**Designation: E1995 – 21**

An American National Standard

# Standard Test Method for Measurement of Smoke Obscuration Using a Conical Radiant Source in a Single Closed Chamber, With the Test Specimen Oriented Horizontally[1]

This standard is issued under the fixed designation E1995; 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 of measuring smoke obscuration resulting from subjecting essentially flat materials, products, or assemblies (including surface finishes), not exceeding 25 mm (1 in.) in thickness, in a horizontal orientation, exposed to specified levels of thermal irradiance, from a conical heater, in the presence of a pilot flame, in a single closed chamber. Optional testing modes exclude the pilot flame.

NOTE 1—The equipment used for this test method is technically equivalent to that used in ISO 5659-2 and in NFPA 270.

1.3 The principal fire-test-response characteristic obtained from this test method is the specific optical density of smoke from the specimens tested, which is obtained as a function of time, for a period of 10 min.

1.4 An optional fire-test-response characteristic measurable with this test method is the mass optical density (see Annex A1), which is the specific optical density of smoke divided by the mass lost by the specimens during the test.

1.5 The fire-test-response characteristics obtained from this test are specific to the specimen tested, in the form and thickness tested, and are not an inherent property of the material, product, or assembly.

1.6 This test method does not provide information on the fire performance of the test specimens under fire conditions other than those conditions specified in this test method. For limitations of this test method, see 5.5.

1.7 Use the SI system of units in referee decisions; see IEEE/ASTM SI-10. The inch-pound units given in parentheses are for information only.

1.8 *This test method is used to measure and describe 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.*

1.9 Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be employed in conducting these tests. This test method may involve hazardous materials, operations, and equipment. See also 6.2.1.2, Section 7, and 11.7.2.

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]

C1186 Specification for Flat Fiber-Cement Sheets
C1288 Specification for Fiber-Cement Interior Substrate Sheets
D2843 Test Method for Density of Smoke from the Burning or Decomposition of Plastics
D4100 Test Method for Gravimetric Determination of Smoke Particulates from Combustion Of Plastic Materials (Withdrawn 1997)[3]
D5424 Test Method for Smoke Obscuration of Insulating Materials Contained in Electrical or Optical Fiber Cables When Burning in a Vertical Cable Tray Configuration

[1] This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.21 on Smoke and Combustion Products.

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[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] The last approved version of this historical standard is referenced on www.astm.org.

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

E84 Test Method for Surface Burning Characteristics of Building Materials
E176 Terminology of Fire Standards
E603 Guide for Room Fire Experiments
E662 Test Method for Specific Optical Density of Smoke Generated by Solid Materials
E906 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using a Thermopile Method
E1354 Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter
E1474 Test Method for Determining the Heat Release Rate of Upholstered Furniture and Mattress Components or Composites Using a Bench Scale Oxygen Consumption Calorimeter
E1537 Test Method for Fire Testing of Upholstered Furniture
E1590 Test Method for Fire Testing of Mattresses
IEEE/ASTM SI-10 Practice for Use of the International System of Units (SI): The Modernized Metric System

2.2 *ANSI/AHA Standard:*[4]
A135.4 Basic Hardboard

2.3 *ISO Standards:*[5]
ISO Guide 52—Glossary of Fire Terms and Definitions
ISO 3261 Fire Tests–Vocabulary
ISO 5659-2 Determination of Specific Optical Density by a Single-Chamber Test
ISO 5725 Precision of Test Methods—Determination of Repeatability and Reproducibility for Standard Test Method by Interlaboratory Tests

2.4 *British Standards:*[6]
BS 6809 Method of Calibration of Radiometers for Use in Fire Testing

2.5 *NFPA Standards:*[7]
NFPA 270 Standard Test Method for Measurement of Smoke Obscuration Using a Conical Radiant Source in a Single Closed Chamber

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology E176 and ISO 3261. In case of conflict, the definitions given in Terminology E176 shall prevail.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *assembly, n*—a unit or structure composed of a combination of materials or products, or both.

3.2.2 *continuous (as related to data acquisition), adj*—conducted at data collection intervals of 5s or less.

3.2.3 *essentially flat surface, n*—surface where the irregularity from a plane does not exceed ±1 mm.

3.2.4 *exposed surface, n*—that surface of the specimen subjected to the incident heat.

3.2.5 *flaming mode, n*—the mode of testing that uses a pilot flame.

3.2.6 *ignition, n*—the initiation of combustion.

3.2.6.1 *Discussion*—The combustion may be evidenced by glow, flame, detonation, or explosion. The combustion may be sustained or transient.

3.2.7 *mass optical density, n*—the ratio of the optical density of smoke and the mass loss of the test specimen, multiplied by the volume of the test chamber and divided by the length of the light path.

3.2.7.1 *Discussion*—The mass optical density as determined in this test method is not an intrinsic material property; it is a function of the test procedure and conditions used.

3.2.8 *Nonflaming mode, n*—the mode of testing that does not use a pilot flame.

3.2.9 *sample, n*—an amount of the material, product, or assembly, to be tested, which is representative of the item as a whole.

3.2.10 *smoke obscuration, n*—the reduction in visibility due to smoke (ISO Guide 52).

3.2.11 *specimen, n*—the actual section of material, product, or assembly, to be placed in the test apparatus.

3.2.12 *time to ignition, n*—time between the start of the test and the presence of a flame on the specimen surface for a period of at least 4s.

## 4. Summary of Test Method

4.1 This test method assesses the reduction of light by smoke obscuration from a burning sample. The test method employs a conically-shaped, electrically-heated, radiant-energy source to produce irradiance levels of 25 and 50 kW/m$^2$, averaged over the center of the exposed surface of an essentially flat specimen, and mounted horizontally inside a closed chamber. The equipment is suitable for testing at irradiance levels of up to 50 kW/m$^2$.

4.2 The specimen is 75 by 75 mm (3 by 3 in.), at a thickness not exceeding 25 mm (1 in.) and is mounted horizontally within a holder.

4.3 The exposure is conducted in the presence or in the absence of a pilot flame (see details in 6.3.6). If a pilot flame is used for ignition, the test is deemed to be in the "flaming" mode; if a pilot flame is not used, the test is deemed to be in the "nonflaming" mode.

4.4 The test specimens are exposed to flaming or nonflaming conditions within a closed chamber. A photometric system with a vertical light path is used to measure the varying light transmission as smoke accumulates. The light transmittance measurements are used to calculate the specific optical density of the smoke generated during the test.

4.5 The specimens are exposed to two conditions, out of the four standard exposure conditions, to be chosen by the test

[4] Available from American Hardboard Association, 1210 West Northwest Highway, Palatine, IL 60067, United States.

[5] Available from International Standardization Organization, P.O. Box 56, CH-1211; Geneva 20, Switzerland, or from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

[6] Available from British Standards Institute (BSI), 389 Chiswick High Rd., London W4 4AL, U.K.

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

requester. The four standard exposure conditions are: flaming mode at an irradiance of 25 kW/m$^2$, flaming mode at an irradiance of 50 kW/m$^2$; nonflaming mode at an irradiance of 25 kW/m$^2$; and, nonflaming mode at an irradiance of 50 kW/m$^2$. Unless specified otherwise, conduct testing in the two flaming mode exposure conditions (see 8.3, X1.3 and X1.4). Exposures to other irradiances also are possible.

4.6 Mass optical density is an optional fire-test-response characteristic obtainable from this test method, by using a load cell, which continuously monitors the mass of the test specimen (see Annex A1).

## 5. Significance and Use

5.1 This test method provides a means for determining the specific optical density of the smoke generated by specimens of materials, products, or assemblies under the specified exposure conditions. Values determined by this test are specific to the specimen in the form and thickness tested and are not inherent fundamental properties of the material, product, or assembly tested.

5.2 This test method uses a photometric scale to measure smoke obscuration, which is similar to the optical density scale for human vision. The test method does not measure physiological aspects associated with vision.

5.3 At the present time no basis exists for predicting the smoke obscuration to be generated by the specimens upon exposure to heat or flame under any fire conditions other than those specified. Moreover, as with many smoke obscuration test methods, the correlation with measurements by other test methods has not been established.

5.4 The current smoke density chamber test, Test Method E662, is used by specifiers of floor coverings and in the rail transportation industries. The measurement of smoke obscuration is important to the researcher and the product development scientist. This test method, which incorporates improvements over Test Method E662, also will increase the usefulness of smoke obscuration measurements to the specifier and to product manufacturers.

5.4.1 The following are improvements offered by this test method over Test Method E662: the horizontal specimen orientation solves the problem of melting and flaming drips from vertically oriented specimens; the conical heat source provides a more uniform heat input; the heat input can be varied over a range of up to 50 kW/m$^2$, rather than having a fixed value of 25 kW/m$^2$; and, the (optional) load cell permits calculations to be made of mass optical density, which associates the smoke obscuration fire-test-response characteristic measured with the mass loss.

5.5 *Limitations*[8]:

5.5.1 The following behavior during a test renders that test invalid: a specimen being displaced from the zone of controlled irradiance so as to touch the pilot burner or the pilot flame; extinction of the pilot flame (even for a short period of time) in the flaming mode; molten material overflowing the specimen holder; or, self-ignition in the nonflaming mode.

5.5.2 As is usual in small-scale test methods, results obtained from this test method have proven to be affected by variations in specimen geometry, surface orientation, thickness (either overall or individual layer), mass, and composition.

5.5.3 The results of the test apply only to the thickness of the specimen as tested. No simple mathematical formula exists to calculate the specific optical density of a specimen at a specimen thickness different from the thickness at which it was tested. The literature contains some information on a relationship between optical density and specimen thickness (**1**).[9]

5.5.4 Results obtained from this test method are affected by variations in the position of the specimen and radiometer relative to the radiant heat source, since the relative positioning affects the radiant heat flux (see also Appendix X2).

5.5.5 The test results have proven sensitive to excessive accumulations of residue in the chamber, which serve as additional insulators, tending to reduce normally expected condensation of the aerosol, thereby raising the measured specific optical density (see 5.5.8.3 and 11.1.2).

5.5.6 The measurements obtained have also proven sensitive to differences in conditioning (see Section 10). Many materials, products, or assemblies, such as some carpeting, wood, plastics, or textiles, require long periods to attain equilibrium (constant weight) even in a forced-draft conditioning chamber. This sensitivity reflects the inherent natural variability of the sample and is not specific to the test method.

5.5.7 In this procedure, the specimens are subjected to one or more specific sets of laboratory test conditions. If different test conditions are substituted or the end-use conditions are changed, it is not necessarily possible by or from this test method to predict changes in the fire-test-response characteristics measured; therefore, the results are valid only for the fire test exposure conditions described in this procedure.

5.5.8 This test method solves some limitations associated with other closed chamber test methods, such as Test Method E662(**2-6**) (see 5.4.1). The test method retains some limitations related to closed chamber tests, as detailed in 5.5.8.1 – 5.5.8.5.

5.5.8.1 Information relating the specific optical density obtained by this test method to the mass lost by the specimen during the test is possible only by using the (optional) load cell, to determine the mass optical density (see Annex A1).

5.5.8.2 All specimens consume oxygen when combusted. The smoke generation of some specimens (especially those undergoing rapid combustion and those which are heavy and multilayered) is influenced by the oxygen concentration in the chamber. Thus, if the atmosphere inside the chamber becomes oxygen-deficient before the end of the experiment, combustion may ceases for some specimens; therefore, it is possible that those layers furthest away from the radiant source will not undergo combustion.

5.5.8.3 The presence of walls causes losses through deposition of combustion particulates.

5.5.8.4 Soot and other solid or liquid combustion products settle on the optical surfaces during a test, resulting in

[8] Some of these limitations are common to many small scale fire-test-response methods.

[9] The boldface numbers in parentheses refer to the list of references at the end of this standard.

potentially higher smoke density measurements than those due to the smoke in suspension.

5.5.8.5 This test method does not carry out dynamic measurements as smoke simply continues filling a closed chamber; therefore, the smoke obscuration values obtained do not represent conditions of open fires.

## 6. Apparatus and Ancillary Equipment

6.1 *General*—The apparatus (Fig. 1) consists of an air-tight test chamber with provision for containing a sample holder, radiation cone, pilot burner, a light transmission and measuring system and other ancillary facilities for controlling the conditions of operation during a test.[10]

6.2 *Test Chamber:*

6.2.1 *Construction:*

6.2.1.1 Fabricate the test chamber (Figs. 1 and 2)from laminated panels, the inner surfaces of which shall consist of either a porcelain-enamelled metal, not more than 1 ± 0. 1 mm (0.04 ± 0.004 in.) thick, or an equivalent coated metal, which is resistant to chemical attack and corrosion and capable of easy cleaning. The internal dimensions of the chamber shall be 914 ± 3 mm long, 914 ± 3 mm high and 610 ± 3 mm deep (36 ± 0.1 in. by 36 ± 0.1 in. by 24 ± 0.1 in.) (Fig. 2, where the numbers are dimensions, in mm). Provide the chamber with a hinged front-mounted door with an observation window and a removable opaque door cover to the window to prevent light entering the chamber.

[10] A list of suppliers for such equipment is available from ASTM Headquarters.

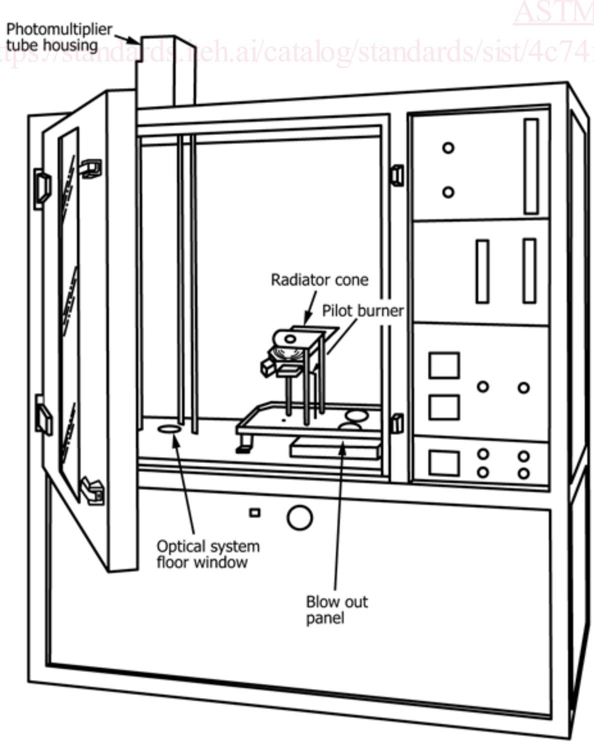
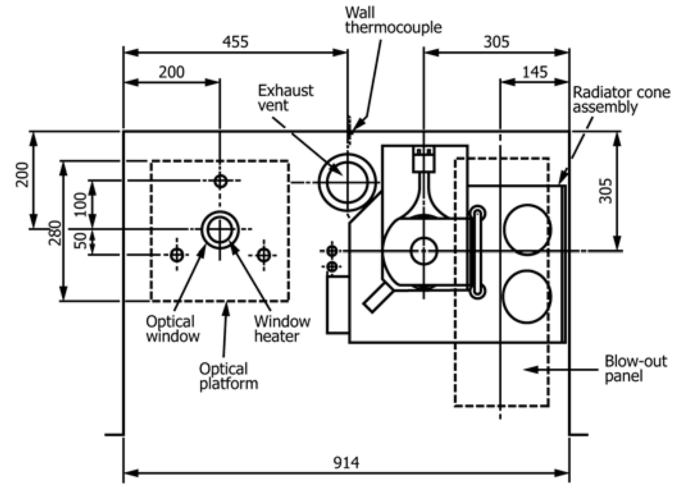



**FIG. 1 Typical Arrangement of Test Chamber**




NOTE 1—All dimensions in this figure are given in mm unless stated otherwise.

**FIG. 2 Plan View of Typical Test Chamber**

6.2.1.2 Fit the chamber with a safety blow-out panel, consisting of a sheet of aluminum foil of thickness not greater than 0.04 mm ($1.6 \times 10^{-3}$ in.) and having a minimum area of 80 600 mm$^2$ (125 in.$^2$), fastened in such a way as to provide an airtight seal. Figs. 1 and 2 show the blow-out panel location.[11]

6.2.1.3 Mount two optical windows, each with a diameter of 75 ± 1 mm (3 ± 0.04 in.), one each in the top and bottom of the cabinet, at the position shown in Fig. 2, with their interior faces flush with the outside of the cabinet lining. Provide the underside of the window on the floor with an electric heater of 9 ± 1 W capacity, in the form of a ring, which shall be capable of maintaining the upper surface of the window at a temperature just sufficient to minimize smoke condensation on that face.[12] Mount the heater around the window edge so as not to interrupt the light path (Fig. 2).

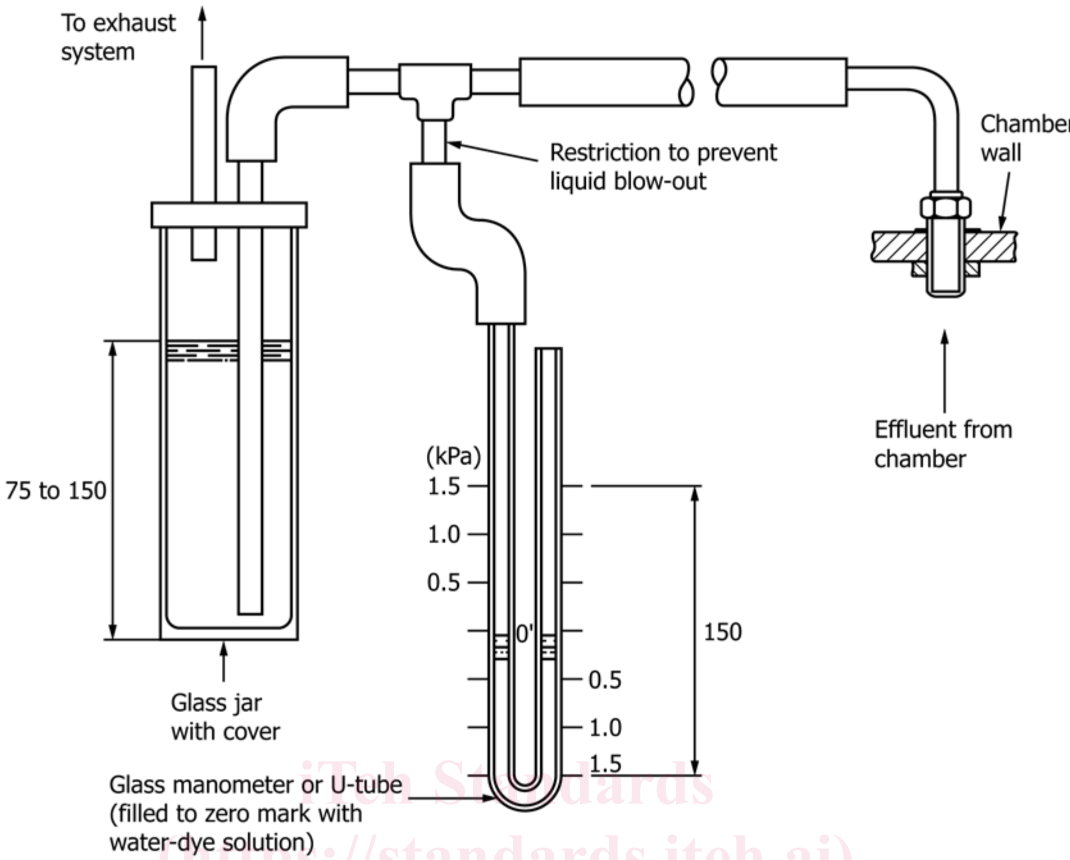
6.2.1.4 Mount optical platforms, 8 ± 0.1 mm (0.31 ± 0.004 in.) thick, around the windows on the outside of the chamber and hold them rigidly in position relative to each other by three metal rods, with a diameter of at least 12.5 mm (0.5 in.), extending through the chamber and fastened securely to the platforms.

6.2.1.5 Provide other openings in the cabinet for services, as specified. They shall be capable of being closed so as to develop a positive pressure of up to 1.5-kPa (150-mm water gage) above atmospheric pressure inside the chamber (see 6.2.2) and maintained when checked in accordance with 6.6 and 9.6. All components of the chamber shall be capable of withstanding a greater internal positive pressure than the safety blow-out panel.

6.2.1.6 Provide an inlet vent with shutter in the front of the chamber at the top and away from the radiator cone. Also, provide an exhaust vent with shutter in the bottom of the chamber to lead, via flexible pipe with a diameter of 50 to 100

[11] Stainless steel wire mesh for fastening the aluminum foil, offers adequate protection for the blow-out panel.

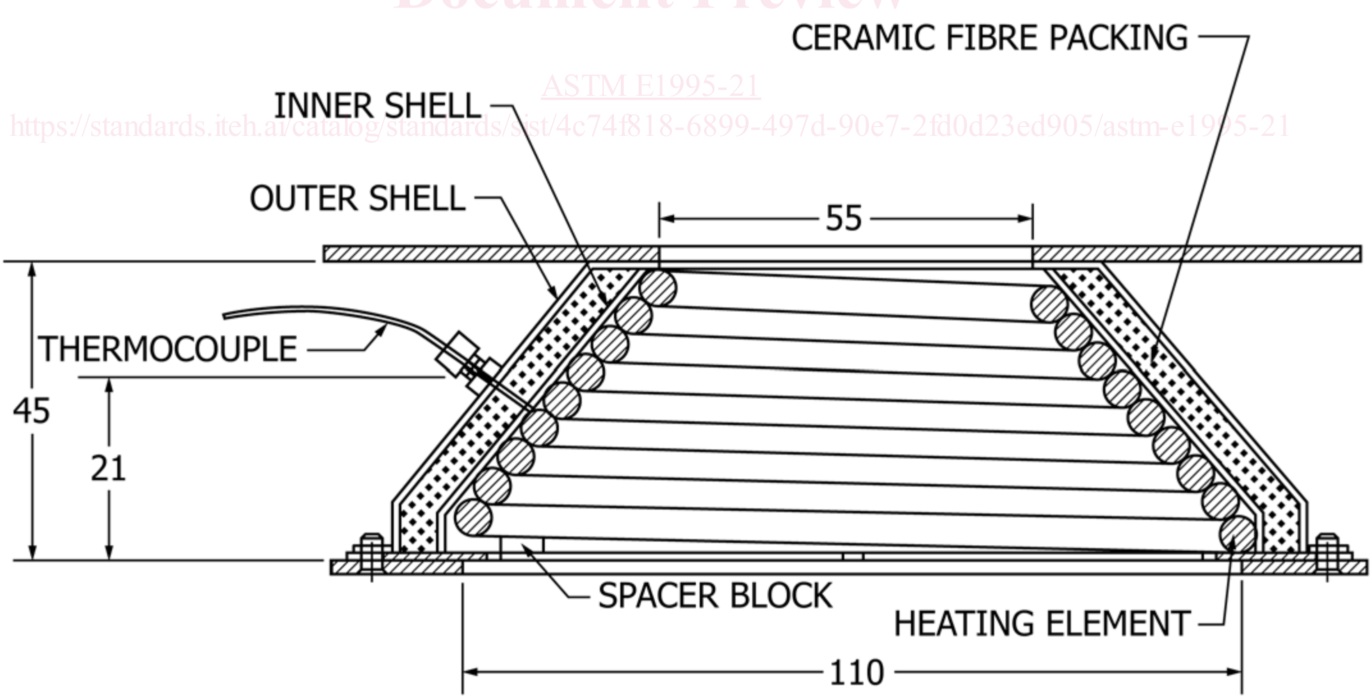
[12] A window temperature of at least 50-55 °C (122-131 °F) has been found suitable and normally is achieved with a 9W heater.




NOTE 1—All dimensions in this figure are given in mm unless stated otherwise.

**FIG. 3 Typical Chamber Pressure Relief Manometer**



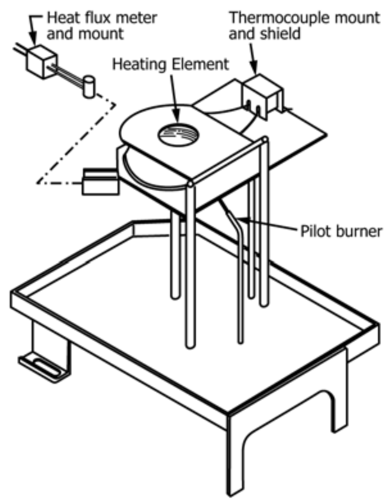



NOTE 1—All dimensions in this figure are given in mm unless stated otherwise.

**FIG. 4 Cross-sectional View Through the Radiator Cone Heater**

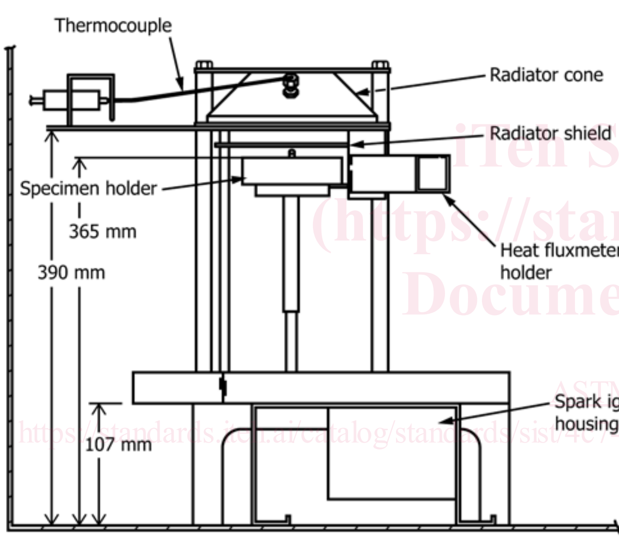
mm (2 to 4 in.), to an extraction fan capable of creating a negative pressure of at least 0.5-kPa (50-mm water gage).

6.2.2 *Sensor for Chamber Pressure Measurements*—A pressure sensor (for example, a manometer or pressure transducer)




NOTE 1—All dimensions in this figure are given in mm unless stated otherwise.

**FIG. 5 Typical Framework for Support of Radiator Cone, Specimen and Flux Meter**




NOTE 1—The dimensions in this figure are given in mm unless stated otherwise.

**FIG. 6 Typical Arrangement of Radiator Cone, Specimen Holder and Radiator Shield (Side View)**

with a range up to 6 in. (152 mm) of water (1.5 kPa) shall be provided to monitor chamber pressure and leakage. The pressure measurement point shall be through a gas sampling port in the chamber.

6.2.3 *Chamber Pressure Relief System*—A simple water column or relief valve shall be provided to permit control of chamber pressure.

6.2.4 *Chamber Temperature*—A thermocouple junction, made from wires of diameter not greater than 1 mm (0.04 in.), shall be mounted on the inside of the back wall of the chamber, at the geometric center, by means of an insulating disc, such as polystyrene foam, with a thickness of 6.5 ± 0.2 mm (0.25 in.) and a diameter of not more than 20 mm (0.8 in.) attached with a suitable cement. The thermocouple junction shall be connected to a recorder, meter, or data acquisition unit, and the system shall be suitable for measuring temperatures in the range of 35 to 60 °C (64 to 140 °F) (see 11.1.4).

6.3 *Sample Support and Heating Arrangements:*

6.3.1 *Radiator Cone:*

6.3.1.1 The radiator cone (Fig. 4) shall consist of a heating element, of nominal rating 450 W, contained within a stainless steel tube, 2210 ± 5 mm (87 ± 0.2 in.) in length and 6.5 ± 0.2 mm (0.25 ± 0.008 in.) in diameter, coiled into the shape of a truncated cone and fitted into a shade. The shade shall have an overall height of 45 ± 0.04 mm (1.8 ± 0.02 in.), an internal diameter of 55 ± 1 mm (2.2 ± 0.04 in.) and an internal base diameter of 110 ± 3 mm (4.3 ± 0.1 in.). It shall consist of two layers of 1 ± 0.1 mm (0.04 ± 0.004-in.) thick stainless steel with a 10 ± 0.5-mm (0.4 ± 0.02-in.) thickness of ceramic fibre insulation of nominal density 100 kg/m$^3$ (6.2 lb/ft$^3$), sandwiched between them. Clamp the heating element by two plates at the top and bottom of the element (see also Appendix X1).

6.3.1.2 The radiator cone shall be capable of providing irradiance in the range 10 to 50 kW/m$^2$, at the center of the surface of the specimen. The irradiance shall also be determined at a position of 25 ± 2 mm (1 ± 0.08 in.) to each side of the specimen center, and the irradiance at these two positions shall be not less than 85 %, and not more than 115 %, of the irradiance at the center of the specimen.



6.3.1.3 The irradiance of the radiator cone shall be controlled by reference to the averaged reading of two type K thermocouples. The thermocouples shall be 1.6 ± 0.2 mm (0.055 to 0.071 in.) outside diameter, sheathed with an unexposed hot junction, mounted diametrically opposite, in contact with, but not welded to, the heating element, and positioned at one third of the distance from the top surface of the cone. It has been found that thermocouples of equal length and wired in parallel to the temperature controller perform adequately; alternate wiring methods shown to give equivalent results also are acceptable (see also Appendix X2).[13]

6.3.1.4 The temperature at the heater is to be controlled and shall be held steady to ±2 °C (±4 °F). The temperature controller for the radiator cone shall be of the proportional, integral and derivative Type 3-term controller with thyristor stack fast-cycle or phase angle control of not less than 10 A max rating. Capacity for adjustment of integral time between 10 s and 50 s and differential time between 25 s and 30 s shall be provided to permit reasonable matching with the response characteristics of the heater. A temperature input range of 0 to 1000 °C (32 to 1832 °F) is suitable; an irradiance of 50 kW/m$^2$ will be given by a heater temperature in the 700 to 750 °C (1292 to 1382 °F) temperature range. Automatic cold junction compensation of the thermocouple shall be provided. The described design has been shown to be satisfactory; alternate devices shown to give equivalent results are also acceptable.[14]

6.3.2 *Framework for Support of the Radiator Cone, Specimen Holder, and Heat-Flux Meter:*

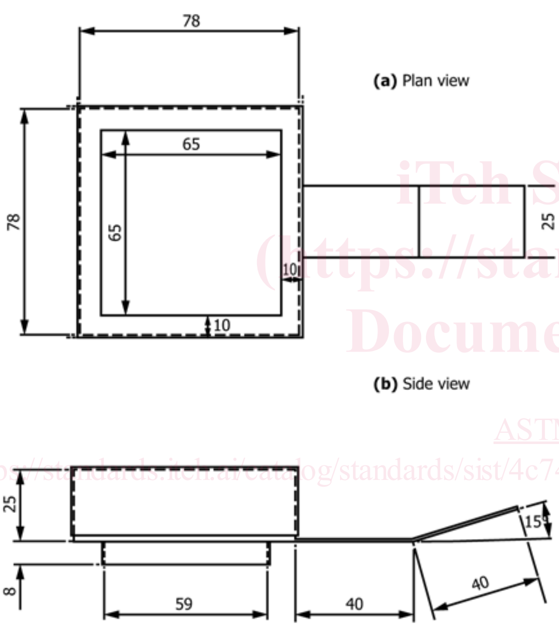
[13] Sheathed chromel/alumel type K thermocouples have been found suitable for this purpose.

[14] While phase angle control is allowed for the temperature controller of the radiator cone, it must be noted that this usually will require electrical filtering to avoid the risk of inducing noise in low signal level lines.

6.3.2.1 The radiator cone shall be secured from the vertical rods of the support framework and located so that the lower rim of the radiator cone shade is 25 ± 1 mm (1 ± 0.04 in.) above the upper surface of the specimen, when oriented in the horizontal position. Details of the radiator cone and supports are shown in Figs. 5 and 6. The base of the specimen holder contains a height adjustment device to ensure a consistent distance between radiator cone and specimen surface.

6.3.3 *Radiation Shield*—The cone heater shall be provided with a removable radiation shield to protect the specimen from the irradiance prior to the start of the test. The radiation shield shall be made of noncombustible material with a total thickness not to exceed 12 mm. The radiation shield shall comply with either 6.3.3.1 or 6.3.3.2 and shall be kept in place for a maximum period of 10s.[15]

6.3.3.1 A water-cooled radiation shield coated with a durable matte black finish of surface emissivity $e = 0.95 \pm 0.05$; or,




NOTE 1—The dimensions in this figure are given in mm unless stated otherwise.

**FIG. 7 Specimen Holder**

6.3.3.2 A radiation shield with a reflective top surface in order to minimize radiation transfer but not water-cooled.

6.3.3.3 The radiation shield shall be equipped with a handle or other suitable means for quick insertion and removal. The cone heater base plate shall be equipped with the means for holding the radiation shield in position and allowing its easy and quick removal.[16]

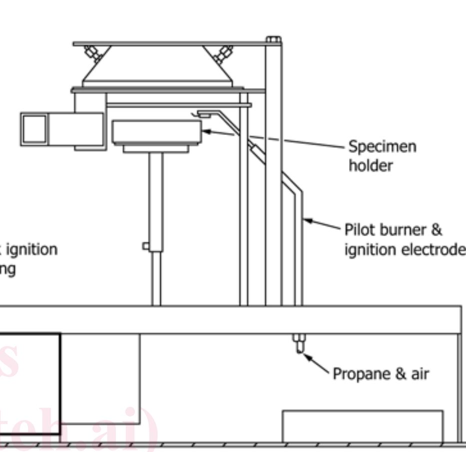
6.3.4 *Heat Flux Meter:*

6.3.4.1 The heat flux meter shall be of the Schmidt-Boelter (thermopile) type, with a design range of at least 50 kW/m$^2$. The sensing surface of the heat flux meter (Fig. 5) shall have a flat, circular face of 10 ± 1-mm (0.4 ± 0.04-in.) diameter, coated with a durable matt black finish. The heat flux meter shall be water-cooled[17, 18] and shall have an accuracy of ±3 % (see also Appendix X2).

6.3.4.2 The heat flux meter shall be connected directly to a suitable recorder, or data acquisition unit (6.8.6), so that it is capable, when calibrated, of recording heat fluxes of 25 kW/m$^2$ and 50 kW/m$^2$.[19]

6.3.4.3 For calibration of the heat flux meter system, see 9.8.

6.3.5 *Specimen Holders:*




NOTE 1—The dimensions in this figure are given in mm unless stated otherwise.

**FIG. 8 Typical Arrangement of Radiator Cone, Specimen Holder and Radiator Shield (Front View)**



6.3.5.1 Details of the specimen holder are shown in Fig. 7. The base shall be lined with a low density (nominally 65 kg/m$^3$ (4 lb/ft$^3$)) refractory fibre blanket, with a minimum thickness of 10 mm (0.4 in.).

6.3.5.2 A retainer frame and wire grid shall be used for all tests. The wire grid shall be 75 ± 1 mm (3 ± 0.04-in.) square with 20 ± 0.5 mm (0.8 ± 0.02 in.) square holes constructed from 2 ± 0.2 mm (0.08 ± 0.008 in.) stainless steel rod, welded at all intersections.[20]

6.3.6 *Pilot Burner:*

[15] It is possible that the use of a radiation shield for periods longer than 10s will affect radiator heat control and, consequently, the heat-flux level applied to the specimen.

[16] This device is necessary in order to enable repeat tests to be carried out without switching off the radiator cone.

[17] If the cooling temperature is lower than the temperature at which the gage is calibrated, condensation on the sensor is possible and would lead to serious measurement errors.

[18] The manufacturer of Schmidt-Boelter gages has the following specifications for cooling water: pressure 413-621 kPa, temperature 20.0–26.6°C and flow rate 0.76–1.14 L/min.

[19] If a chart recorder which only displays a millivolt output is used, the millivolt value shall be converted to heat flux, in kW/m$^2$, using the calibration factor (or equation, if appropriate) specific to the heat flux meter.

[20] The retainer frame and wire grid particularly are appropriate when testing intumescing specimens and also for reducing unrepresentative edge combustion of composite samples or for retaining specimens prone to delamination. The wire grid is likely to affect the test results, compared to tests conducted in its absence; however, its use is recommended for several reasons: it helps to promote uniformity in testing by different laboratories, in view of the expected effect of the retainer frame and wire grid on test results, it is needed for certain specimens, as explained above, and it is required in ISO 5659–2.

6.3.6.1 The flame from the single-flame burner, Fig. 8, shall have a length of 30 ± 5 mm (1.2 ± 0.2 in.) and shall be positioned horizontally 10 ± 1 mm (0.4 ± 0.04 in.) above the top face of the specimen. The color of the flame shall be blue, with a yellow tip. Ensure that the tip of the burner is aligned with the edge of the specimen, as shown in Fig. 9.

6.3.6.2 Install a small spark ignition device, sited next to the outlet tube of the burner, for the operator to cause reignition of the flame without opening the door of the chamber. A suitable system is a spark plug with a 3 mm (0.11-in.) gap, powered from a 10-kV transformer. A suitable transformer is of a type specifically designed for spark-ignition use, with an isolated (ungrounded) secondary to minimize interference with the data-transmission lines. An acceptable electrode length and spark plug location is such that the spark gap is located 13 mm (0.5 in.) above the specimen, close to the pilot burner.

6.4 *Gas Supply:*

6.4.1 A mixture of propane, of at least 95 % purity and at a pressure of 3.5 ± 1-kPa (350 ± 100-mm water gage), and air at a pressure of 170 ± 30-kPa (17 ± 3-m water gage) shall be supplied to the burner. Each gas shall be fed to a point at which they are mixed and supplied to the burner.

6.4.2 The use of needle valves and calibrated flowmeters is a suitable method of controlling gas flows. The flowmeter for the propane supply shall be capable of measuring 50 $cm^3$/min ($18 \times 10^{-4}$ $ft^3$/min) flow rates and that for air a value of 500 $cm^3$/min ($18 \times 10^{-3}$ $ft^3$/min). Alternate devices shown to give equivalent results are also acceptable.

6.5 *Photometric System:*

6.5.1 *General:*

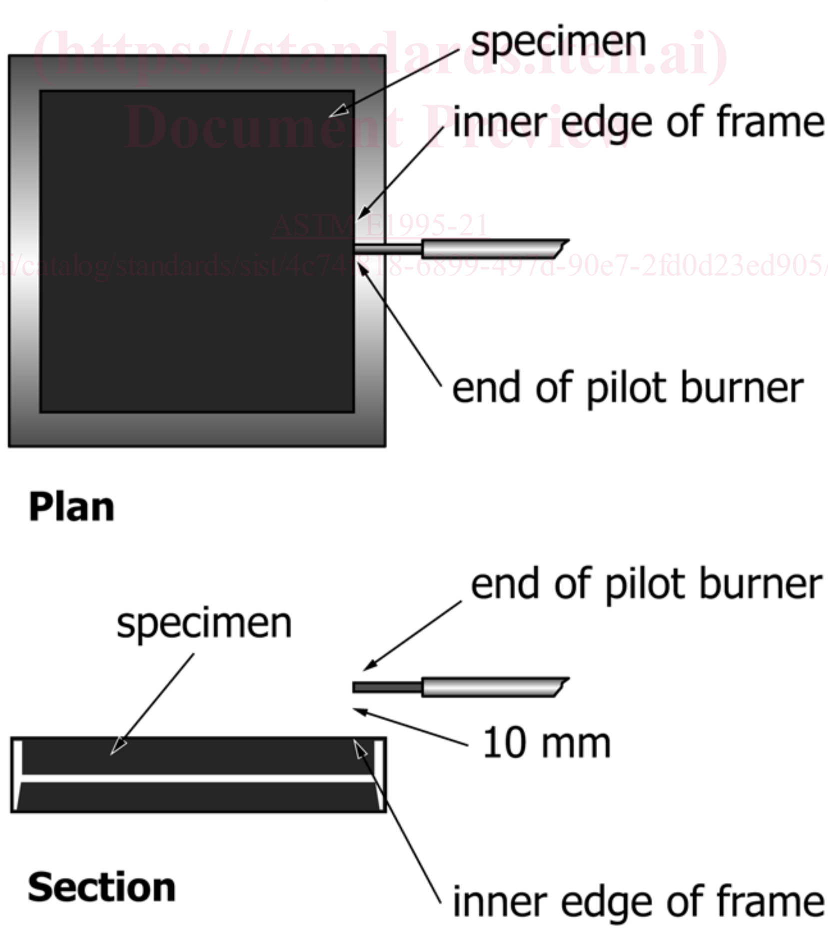
6.5.1.1 The photometric system shall consist of a light source and lens in a light-tight housing mounted below the optical window in the floor of the cabinet, and a photo-detector with lens, filters and shutter in a light-tight housing above the optical window in the top of the chamber.

6.5.1.2 The system shall be as shown in Fig. 10. Equipment shall be provided to control the output of the light source and to measure the amount of light falling on the photo-detector.

6.5.2 *Light Source:*

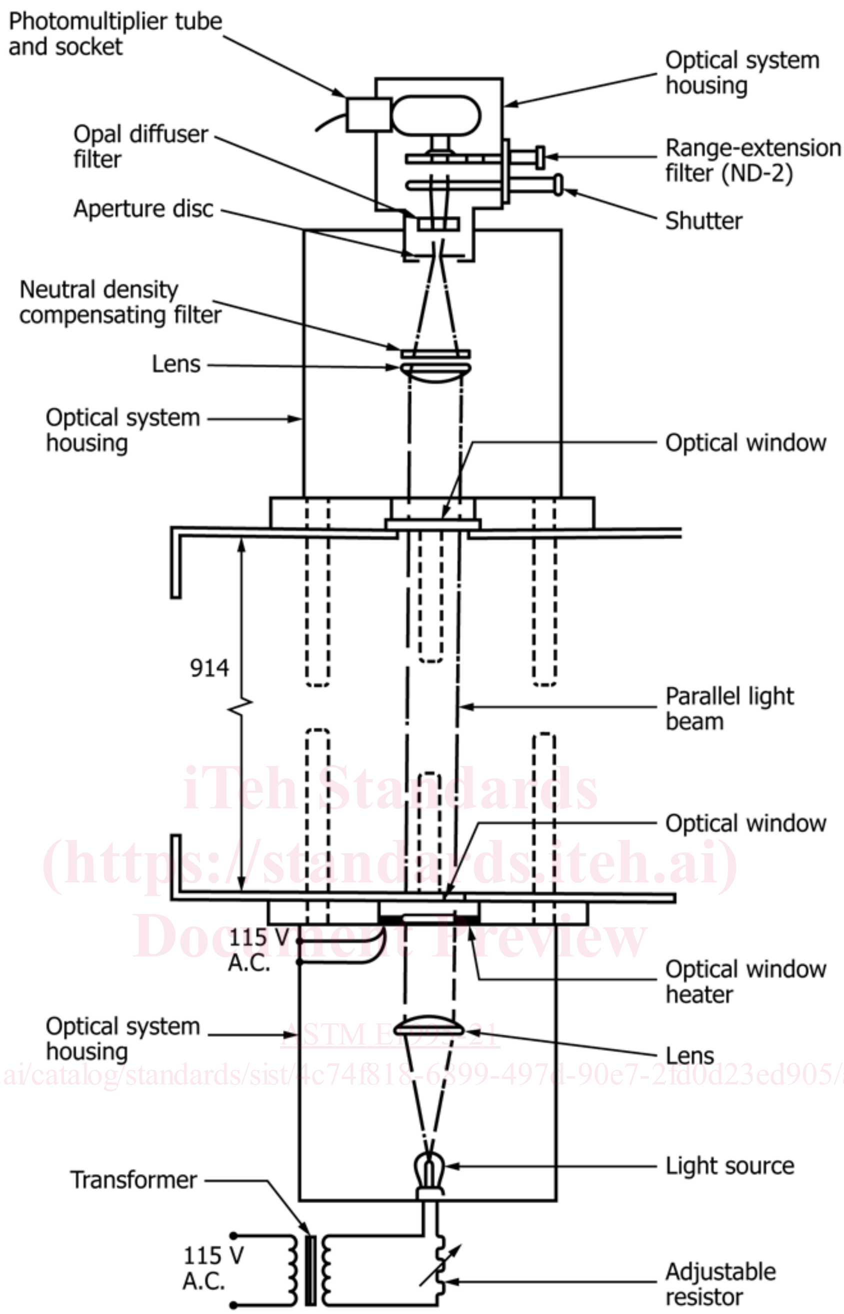
6.5.2.1 The light source shall be a 6.5 V incandescent lamp. Power for the lamp shall be provided by a transformer producing 6.5 V and a rheostat so that the r.m.s. voltage across the lamp, as determined by a voltmeter, is maintained at 4 ± 0.2 V. The lamp shall be mounted in the lower light-tight box, and a lens to provide a collimated light beam of 51 mm (2-in.) diameter, passing towards and through the optical window on the floor of the chamber, shall be mounted, with provision for adjustment, to control the collimated beam in direction and diameter. The housing shall be provided with a cover to allow access for adjustments to be made to the position of the lens.






NOTE 1—The dimensions in this figure are given in mm unless stated otherwise.

**FIG. 9 Detailed Location of Pilot Burner**




NOTE 1—The dimensions in this figure are given in mm unless stated otherwise.

**FIG. 10 Photometric System**

6.5.3 *Photo-Detector:*

6.5.3.1 The light-measuring device system shall consist of a photo-multiplier tube connected to a multirange amplifier coupled to a recording device, or data acquisition unit (6.8.6), capable of measuring continuously relative light intensity against time as percentage transmission over at least five orders of magnitude, with an S-4 spectral sensitivity response similar to that of human vision and a dark current less than $10^{-9}$ A. The system shall have a linear response with respect to transmittance and an accuracy of better than ± 3 % of the maximum reading on any range. For selection of photomultiplier tubes, as applicable, the minimum sensitivity shall allow a 100 % reading to be obtained with a 0.5 neutral density filter and an ND-2 range extension filter (see 6.5.3.2) in the light path. Provision shall be made for adjusting the reading of the instrument under given conditions over the full range of any scale.[21]

6.5.3.2 The photo-multiplier tube shall be mounted in the upper section of the detector housing. Below it, there shall be an assembly which provides for the rapid positioning of a filter

[21] The required accuracy of the photo-detector is obtained more easily if the measuring systems incorporate scale ranges of 30, 3, 0.3, etc., as well as ranges of 100, 10, 1, etc.

and of a shutter, in or out of the path of the collimated light beam, each being operated separately. The filter, referred to as the range-extension filter (ND-2), shall be a glass neutral density filter of nominal optical density 2. When in the closed position, the shutter shall prevent all light in the test chamber from reaching the photo-multiplier tube. An opal diffuser shall be mounted permanently below the shutter.

6.5.3.3 The lower part of the housing shall support a 51 ± 1 mm (2 ± 0.04-in.) diameter lens, capable of being adjusted so that the collimated beam is focused to form a small intense spot of light at the disc aperture between the upper and lower parts of the housing. Above the lens, there shall be a mount for supporting one or more compensating filters from a set of nine gelatin neutral density filters, with optical density varying from 0.1 to 0.9 in steps of 0.1. The housing shall be provided with a cover, to allow access for adjustments to be made to the position of the lens and for inserting or removing filters.

6.5.3.4 A neutral density filter, with a nominal optical density of 3.0, large enough to cover the lower optical window, the actual optical density having been determined by calibration, shall be available for calibrating the photometric system.[22]

6.5.4 *Additional Equipment:*

6.5.4.1 A template for checking the collimated light beam shall consist of an opaque disc marked with a concentric ring of 51 ± 1 mm (2 ± 0.04-in.) diameter, shall be capable of fitting snugly between the support pillars. It shall be capable of being attached to, and centered on, the underside of the upper optical window in the chamber.

6.5.4.2 A piece of white cloth, paper tissue or a neutral density filter of sufficient size to cover completely the lower optical window of the chamber and capable of transmitting a sufficient amount of light to give a midscale reading of the photometric system when switched to the scale with a range of 1 % transmission, shall be available for calibrating the range-extender filter.

6.5.4.3 A piece of opaque material, sufficiently large to cover the lower optical window, shall be available for blocking the light from the light source entering the chamber.

6.6 *Chamber Leakage*—With the specified items of equipment assembled properly and ready for test, the chamber shall be sufficiently air-tight to comply with the requirements of the leakage rate test given in 9.6.[23]

6.7 *Cleaning Materials*—Conduct periodic cleaning to ensure proper operation (see also 11.1.2). Have available appropriate materials for cleaning the inside of the chamber. The optical system windows, viewing window, chamber walls, and specimen holders must all be cleaned regularly. A recommended cleaning procedure is presented in 6.7.1 – 6.7.4.

6.7.1 *Optical System Windows Recommended Procedure*—Clean the exposed surfaces of the glass separating the photodetector and light source housings from the interior of the chamber after each test. Clean the top window first, then the bottom window, using a nonabrasive cloth dampened with a suitable cleaner.[24] Dry the window to prevent streaking or film buildup. Do not use any cleaners that contain wax because wax will cause the smoke to adsorb to the glass more quickly.

6.7.2 *Viewing Window*—Clean the viewing window periodically, as required, to allow viewing the chamber interior during testing.[22]

6.7.3 *Chamber Walls*—Clean the chamber walls periodically to prevent excessive build-up of smoke products. An ammoniated spray detergent and soft scouring pads have been found effective for cleaning the chamber walls.

6.7.4 *Specimen Holders*—Remove any charred residues on the specimen holders and horizontal rods securing the holder position to prevent contamination of subsequent specimens.

6.8 *Ancillary Equipment:*

6.8.1 *Balance*—Use a balance with a capacity exceeding the mass of the specimen and which shall be readable and accurate to 0.5 % of the specimen mass.

6.8.2 *Timing Device*—Use a timing device capable of recording elapsed time to the nearest second, over a period of at least 1 hour, with an accuracy of 1s in 1 hour, for timing operations and observations.

6.8.3 *Linear Measuring Devices*—Use rules, calipers, gages, or other devices of suitable accuracy, for checking all dimensions specified with given tolerances.

6.8.4 *Auxiliary Heater*—Use an auxiliary heater of 500 W capacity, capable of raising the air temperature uniformly without local heating of the walls, if required, to help the chamber to reach the stabilized temperature more rapidly under adverse conditions.

6.8.5 *Protective Equipment*—Protective clothing, such as gloves, goggles, respirators, and handling equipment, such as tongs, always shall be available and shall be used when the type of sample being tested demands them (see Section 7).

6.8.6 *Data Acquisition*—Use a recorder, or a data acquisition unit, capable of continuously recording the millivolt output of the photo-detector (6.5.3) to an accuracy of better than 0.5 % of full-range deflection. The device used also shall be capable of recording the heat-flux meter output (see 6.3.4.2) to the required accuracy. If a data acquisition unit is used, the data collection intervals shall be 5s or less. If a recorder is used, the recording chart drive shall be used at a minimum chart speed of 10 mm/min (0.4 in./min).

6.8.7 *Thermometer*—Use a thermometer, or a Type K thermocouple, capable of measuring temperature over the range 20 to 100 °C (68 to 212 °F), to an accuracy of ± 0.5 °C (± 0.9 °F), for determining ambient temperature or any other needed temperature.

6.8.8 *Water Circulating Device*—Use a device for water circulation to cool the heat-flux meter.

6.9 *Test Environment:*

6.9.1 Protect the test apparatus from direct sunlight or any strong light source to avoid the possibility of spurious light readings.



[22] Handle all filters by their edges, because fingerprints greatly affect their rating. Do not attempt to clean the surface of a filter; once the surface has been damaged replace the filter.

[23] The most likely sources of leakage have been found to be the door seal, the inlet and outlet vents and the safety blow-out panel.

[24] Ethyl alcohol, ethyl ketone, or equivalent, and soft tissue have been found effective for cleaning the optical windows and the viewing window.

6.9.2 Make adequate provision for removing potentially hazardous and objectionable smoke and gases from the area of operation. Also, take suitable precautions to prevent exposure of the operator to such gases, particularly during the removal of specimens from the chamber or when cleaning the apparatus.

## 7. Operator Safety

7.1 **Warning—**This test procedure involves high temperatures and combustion processes; therefore, it is possible for eye injuries, burns, ignition of extraneous objects, and inhalation of smoke or combustion products to occur, unless proper precautions are taken. To avoid accidental leakage of toxic combustion products into the surrounding atmosphere, it is advisable to evacuate the chamber, at the end of a test, into an exhaust system with adequate capacity. The operator must use heavy gloves, safety tongs, or other suitable protection for removal of the specimen holder. The venting must be checked periodically for proper operation.

## 8. Test Specimen

8.1 *Suitability of Sample for Testing:*

8.1.1 The method is suitable for essentially flat specimens only (see 3.2.3).

8.1.2 The results of this test method are sensitive to variations in surface characteristics, thickness of individual layers, overall thickness, mass, and composition.

8.1.3 When preparing replicate specimens for testing, take precautions to ensure all specimens fall within the requirements in 8.6. Keep individual records of the mass of each specimen together with the individual test data of that specimen.

8.2 If the top and bottom faces of samples submitted for evaluation by this test method are different from one another, evaluate both faces if it is possible that each face will be exposed to fire when in use.

8.3 A minimum of six specimens shall be tested so that three specimens are tested at each one of the two required conditions. Unless specified otherwise by the test requester, the standard exposure conditions are flaming at an irradiance of 25 kW/m$^2$, and flaming at an irradiance of 50 kW/m$^2$.

NOTE 2—Optional testing modes include nonflaming, at an irradiance of 25 kW/m$^2$ (needed if comparison is required with the test results from Test Method E662), and nonflaming, at an irradiance of 50 kW/m$^2$ (needed if comparison is required with the test results from ISO 5659-2). These additional exposures are not mandatory (see also X1.4.9). Other testing modes are also possible with this equipment.

8.4 An additional number of specimens, as specified in 8.3, shall be used for each face in accordance with the requirements of 8.2.

8.5 An additional nine specimens (three specimens per mode to be tested) shall be held in reserve, in case they are required by the conditions specified in 11.9.2.

8.6 *Size of Specimens:*

8.6.1 The specimens shall be square, with sides 75 ± 1 mm (3 ± 0.04 in.).

8.6.2 Whenever possible, test samples in their end-use thickness. If the end-use thickness is 25 mm (1 in.) or less, test the samples at their full end-use thickness. It is recommended that materials for which end-use thickness is not available be tested at a thickness of 1.0 ± 0.1 mm (0.04 ± 0.004 in.), unless otherwise specified in the material or performance standard or specification.

8.6.3 Samples with a thickness greater than 25 mm (1 in.) shall be cut to give a specimen thickness of 25 ± 1 mm (1 ± 0.04 in.), in such a way that the original (uncut) face is evaluated.

8.6.4 Samples of multilayer materials, products, or assemblies, with a thickness greater than 25 mm (1 in.), consisting of core material(s) with facings of different materials shall be prepared in accordance with 8.6.3, by cutting from the layers behind the facing one (see also 8.7.2).

8.7 *Specimen Assembly and Mounting:*

8.7.1 *General*—The specimen shall be representative of the materials or composite and shall be prepared in accordance with recommended application procedures. Flat sections of the same thickness and composition are to be tested rather than curved, molded, or specialty parts. Substrate or core materials for the test specimens shall be the same as those for the intended application. If a material or assembly has the potential to be exposed to a fire on either side, both sides shall be tested. If an adhesive is intended for field application of a finish material or substrate, the prescribed type of adhesive and the spreading rate recommended for field application of the assembly of test specimen shall be used and the details shall be reported.

8.7.2 *Finish Materials*—Finish materials, including sheet laminates, tiles, fabrics, and others secured to a substrate material with adhesive, and composite materials not attached to a substrate, have the potential to be subject to delamination, cracking, peeling, or other separations affecting their smoke generation. To evaluate these effects, it is often necessary to perform supplementary tests on a scored (split) exposed surface, or on interior layers or surfaces. When supplementary tests are conducted for this purpose, the manner of performing such supplementary tests, and the test results, shall be included in the report, together with the test results from the conventional tests.

8.7.2.1 *Finish Materials without Substrate or Core*—For comparative tests of finish materials without a normal substrate or core, and for screening purposes only, the following procedures shall be employed:

8.7.2.2 Rigid or semirigid sheet materials shall be tested by the standard procedure regardless of thickness.

8.7.2.3 In the absence of a specified assembly system, veneers that are not rigid or semi-rigid sheet materials, intended for application to combustible substrate materials, shall be applied to the smooth face of ¼-in. (6.4 mm) nominal tempered hardboard, complying with ANSI/AHA A135.4 "Basic Hardboard", using recommended application techniques and coverage rates. Supplementary tests shall also be conducted on the hardboard alone, and these values shall be recorded as supplemental to the measured values for the composite specimen. Both sets of values shall be reported.

NOTE 3—Tempered hardboard sheets conforming to ANSI/AHA A135.4 are marked with a 0.5 in. (12.7 mm) wide single red stripe placed