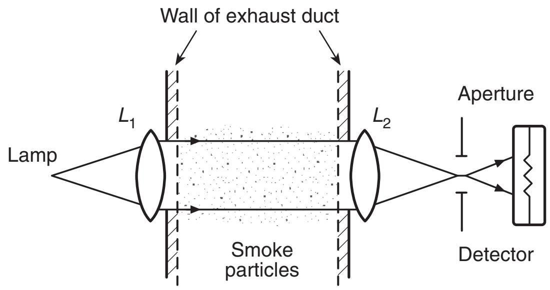



**FIGURE 5-3.7.4(a) Laser extinction beam.**

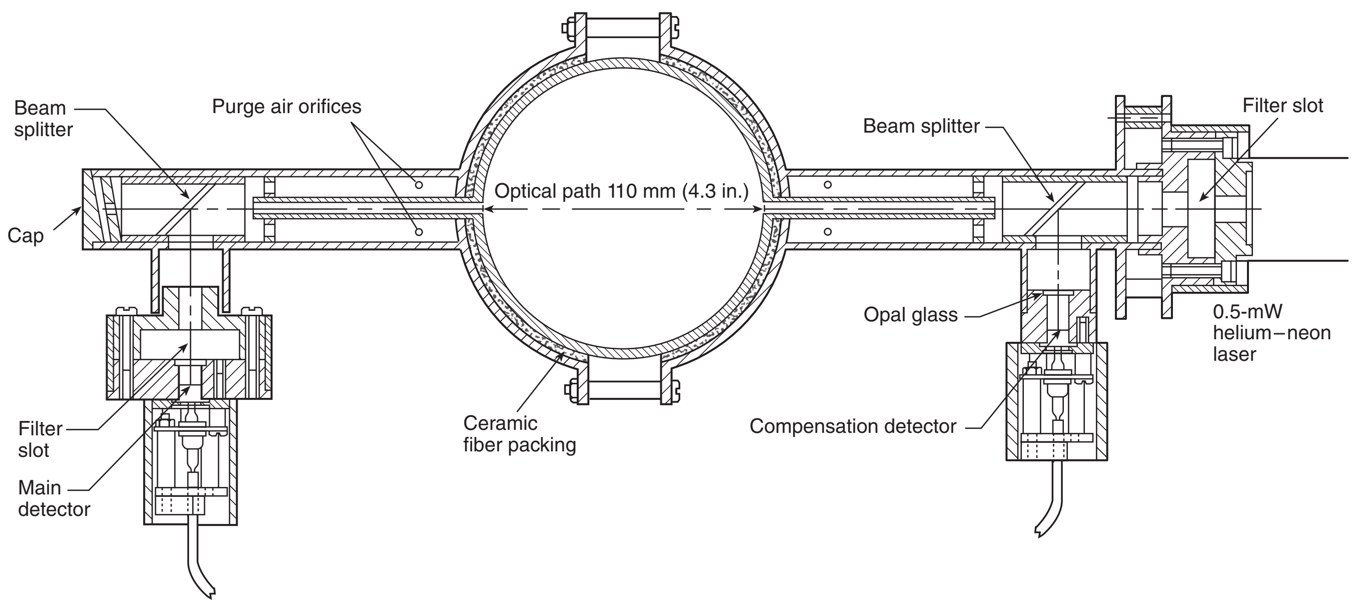
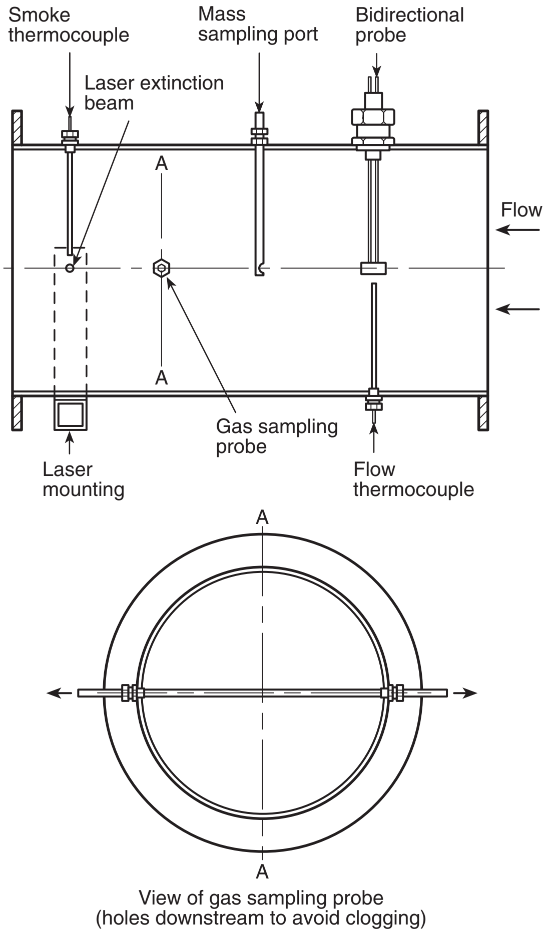


**FIGURE 5-3.7.4(b) Recommendations for mounting the laser beam and other instrumentation in exhaust duct.**




## Chapter 6 Calibration

**6-1 Calibration and Documentation of Ignition Source and Test Equipment.**

**6-1.1** All instruments shall be calibrated with standard sources after initial installation. The instruments to be calibrated shall be smoke meters, flow or velocity transducers, and gas analyzers.

**6-1.2** A calibration test shall have been performed prior to and within 30 days of any fire test. Such calibration tests shall be performed no more than 30 days prior to any fire test. If modifications are made to the system, a recalibration test shall be performed before any fire test. The calibration test shall use the standard ignition source intended for the test, centered under the exhaust hood.

**6-1.3*** The data resulting from a calibration test shall provide the following:

(1) The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test
(2) The maximum extension of the burner flame, as recorded by still photographs taken at 30-second intervals or by continuous video recording
(3) The temperature and velocity profiles across the duct cross section at the location of the bidirectional probe
(4) The differential pressure across the bidirectional probe

The results in (3) and (4) shall be used to determine the calibration factor, $C$, in 8-1.1.

**6-2* Calibration Procedure.** The calibration procedure for heat release measurements shall be conducted as follows:

(1) Estimate an approximate value, $C_{est}$, of the calibration factor $C$ as the product of the cross section of the duct (in $m^2$) multiplied by 22.1.
(2) *Burn propane, as described in 2-1.3, for 15 minutes at a heat release rate of 160 kW. Take measurements at least once every 6 seconds. The response of the system to a stepwise change of the heat output from the burner shall be a maximum of 12 seconds to 90 percent of final value. Use the following values of the combustion expansion factor, $a$; of energy, $E$, and of heat of combustion, $Ht_{comb}$: $a = 1.084$, $E = 12.8$ MJ/kg and effective $Ht_{comb} = 44.2$ MJ/kg. *(See Section 8-4.)*
(3) Calculate the total heat released and the corrected calibration factor, $C_{cor}$, so that the total heat released, as determined by the oxygen consumption calculation *(see Chapter 8)* agrees with the theoretical value, obtained from measurement of the volumetric flow rate and weight loss of the fuel, to within ±5 percent, by using the following equation:

$$C_{cor} = \frac{(Ht_{comb} \times F_{mb})}{\int \dot{q}(MW)\,dt} \times C_{est}$$

where:

$C_{cor}$ = the corrected calibration factor
$Ht_{comb}$ = heat of combustion of used fuel (MJ/kg)
$F_{mb}$ = mass fuel burned [kg (16)]
$\dot{q}$ = seal release safe (kW)
$MW$ = fuel mass loss
$dt$ = time (sec)

(4) Use the corrected value of calibration factor for all tests.
(5) If the calibration factor does not agree within ±5 percent with the value determined during the previous calibration, check the system for leaks or other problems before proceeding with the test. Correct the problem and perform a new calibration, in accordance with this chapter.

**6-3 Smoke Measurement Calibration.** Calibrate the smoke measuring system initially by using two neutral density filters of significantly different values and one at 100 percent transmission. Once this calibration is set, at least the zero value of extinction coefficient (100 percent transmission) shall be verified each day prior to testing. If departure from the zero line is found at the end of a calibration test, the problem shall be corrected and a new calibration shall be performed in accordance with this chapter.

**6-4* Gas Analyzers Calibration.** Gas analyzers shall be calibrated daily, prior to testing, using the manufacturer's instructions.

## Chapter 7 Test Procedure

**7-1 Procedure.** The test procedure shall be as follows:

(1) Establish an initial volumetric flow rate of at least 0.47 $m^3$/sec (1000 $ft^3$/min) through the duct, and increase the volume flow rate as required to keep the oxygen content above 14 percent and to capture all effluents from the burn room.
(2) Turn on all sampling and recording devices, establish steady-state baseline readings for at least 2 minutes, and cease data collection until burner ignition.
(3) Ignite the gas burner. Start the clock and the data acquisition device once burner ignition has been observed, and increase gas flow rate to provide a burner rate of heat release equal to the required heat output for the initial period. This rate shall be 40 kW ± 1 kW for 5 minutes ± 10 seconds. Continue the exposure at that same level for the prescribed time period. Within 10 seconds after the 5-minute initial exposure following the initial exposure, increase the gas flow rate to provide a rate of heat release by the burner equal to the final heat output for a 10-minute period. This rate shall be 160 kW ± 5 kW. Continue the exposure at that same level for 10 minutes ± 10 seconds.
(4) Take color photographs at 30-second intervals, or provide a continuous video recording to document the growth of the fire.
(5) Provide a voice or written record of the fire that will provide the times of all significant events, such as, but not limited to, times of ignition, escape of flames through the doorway, and flashover.
(6) Shut off the ignition burner 15 minutes after start of the test and terminate the test at that time, unless safety considerations dictate an earlier termination.
(7) Document damage after the test, using words, pictures, and drawings.

## Chapter 8 Calculation Methods for Total Rate of Heat Release

**8-1* Mass Flow Rate.** The mass flow rate through the exhaust duct shall be obtained from the velocity measured with a bidirectional probe *(see 5-3.2)* at one point in the duct. The mass flow rate shall be calculated using the results found in Section 6-2 and the equation in 8-1.1.

**8-1.1** The mass flow rate shall be monitored by using the following equation (the variables are described in Section 8-4):

$$\dot{m}_e = C\sqrt{\frac{\Delta\rho}{T_e}}$$

**8-1.2*** Concentration measurements of $O_2$, $CO_2$, and CO shall be used. The oxygen depletion factor shall be calculated according to the following equation:

$$\phi = \frac{X^0_{O_2}(1 - X_{CO_2} - X_{CO}) - X_{O_2}(1 - X^0_{CO_2})}{X^0_{O_2}(1 - X_{O_2} - X_{CO_2} - X_{CO})}$$

The rate of heat release shall then be calculated according to the following equation:

$$\dot{q} = \left[E\phi - (E_{CO} - E)\frac{1-\phi}{2}\left(\frac{X_{CO}}{X_{O_2}}\right)\right]\frac{M_{O_2}}{M_e}\left(\frac{\dot{m}}{1 + \phi(\alpha - 1)}\right)(X^0_{O_2})$$

**8-1.3** The total heat released shall be calculated according to the following equation:

$$THR = \int \dot{q}\, dt$$

**8-2 Smoke Measurement Equations.**

**8-2.1** The extinction coefficient, *k*, shall be calculated from the following equation:

$$k = \frac{1}{L_p} ln\left(\frac{I_0}{I}\right)$$

**8-2.2** The optical density per unit light path length shall be calculated according to the following equation:

$$OD = \frac{1}{D}\log\left(\frac{I_0}{I}\right)$$

**8-2.3** The volumetric flow rate at the smoke meter shall then be calculated as the product of the mass flow rate and the temperature at the measurement point (bidirectional probe), corrected by the density of air at the standard temperature 273.15 K and by the temperature, in Kelvins, as in the following equation:

$$\dot{V}_s = m_e\left(\frac{T_e}{\rho_o 273.15}\right) = \frac{\dot{m}_e T_e}{353}$$

**8-2.4** The rate of smoke release shall be defined by the following equation:

$$RSR = \dot{V}_s k$$

**8-2.5** Total smoke released shall be defined by the following equation:

$$TSR = \int RSR\, dt$$

**8-3 Release Rate of Combustion Gases.**

**8-3.1** The release rate of carbon monoxide shall be calculated from the following equation:

$$\dot{m}_{CO} = \frac{X_{CO}(1 - X^0_{O_2} - X^0_{CO_2})}{1 - X_{O_2} - X_{CO_2} - X_{CO}}\left(\frac{M_{CO}}{M_a}\right)\frac{\dot{m}_e}{1 + \phi(\alpha - 1)}$$

**8-3.2** For other combustion gases, the release rate is a function of the sum of the concentrations of that gas at each scan in the exhaust (that is, the products of the mole fraction of the combustion gas, the overall mass flow rate for that scan, and the scan period), its molecular weight, and the total test period, as shown in the following equation:

$$\dot{m}_x = \frac{\sum (X_{xi}\dot{m}_{ei}\Delta t_i)(M_x/M_a)}{\text{test period}}$$

**8-4 Symbols.**

| | | |
|---|---|---|
| $C$ | = | calibration factor for orifice plate or bidirectional probe ($kg^{1/2}$, $m^{1/2}$, or $k^{1/2}$) |
| $E$ | = | net heat released per unit mass of oxygen consumed (13.1 MJ/kg) |
| $E_{CO}$ | = | net heat released per unit mass of oxygen consumed, for carbon monoxide (17.6 MJ/kg) |
| $Ht_{comb}$ | = | heat of combustion of the fuel used (46.5 MJ/kg for propane and 50.0 MJ/kg for methane) |
| $I_0$ | = | light intensity for a beam of parallel light rays, measured in a smoke-free environment, with a detector having the same spectral sensitivity as the human eye and reaching the photodetector |
| $I$ | = | light intensity for a parallel light beam having traversed a certain length of smoky environment and reaching a photodetector |
| $k$ | = | extinction coefficient (1/m) |
| $L_p$ | = | light path length of beam through smoky environment, which is equal to the duct diameter (m) |
| $\dot{m}_e$ | = | mass flow rate in exhaust duct (kg/sec) |
| $\dot{m}_{CO}$ | = | release rate of carbon monoxide (kg/sec) |
| $\dot{m}_x$ | = | release rate of combustion product *x* (kg/sec) |
| $M_a$ | = | molecular weight of incoming and exhaust air (29 kg/kmol) |
| $M_{CO}$ | = | molecular weight of carbon monoxide (28 kg/kmol) |
| $M_{O_2}$ | = | molecular weight of oxygen (32 kg/kmol) |
| $OD$ | = | optical density per unit light path length (L/m) |
| $\Delta\rho$ | = | pressure drop across the orifice plate or bidirectional probe (Pa) |
| $\dot{q}$ | = | rate of heat release (kW) |
| $RSR$ | = | rate of smoke release ($m^2$/sec) |
| $\Delta t$ | = | scan period (sec) |
| $T_e$ | = | gas temperature at the orifice plate or bidirectional probe (K) |
| test period | = | duration of test period (sec) |
| $THR$ | = | total heat released (MJ) |
| $TSR$ | = | total smoke released ($m^2$) |
| $\dot{V}_s$ | = | volumetric flow rate at location of smoke meter (value adjusted for smoke measurement calculations) ($m^3$/sec) |
| $X_{CO}$ | = | measured mole fraction of CO in exhaust flow (nondimensional) |
| $X_{CO_2}$ | = | measured mole fraction of $CO_2$ in exhaust flow (nondimensional) |
| $X^0_{CO_2}$ | = | measured mole fraction of $CO_2$ in incoming air (nondimensional) |
| $X_{O_2}$ | = | measured mole fraction of $O_2$ in exhaust flow (nondimensional) |
| $X^0_{O_2}$ | = | measured mole fraction of $O_2$ in incoming air (nondimensional) |
| $X_x$ | = | measured mole fraction of combustion gas *x* in exhaust flow (nondimensional) |
| $\alpha$ | = | combustion expansion factor (nondimensional) (Use a value of 1.105, unless the value for the test specimen, and not the ignition gas, is known.) |
| $\mu$ | = | combustion expansion factor (nondimensional; use a value of 1.105, unless the value for the test specimen and not the ignition gas is known) |
| $\phi$ | = | oxygen depletion factor (nondimensional) |
| $\rho_o$ | = | density of air at 273.15 K: 1.293 ($kg/m^3$) |

## Chapter 9 Report

**9-1 Report.** The report shall include the data and information specified in 9-1.1 through 9-1.7.

**9-1.1 Materials.** Materials shall include the following:

(1) Name, thickness, density, and size of the test material, along with other identifying characteristics or labels
(2) Mounting and conditioning of materials, including detailed description of mounting procedure and justification for any variations from end-use installation
(3) Layout of specimens and attachments, including appropriate drawings, in fire test room
(4) Relative humidity and temperature of the fire test room and the test building prior to and during the test

**9-1.2 Burner Gas Flow.** The burner gas flow shall be the fuel gas flow to the ignition burner and its calculated rate of heat output.

**9-1.3 Time History of the Total Heat Flux to Floor.** The time history of the total heat flux to floor shall be the total incident heat flux at the center of the floor for the heat flux gauge as a function of time starting 3 minutes prior to the test.

**9-1.4 Time History of the Gas Temperature.** The time history of the gas temperature shall be the temperature of gases in the fire test room, in the doorway, and in the exhaust duct for each thermocouple as a function of time starting 3 minutes prior to the test.

**9-1.5 Time History of the Rate of Heat Release of the Fire.** The rate of heat release shall be calculated from the measured oxygen, carbon monoxide, and carbon dioxide concentrations and the temperature and volumetric flow rate of the gas in the duct. The time history of the rate of heat release as well as the maximum and average values shall be reported. Similarly, the time history of total heat released as well as the final value and the values shall be reported every 5 minutes. The measurement method used shall also be reported.

**9-1.6 Time History of the Fire Growth.** The time history of the fire growth shall be a transcription of the visual, photographic, audio, and written records of the fire test. The records shall indicate the time of ignition of the wall finish and the ceiling finish where present, the approximate location of the flame front most distant from the ignition source at intervals not exceeding 15 seconds during the fire test, the time of flashover, and the time at which flames extend outside the doorway. In addition, still photographs taken at intervals not exceeding 30 seconds or continuous video recording shall be supplied. Drawings and photographs or video recording showing the extent of the damage of the materials after the test also shall be supplied.

**9-1.7 Time History of Smoke Obscuration.** The smoke obscuration shall be described by means of the optical density, rate of smoke release, and total smoke released measured with the instrumentation in the exhaust duct. The following shall be reported:

(1) Time histories of smoke release rate, optical density, and volumetric duct flow rate, as well as the maximum and average values
(2) The total smoke release time history, as well as the final value and the values every 5 minutes
(3) Details of the smoke obscuration measurement equipment used, including the orientation of the light beam

**9-2* Discussion of Performance.** A complete discussion of sample performances shall be provided and shall include the following:

(1) Flame spread to ceiling during initial exposure
(2) Burning to outer extremities of walls or ceilings
(3) Presence of burning droplets on the floor that persist in burning for 30 seconds or more
(4) Visibility information in the fire test room
(5) Other pertinent details with respect to fire growth
(6) Melting or dripping of materials

## Chapter 10 Referenced Publications

**10-1** The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix B.

**10-1.1 ASTM Publication.** American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM C 36, *Standard Specification for Gypsum Wallboard*, 1995.

## Appendix A Explanatory Material

*Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.*

**A-1-1.1** The fire performance of textile wall coverings is addressed specifically in NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*. Further information on testing of textile wall coverings can be found in *Room Fire Tests of Textile Wall Coverings*, by F. L. Fisher, B. MacCracken, and R. B. Williamson. The fire performance of other wall covering systems is addressed in this standard. Some interior finish materials, such as expanded vinyl wall coverings, are required (for example, in NFPA *101*®, *Life Safety Code*®) to be tested in the same manner as textile wall coverings.

**A-1-3.3** One important difference between the ignition source used in this test method and that used in NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Wall Coverings*, is that the flame in the NFPA 265 ignition source does not reach the ceiling. Thus, the NFPA 265 ignition source should not be used when testing materials that are to be installed on the ceiling.

There are significant differences between the ignition source used in this test method and that source used in the NFPA 265 test method. Although both test methods use the same burner equipment, there are differences in burner placement and fuel flow. The burner arrangement (spacing, gas flows, and so on) used in this test method provides a sustained flame impingement on the ceiling of the test room, whereas the burner arrangement in NFPA 265 does not. The spacing of the burner, moreover, can change the heat flux to which the test wall materials are exposed.

**A-2-1.1** The ignition source described in 2-1.1 has been referred to as the "proposed ASTM room-corner test" ignition source. See further information in "Interlaboratory Test Program on Proposed ASTM Standard Method for Room Fire Test of Wall and Ceiling Materials and Assemblies."

**A-2-1.4** The heat of combustion corresponds to a propane gas flow rate of 26.9 L/min at 40 kW and 107.5 L/min for 160 kW for propane with a net heat of combustion of 46.5 MJ/kg, under standard conditions of 101 kPa pressure (14.7 psia) and 20°C (68°F). Figure A-2-1.4 is a schematic of two typical gas flow regulation systems.