NFPA No.

258

SMOKE GENERATED BY SOLID MATERIALS 1976

NATIONAL FIRE PROTECTION ASSOCIATION
470 Atlantic Avenue, Boston, MA 02210

3M-7-76-FP
Printed in U.S.A.

See Inside Back Cover for Official NFPA Definitions

Standard Test Method for Measuring the Smoke Generated by Solid Materials

NFPA 258 — 1976

Origin and Development of NFPA 258

The smoke problem which develops during unwanted fires has been recognized for years. There is continuing recognition of the importance of combustion products in playing a major role in the majority of fire fatalities. Fire fighters are faced with the smoke problem daily in their work.

The many ways in which fire gases influence the hazard to life have, so far, precluded an exact technical assessment of them. A test method, such as the one discussed in this Standard, has obvious merit as a measurement tool for assisting in research, development, and production quality control of materials and products. Use of the test method for rough analysis of the smoke production during an actual fire is informative in showing the magnitude of the smoke problem.

The smoke density chamber provides a means for characterizing smoke production with an accuracy far in excess of any application requirements which should be recommended. It also provides a means for reporting rate of smoke production and time at which specific smoke levels are reached under the test conditions applied.

The concept of specific optical density, while old in terms of photometric practice, was first introduced for measuring smoke as part of the smoke density chamber test method. It is based on Bouguer's law and permits reporting smoke developed in terms which recognize the area of the specimen involved, the volume of the box, and the optical path length of the photometer. The test method was developed at the National Bureau of Standards and first described publicly in 1967. Since then there have been numerous publications reporting on its application and on studies of the correlation of results of interlaboratory tests through its use.

This Standard was first adopted by the NFPA as a Tentative Standard in 1974. The current edition was adopted as a Standard at the NFPA Annual Meeting on May 19, 1976.

Committee on Fire Tests

Jack A. Bono, *Chairman*
Underwriters Laboratories Inc., 333 Pfingsten Rd., Northbrook, IL, 60062

M. S. Abrams, Portland Cement Association
Irwin A. Benjamin, National Bureau of Standards
James R. Bercaw, duPont Company, Wilmington, DE (rep. Man-Made Fiber Producers Assoc.)
John A. Blair, E. I. duPont de Nemours & Co., Plastics Dept., Society of the Plastics Industry
Herbert B. Carlsen, Gypsum Assn.
Robert W. Dougherty, M & M Protection Consultants
Buell B. Dutton (rep. Building Officials & Code Administrators International, Inc.)
Richard G. Gewain, American Iron & Steel Institute
George B. Krumholz, Jr., U.S. Testing Co., Inc. (vote restricted to matters pertaining to textiles)
Gerald E. Lingenfelter, American Insurance Assn.
W. F. Maroni, Factory Mutual Research Corp.
William H. McLain, Southwest Research Institute
E. E. Miller, Industrial Risk Insurers
Norman S. Pearce, Underwriters' Laboratories of Canada
T. P. Pritsker, The Dallas Laboratories
Dr. A. F. Robertson, Institute of Applied Technology, National Bureau of Standards
John Ed Ryan, National Forest Products Assn.
Louis Segal, Office of State Fire Marshal, Los Angeles, CA (rep. Fire Marshals Assn. of North America)
Herman Spaeth, ISO
K. Sumi, National Research Council of Canada
Louis W. Vaughan, Canadian Sheet Steel Building Institute

Alternates

J. S. Barritt, Industrial Risk Insurers (Alternate to E. E. Miller)
David E. Brackett, Gypsum Assn. (Alternate to Herbert B. Carlsen)
R. Buchan, National Forest Products Assn. (Alternate to John Ed Ryan)
B. J. Callahan, Factory Mutual Engineering (Alternate to W. F. Maroni)
Peter McOrmand, ISO (Alternate to Herman Spaeth)
G. M. Watson, American Insurance Assn. (Alternate to Gerald E. Lingenfelter)

Nonvoting Member

A. J. Bartosic, Rohm & Haas Co.

This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

Interpretation Procedure of the Committee on Fire Tests

Those desiring an interpretation shall supply the Chairman with five identical copies of a statement in which shall appear specific reference to a single problem, paragraph, or section. Such a statement shall be on the business stationery of the inquirer and shall be duly signed.

When applications involve actual field situations they shall so state and all parties involved shall be named.

The Interpretations Committee will reserve the prerogative to refuse consideration of any application that refers specifically to proprietary items of equipment or devices. Generally inquiries should be confined to interpretation of the literal text or the intent thereof.

Requests for interpretations should be addressed to the National Fire Protection Association, 470 Atlantic Avenue, Boston, MA 02210.

TABLE OF CONTENTS

Standard Test Method for Measuring the Smoke Generated by Solid Materials

NFPA 258 – 1976

Chapter 1 General

1-1 Scope. This method of test covers a procedure for measuring the smoke generated by solid materials and assemblies in thickness up to and including 1 inch (25.4mm). Measurement is made of the attenuation of a light beam by smoke (suspended solid or liquid particles) accumulating within a closed chamber due to nonflaming pyrolytic decomposition and flaming combustion. Results are expressed in terms of specific optical density,[1] which is derived from a geometrical factor and the measured optical density (absorbance).

1-2 Significance[2,3]

1-2.1 This method provides a means for comparing the specific optical density of the smoke generated by materials and assemblies in the form and thickness tested, and under the specified exposure conditions.

1-2.2 Values determined by this test are specific to the specimen or assembly material in the form and thickness tested and shall not be considered inherent, fundamental properties of a given material.

1-2.3 This test is intended for use in research and development and not as a basis for ratings for building code purposes. At the present time, no basis is provided for predicting the density of smoke which may be generated by the materials upon exposure to heat and flame under other fire conditions.

---

[1]A commentary describing the significance of specific optical density and appropriate considerations for application of test results is included as Appendix C.

[2]Attempts are now underway to relate the results of this test to the measurement of smoke generated under large-scale test conditions. Other test methods for measuring smoke have been reviewed and summarized in "The Control of Smoke in Building Fires — A State-of-the-Art Review," *Materials Research and Standards,* pp. 16-23, 42, April 1971.

[3]The values stated in U.S. customary units shall be regarded as the standard. The metric equivalent of U.S. customary units given in the standard may be approximate.

1-2.4 Values determined by this test are specific to the effect of attenuation of light transmission within the chamber of the smoke generated by the material in the form, thickness, and quantity tested when subjected to the energy sources specified. These values by themselves do not provide a basis of predicting material performance in actual fires.

1-3 Summary of Method

1-3.1 This method for measuring the smoke generated by materials employs an electrically heated radiant energy source mounted within an insulated ceramic tube and positioned so as to produce an irradiance level of 2.2 Btu/sec ft.^{2} (2.5 W/cm^2) averaged over the central 1.5 in. (38.1 mm) diameter area of a vertically mounted specimen facing the radiant heater. The nominal 3 in. by 3 in. (76.2 mm by 76.2 mm) specimen is mounted within a holder which exposes an area measuring $2\frac{9}{16}$ in. by $2\frac{9}{16}$ in. (65.1 mm by 65.1 mm). The holder can accommodate specimens up to 1 in. (25.4 mm) thick. This exposure provides the nonflaming condition of the test.

1-3.2 For the flaming condition, a six-tube burner is used to apply a row of equidistant premixed (air-propane) flamelets across the lower edge of the exposed specimen area and into the specimen holder trough. This application of flame, in addition to the specified irradiance level from the heating element, constitutes the flaming combustion exposure.

1-3.3 The test specimens are exposed to the flaming and nonflaming conditions within a closed 18 ft.^{3} (0.51 m^3) chamber. A photometric system with a 36 in. (914 mm) vertical light path measures the continuous decrease in light transmission as smoke accumulates. Exposure is continued either for 20 minutes or until minimum light transmission is reached, whichever occurs first.

1-3.4 Calibration procedures for the test equipment, as described in A-2, shall be followed.

1-3.5 The light transmittance measurements are used to express the smoke generated by the test materials in terms of the specific optical density during the time period to reach the maximum value.[1]

---

[1]Additional parameters, such as the maximum rate of smoke accumulation, the time to a fixed optical density level, or a smoke obscuration index may be more appropriate in particular situations.

Chapter 2 Test Apparatus

2-1 The apparatus shall be essentially as shown in Figures 2-1A and 2-1B.[1] The apparatus shall include that given in 2-2 through 2-11.

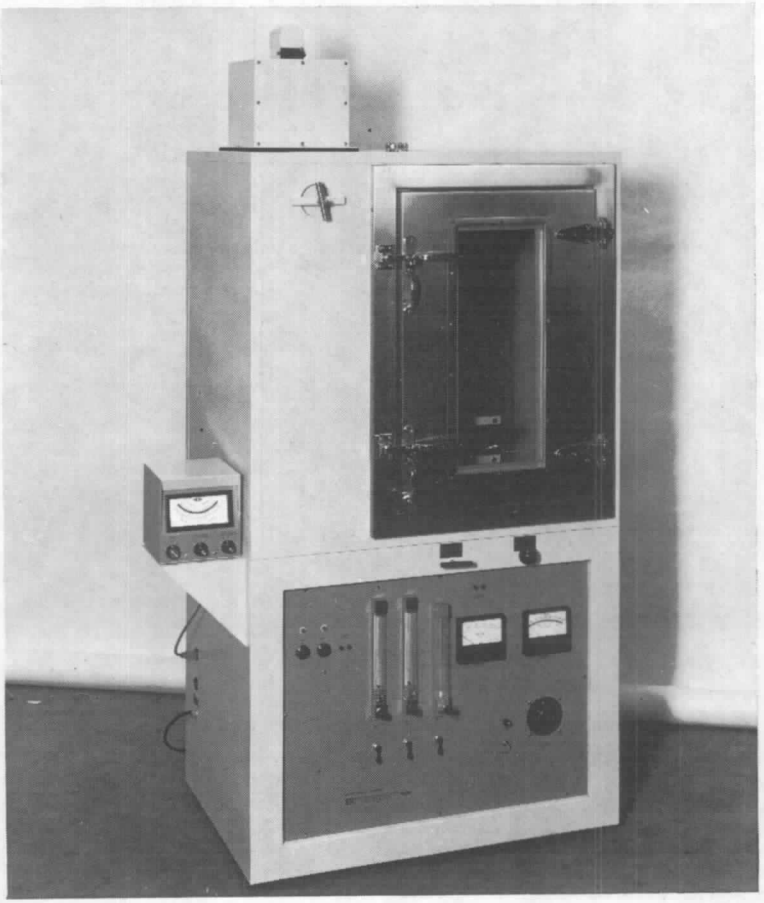
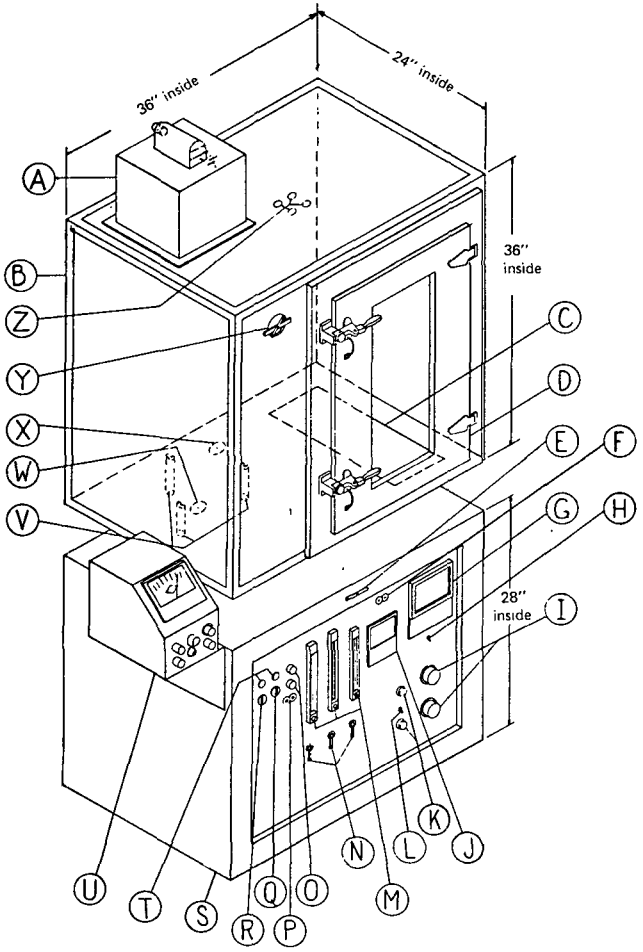


Figure 2-1A.

[1] A more detailed description of suggested details is given in A-1.



A — Phototube Enclosure
B — Chamber
C — Blowout Panel
D — Hinged Door with Window
E — Exhaust Vent Control
F — Radiometer Output Jack
G — Temperature (Wall) Indicator
H — Temperature Indicator Switch
I — Autotransformers
J — Voltmeter (furnace)
K — Fuse Holders
L — Furnace Heater Switch
M — Gas & Air Flowmeters
N — Gas & Air Shutoff Valves
O — Light Intensity Controls
P — Light Voltage Measuring Jack
Q — Light Source Switch
R — Line Switch
S — Support Frame
T — Indicating Lamps
U — Photometer Readout
V — Rods
W — Glass Window
X — Exhaust Vent
Y — Inlet Vent
Z — Access Ports

Figure 2-1B. Smoke Density Chamber Assembly.

2-2 Test Chamber

2-2.1 As shown in Figure 2-1B, the test chamber shall be fabricated from laminated panels[1] to provide inside dimensions of 36 in. by 24 in. by 36. in. ± ⅛ in. (914 mm by 610 mm by 914 mm ± 3 mm) for width, depth, and height, respectively.

2-2.2 The interior surfaces shall consist of porcelain-enameled metal or equivalent coated metal, resistant to chemical attack and corrosion, and suitable for periodic cleaning.

2-2.3 Sealed openings shall be provided to accommodate a vertical photometer, power and signal connectors, air and gas supply tubes, exhaust blower, inlet and exhaust vents, pressure and gas sampling taps, a pressure relief valve, a rod for remote positioning of the specimen holder, an aluminum foil [0.0010 in. (approx. 0.025 mm) or less] safety blowout panel at least 125 in.^{2} (806 cm^2) in area, and a hinged front-mounted door with an observation port or window.

2-2.4 All openings shall be located on the floor of the chamber.

Exception: The gas sampling taps, the positioning rod, and an inlet vent.

2-2.5 When all openings are closed, the chamber shall be capable of developing and maintaining positive pressure during test periods, in accordance with 4-10.

2-3 Radiant Heat Furnace

2-3.1 An electric furnace with a 3 in. (76.2 mm) diameter opening, as shown in Figure 2-3, shall be used to provide a constant irradiance on the specimen surface.

2-3.2 The furnace shall be located along the centerline equidistant between the front and back of the chamber, with the opening facing toward and about 12 in. (305 mm) from the right wall.

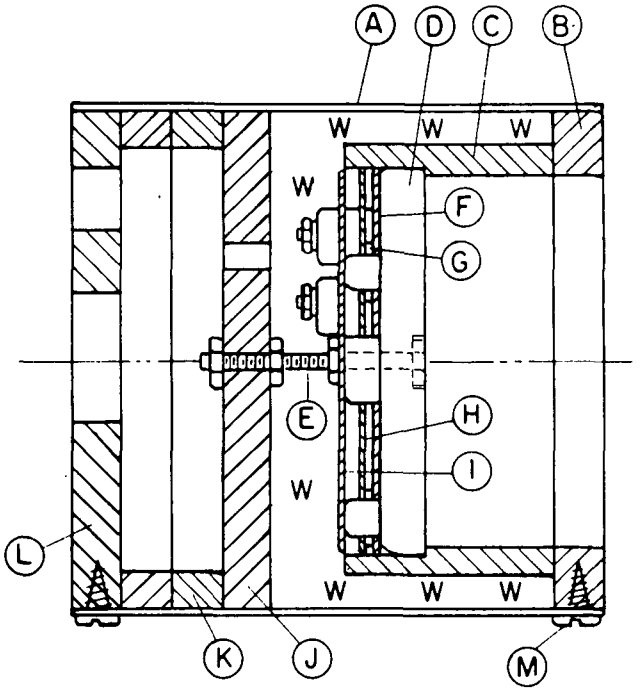
2-3.3 The centerline of the furnace shall be about 7¾ in. (195 mm) above the chamber floor.

2-3.4 Furnace Control System

2-3.4.1 The furnace control system shall maintain the required irradiance level under steady-state conditions with the chamber door closed to within ± .04 Btu/sec ft.^{2} (± .05 W/cm^2) for 20 minutes.

---

[1]Commercially available panels of porcelain-enamel steel (interior surface) permanently laminated to asbestos-cement board and backed with galvanized steel (exterior surface), with a total thickness 3/16 in., have been found suitable.



A — Stainless Steel Tube
B — Asbestos Board
C — Ceramic Tube
D — Heating Element, 525 W
E — Stainless Steel Screw
F — Asbestos Paper Gasket
G — Stainless Steel Spacing Washers (3)
H — Stainless Steel Reflector
I — Stainless Steel Reflector
J — Asbestos Board
K — Asbestos Board Rings
L — Asbestos Board Cover
M — Sheet Metal Screws
W — Pyrex Glass Wool

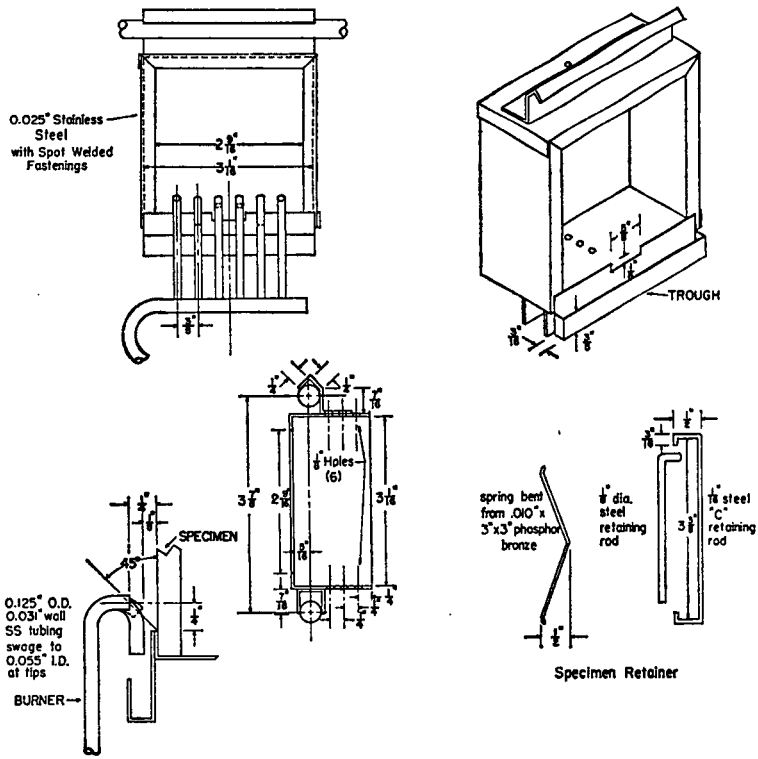
Figure 2-3. Furnace Section.

2-3.4.2 The control system shall consist of an autotransformer or alternate control device and a voltmeter or other means for monitoring the electrical output.[1]

2-4 Specimen Holder

2-4.1 Specimen holders shall conform in shape and dimension to that shown in Figure 2-4, and shall be fabricated to expose a $2\frac{9}{16}$ in. by $2\frac{9}{16}$ in. (65.1 mm by 65.1 mm) specimen area. Also shown in Figure 2-4 are the spring and rods for retaining the specimen within the holders.

[1]Where line voltage fluctuations are present, a constant-voltage transformer may be required to maintain the prescribed irradiance level.



DETAILS OF SPECIMEN HOLDER AND PILOT BURNER

Figure 2-4. Details of Specimen Holder and Pilot Burner.

2-5 Framework for Support of the Furnace and Specimen Holder. The furnace and specimen supporting framework shall be constructed essentially in accordance with Figure 2-5.

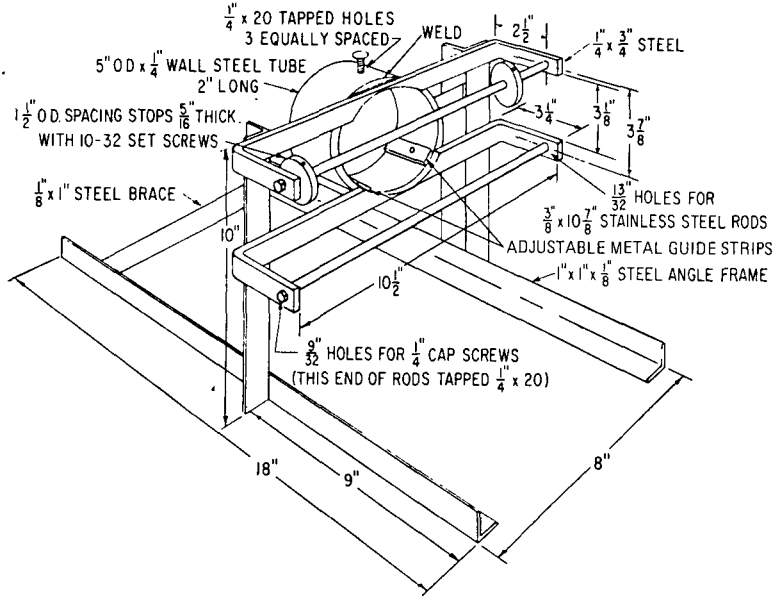


Figure 2-5. Furnace Support.

2-6 Photometric System

2-6.1 The photometric system shall consist of a light source and photodetector, oriented vertically to reduce variations in measurement brought about by stratification of the smoke generated by materials under test.

2-6.2 The system shall be as shown in Figures 2-6A and 2-6B and include the following:

(a) The *light source* shall be an incandescent lamp operated at a fixed voltage in a circuit powered by a voltage regulating transformer. The light source shall be mounted in a sealed and

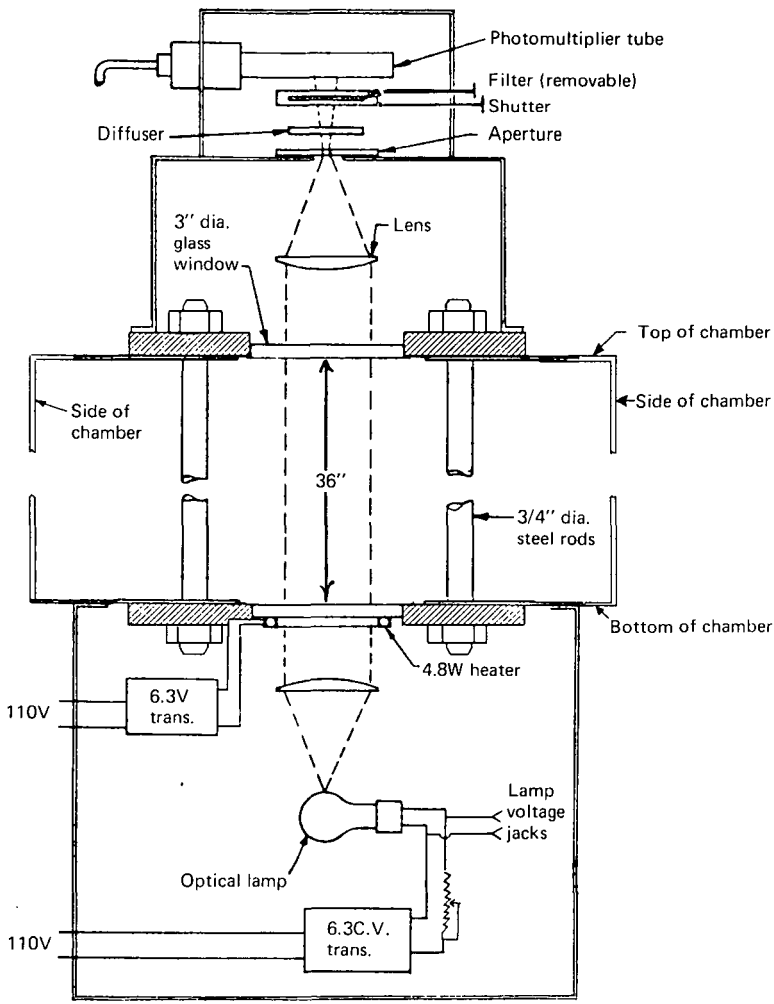


Figure 2-6A. Photometer Details.

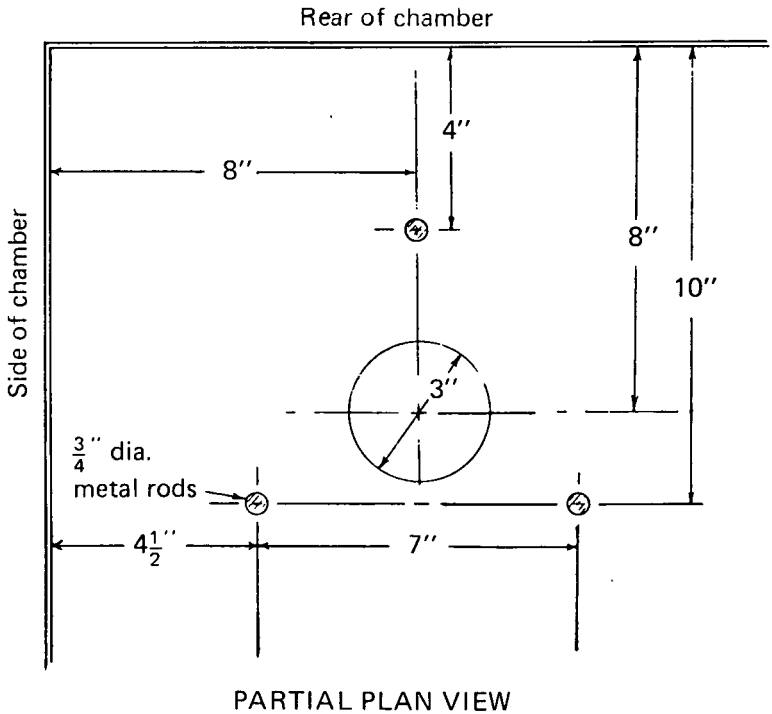


Figure 2-6B. Photometer Location.

light-tight box located below the chamber. This box shall contain the necessary optics to provide a collimated light beam passing vertically through the chamber.

(b) The *photodetector* shall be a photomultiplier tube, with an S-4 spectral sensitivity response and a dark current less than 10^{-9}A. A sealed box located directly opposite the light source shall be provided to house the photodetector and the focusing optics. A glass window shall be used to isolate the photodetector and its optics from the interior of the chamber.

2-7 Radiometer

2-7.1 The radiometer for standardizing the output of the radiant heat furnace shall be of the circular foil type, the operation of which was described by Gardon.[1]

[1]R. Gardon, "An Instrument for the Direct Measurement of Intense Thermal Radiation," *Review of Scientific Instruments,* Vol. 24, pp. 366-370 (1953).

2-7.2 The construction of the radiometer shall be as shown in Figure 2-7.

2-7.3 The radiometer shall have a stainless steel reflective heat shield with a 1½ in. (38.1 mm) aperture on the front and a finned cooler supplied with compressed air mounted on the rear to maintain a constant body temperature of 200 ±5°F (93 ±3°C).

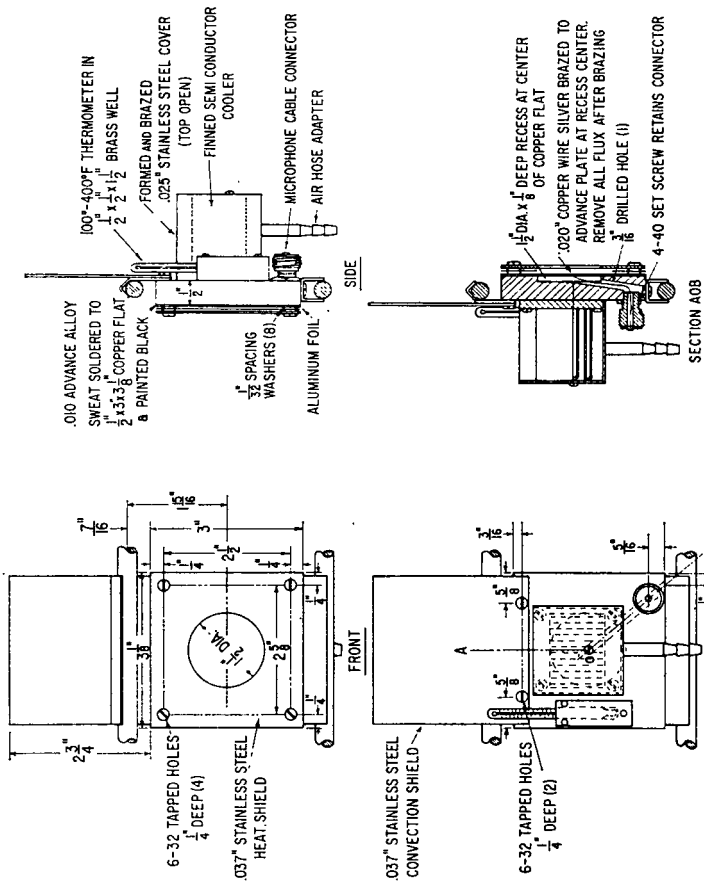


Figure 2-7. Radiometer Detail.

2-8 Thermocouples for Determining Chamber Wall Temperature. A thermocouple shall be provided for determining the chamber wall temperature prior to testing.

2-9 Portable Recorder or Read-Out Meter

2-9.1 The outputs of the radiometer and the thermocouples shall be monitored by a suitable recorder or read-out meter.

2-9.2 The photodetector output shall be recorded or monitored with a potentiometer or other suitable instrument capable of measurement over a range of 5 decades, or more. *(see A-1.4.)*

2-10 Manometer for Chamber Pressure Measurements

2-10.1 A simple water manometer with a range up to 6 in. (152 mm) of water shall be provided to monitor chamber pressure and leakage. *(See A-2.3.)*

2-10.2 The pressure measurement point shall be through a gas sampling hole at the top of the chamber.

2-10.3 A simple water column or relief valve shall be provided to permit control of chamber pressure. *(See A-1.8.)*

2-11 Multiple Flamelet Burner with Premixed Air-Propane Fuel

2-11.1 For a flaming exposure test, a six-tube burner, with construction details as shown in Figure 2-4, shall be used.

2-11.2 The burner shall be centered in front and parallel to the specimen holder.

2-11.3 The tips of the two horizontal tubes shall be centered $\frac{1}{4} \pm \frac{1}{16}$ in. (6.4 ± 1.6 mm) above the holder edge and $\frac{1}{4} \pm \frac{1}{16}$ in. (6.4 ± 1.6 mm) away from the specimen surface.

2-11.4 Provision shall be made to rotate or move the burner out of position during nonflaming exposures.

2-11.5 A premixed air and propane (95% purity or better) test gas shall be used.

2-11.6 The air and propane shall be metered by calibrated flowmeters and needle valves at 500 cm^3/min. for air and 50 cm^3/min. for the propane.

Chapter 3 Test Specimens

3-1 Specimen Description

3-1.1 Size

3-1.1.1 The test specimens shall be 3 in. by 3 in. ± .03 in. (76.2 mm by 76.2 mm ± 0.7 mm) by the intended installation thickness up to and including 1 in. (25.4 mm) thickness.

3-1.1.2 Specimens provided in thicknesses in excess of 1 in. (25.4 mm) shall be sliced to 1 in. (25.4 mm) thickness and the original (uncut) surface tested.

3-1.1.3 Multilayer materials greater than 1 in. (25.4 mm) thick, consisting of a core material with surface facings of different materials, shall be sliced to 1 in. (25.4 mm) thickness, and each original (uncut) surface shall be tested separately if required under 3-1.3.

3-1.2 Specimen Orientation

3-1.2.1 If visual inspection of the specimen indicates a pronounced grain pattern, process-induced surface orientation, or other nonisotropic property, the specimen shall be tested in two or more orientations.

3-1.2.2 The highest smoke density value and the test orientation shall be stated.

3-1.3 Specimen Assembly

3-1.3.1 The specimen shall be representative of the material or composite and shall be prepared in accordance with recommended application procedures.[1]

Exception: Flat sections of the same thickness and composition may be supplied and tested in place of curved, molded, or specialty parts.

3-1.3.2 Where an adhesive is intended for field application of a finish material to a substrate, the prescribed type of adhesive and its spreading rate shall be noted and used for test.

---

[1]Substrate or core materials for the test specimens should be the same as those for the intended application. Where a material or assembly may be exposed to a potential fire on either side, both sides should be tested.

3-1.3.3 When supplementary tests are necessitated by delamination, cracking, peeling, or other separations affecting smoke generation, the manner of performing such supplementary tests, and the test results, shall be included in the report with the conventional test.[1]

3-1.3.4 For comparative tests of finish materials without a normal substrate or core and for screening purposes only, the following procedures shall be employed:

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

(b) Liquid films (paints, adhesives, etc.), intended for application to combustible base materials, shall be applied to the smooth face of ¼ in. (6.4 mm) thick tempered hardboard, nominal density 50 lb./ft.^{3} to 60 lb./ft.^{3} (0.8 g/cm^3 to 0.97 g/cm^3), using recommended (or practical) application techniques and coverage rates. Tests shall also be conducted on the hardboard substrate alone, and these values shall be recorded as supplemental to the measured values for the composite specimen.

(c) Liquid films (paints, adhesives, etc.), intended for application to noncombustible substrate materials, shall be applied to the smooth face of ¼ in. (6.4 mm) thick asbestos-cement board, nominally 120 lb./ft.^{3} (1.9 g/cm^3) in density, using recommended (or practical) application techniques and coverage rates.

3-2 Number of Test Specimens. Three tests under flaming exposure and three tests under nonflaming exposure shall be conducted on each material (total of six specimens) in accordance with the conditions described herein.

3-3 Specimen Conditioning. Specimens shall be predried for 24 hrs at 140 ± 5°F (60 ± 3°C), then conditioned to equilibrium (constant weight) with an ambient temperature of 73 ± 5°F (23 ± 3°C) and a relative humidity of 50 ± 5 percent.

3-4 Specimen Mounting

3-4.1 All specimens shall be covered across the back, along the edges, and over the front surface periphery with a single sheet of aluminum foil (0.0015 ± 0.0005 in. or approximately 0.04 mm).

[1]Finish materials, including sheet laminates, tiles, fabrics, and others secured to a substrate material with adhesive, and composite materials not attached to a substrate, may be subject to delamination, cracking, peeling, or other separations affecting their smoke generation. To evaluate these effects, supplementary tests, performed on a scored (slit) exposed surface or on interior layers or surfaces, may be necessary.

3-4.2 Care shall be taken not to puncture the foil or to introduce unnecessary wrinkles during the wrapping operation.

3-4.3 Foil shall be folded in a way to minimize losses of melted material at the bottom of the holder.

3-4.4 Excess foil along the front edges shall be trimmed off after mounting. A flap of foil should be cut and bent forward at the spout to permit flow from melting specimens.[1]

3-4.5 All specimens shall be backed with a sheet of asbestos millboard. *(See Section 2-4.)*

3-4.6 The specimen and its backing shall be secured with the spring and retaining rod. A modified "C" shape retaining rod shall be used with specimens from 5/8 to 1 in. (1.6 to 2.5 cm) thick.

3-4.7 Flexible specimens shall not be compressed below their normal thickness.

3-4.8 It is the intent of this test method to maintain the prescribed exposure conditions on the specimen for the test duration. If under either the flaming or nonflaming exposure, there is an excess of melted material which overflows the trough, the specimen area should be reduced, e.g. if the area is reduced to 1½ in. wide by 3 in. high (38.1 mm by 76.2 mm) centrally located, the appropriate area should be used in calculating D_s. *(See Section 5-1.)*

[1]Problems associated with interpretation of experimental results when unburned molten drips occur are discussed in Appendix C.

Chapter 4 Test Procedure

4-1 All tests shall be conducted in a room or enclosed space having an ambient temperature of 73 ± 5°F (23 ± 3°C) and relative humidity of 50 ± 20 percent at the time of test. Precautions should be taken to provide a means for removing potential hazardous gases from the area of operation.

4-2 Equipment Cleaning[1]

4-2.1 The chamber walls shall be cleaned whenever periodic visual inspection indicates the need.[2]

4-2.2 The exposed surfaces of the glass windows separating the photodetector and light source housing from the interior of the chamber shall be cleaned before each test (ethyl alcohol is generally effective).

4-3 Warm-up of Furnace[3]

4-3.1 During the warm-up period all electric systems (furnace, light source, photometer readout, etc.) shall be on, the exhaust vent and chamber door closed, and the inlet vent open.

4-3.2 When the temperature on the center surface of the back wall reaches a steady-state value in the range of 95 ± 4°F (35 ± 2°C), the chamber is ready for furnace calibration or testing.

4-3.3 The furnace output irradiance shall be calibrated, without the burner in place, at periodic intervals according to test experience (normally twice per test day).

4-3.4 A "blank" specimen holder, with the asbestos millboard exposed, shall always be directly in front of the furnace.

Exception: When displaced to the side by (1) the specimen holder during a test or (2) the radiometer during calibration.

The specimen holder shall be returned immediately to the above position when testing or calibration is completed.

---

[1]Charred residues on the specimen holder and horizontal rods should be remove to avoid contamination.

[2]An ammoniated spray detergent and soft scouring pads have been found effective.

[3]To increase chamber wall surface temperature to the stated level under adverse conditions, an auxiliary heater may be used. Conversely, to decrease this temperature, the exhaust blower may be used to introduce cooler air from the laboratory.

4-3.5 During calibration, the radiometer shall be placed on the horizontal rods of the furnace support framework and accurately positioned in front of the furnace opening by sliding and displacing the "blank" specimen holder against the prepositioned stop. The furnace support framework, stop, and "blank" specimen holder shall provide for the horizontal and vertical centering within ± 1/16 in. (1.6 mm) with respect to the furnace opening of the radiometer during calibration and of the loaded specimen holder during test.

4-3.6 With the chamber door closed and inlet vent opened, the compressed air supply to the radiometer cooler shall be adjusted to maintain its body temperature at 200 ± 5°F (93 ± 3°C).

4-3.7 The autotransformer setting shall be adjusted so as to obtain the calibrated millivolt output of the radiometer corresponding to a steady-state irradiance of 2.2 ± .04 Btu/sec. ft.^{2} (2.5 ± .05 W/cm^2) averaged over the central 1.5 in. (38.1 mm) diameter area.

4-3.8 The recorder or meter described in 2-9 shall be used to monitor the radiometer output. After the prescribed irradiance level has reached steady-state, the radiometer shall be removed from the chamber and replaced with the "blank" specimen holder.

4-3.9 After the system has reached steady-state conditions, the meter and/or recorder zero shall be adjusted.

4-3.10 The amplifier sensitivity shall be adjusted to obtain a full-scale reading of the photodetector (100 percent transmittance) on the recorder or readout meter.

4-3.11 The "dark current" (zero percent transmittance) on the maximum sensitivity range of the read-out meter shall be determined by blocking the light, and the "dark current" reading shall be adjusted to zero.

4-4 Burner Positioning. For nonflaming exposures, the multiple flamelet burner shall be removed. For flaming exposures, the burner shall be positioned across the lower edge of the specimen as described in 2-11. (Check the burner distances relative to the "blank" specimen before fuel adjustment and ignition.)

4-5 Before positioning the test specimen, the chamber shall be flushed for about 2 minutes with the door and exhaust and inlet vents open and the starting temperature of the chamber shall be verified using the procedure described in 4-3.1 and 4-3.2.

4-6 Then the exhaust vent and blower shall be closed.

4-7 The loaded specimen holder shall be placed on the bar support and pushed into position in front of the furnace (with burner in position for flaming exposure) by displacing the "blank" holder.

4-8 The chamber door shall be quickly closed and the timer and/or recorder chart drive shall be simultaneously started. The inlet vent shall be closed completely only when the photometer indicates smoke.

4-9 Light transmittance and the corresponding time shall be recorded, either as a continuous plot with a multirange recorder or at sufficient time intervals with a multirange meter readout. (Make and note the necessary full-scale range changes in decade steps.)

4-10 The increase in chamber pressure shall be observed with the manometer described in 2-10. A regulator *(see A-1.8)* shall be used to maintain the pressure in the range of 4 ± 2 in. (100 ± 50 mm) of water during most of the test. If negative pressure develops after very intense specimen flaming, the inlet vent shall be opened slightly to equalize the pressure. As a result of pressure rise, the fuel and air valves shall be adjusted during the flaming test to maintain constant flow rate.

4-11 Any observations pertinent to the burning and smoke generating properties of the material under test shall be recorded in accordance with 6-6 and 6-7.

4-12 The test shall continue for 20 minutes or until a minimum light transmittance value is reached, whichever occurs first. If the minimum light transmittance does not occur within the 20 minute exposure period, this shall be noted in reporting the results.

4-13 If transmittance falls below 0.01%, the chamber window shall be covered with an opaque screen to avoid possible light scattering effects from room light. Also, any supplementary optical filter in the photometer system shall be removed or displaced in order to extend the measuring range. (If extraneous light can reflect into the photometer during removal of the filter, turn the high voltage off or adjust the scale to minimize sensitivity. Replace the filter before exhausting smoke from the chamber.)

4-14 The burner on flaming exposures shall be extinguished and exhausting the chamber shall be initiated within one minute after reaching minimum transmittance.[1] The specimen shall be displaced from the front of the furnace by pushing the "blank" specimen holder with the positioning rod. Exhausting shall continue with the inlet vent open until maximum transmittance is reached. (Record this transmittance value as the T_c, "clear beam" reading, which is to be used to correct for deposits on the photometer windows.)

[1]In some cases the transmittance may increase somewhat and subsequently decrease to the ultimate minimum transmittance.

Chapter 5 Calculations

5-1 Calculate specific optical density, D_s, from the percent light transmittance, T, caused by the smoke generated from an exposed specimen area, A, in the closed chamber of volume, V, and over a light path, L, as follows:

$$D_s = \frac{V}{AL}\left[\log_{10}\left(\frac{100}{T}\right)\right] = G\left[\log_{10}\left(\frac{100}{T}\right)\right]$$

where G represents the geometrical factor associated with the dimensions of the chamber and specimen. Corrections for the volume of the furnace assembly and the volume included in the door recess are generally less than 1 percent and may be neglected.

When it is necessary to remove the neutral density filter *(see A-1.4)* to measure low levels of light transmittance, the specific optical density appropriate for the filter shall be added. The value to be added is equal to the known optical density of the filter *(see A-2.1.3)* multiplied by G.

5-2 Calculate the maximum specific optical density, D_m, using the formula in 5-1 with a light transmittance corresponding to the minimum level reached during the test. Correct all maximum specific optical density values by subtracting the specific optical density equivalent for soot and other deposits on the photometer windows. As described in 4-14, the "clear beam" transmittance reading T_c is used to calculate a specific optical density equivalent D_c, using the same formula but with different subscript. A corrected maximum specific optical density calculation is expressed as follows:

$$D_m \text{ (corr.)} = D_m - D_c$$

5-3 For systems without "dark current" cancellation, a correction shall be made for any percent light transmittance reading T, approaching the dark current value T_d. The corrected percent light transmittance T′, shall be obtained from:

$$T' = 100\left[1 - \frac{100 - T}{100 - T_d}\right] = 100\left[\frac{T - T_d}{100 - T_d}\right]$$

and shall be used for the specific optical density calculations described in 5-1 and 5-2.

Chapter 6 Report[1]

6-1 The report *(see Appendix B)* shall include the following:

(a) Complete description of the specimen tested including: Type, manufacturer, shape, thickness and/or other appropriate dimensions, weight or density, coloring, etc.

(b) Complete description of the test specimens, including: Substrate or core, special preparation, mounting, etc.

(c) Test specimen conditioning procedure.

(d) Number of specimens tested.

(e) Test conditions: Type of exposures, type of holder used, exposure period.

(f) Observations of the burning or smoldering characteristics of the specimens during test exposure, such as delamination, sagging, shrinkage, melting, collapse, etc.

(g) Observations of the smoke generating properties of the specimens during exposure, such as color of the smoke, nature of the settled particulate matter, etc.

(h) A record of the geometrical factor, G, as calculated from measured values of chamber volume, V, photometer light path length, L, and exposed specimen area, A. *(See Chapter 5 on Calculations.)*

(i) Test results calculated as described in Chapter 5, including the average and range on each set of specimens for D_m (corr.), and D_c. Sufficient test results should allow development of a smooth curve of D_s versus time.

6-2 If the test is terminated on the basis of a 20-minute exposure limitation, this fact shall be noted when reporting measurements observed at that time.

---

[1]Analysis of products of combustion. Although not specifically required as part of the method, products of combustion may be drawn from the chamber at various times during the progress of the test for analysis. The physical properties of the smoke may be investigated by electrostatic or impact collection and various methods of particle analysis. The presence and concentrations of various toxic and irritating gaseous products may be determined using colorimetric gas detector tubes, gas chromatography methods, ion-selective electrodes, or other techniques.

Appendix A

Apparatus Construction and Calibration

A-1 Construction Details

A-1.1 Radiant Heat Furnace *(see 2-3).* The furnace consists of a coiled wire or other suitable electrical heating element (525 W or greater) mounted vertically in a horizontal ceramic tube 3 in. (76.2 mm) i.d. by 3⅜ in. (85.7 mm) o.d. by 1⅝ in. (41.3 mm) long. The tube is bored out at one end to 3 1/32 in. (77.0 mm) i.d. and to a depth of ⅝ in. (15.9 mm) to accommodate the heating element. A 1/16 in. (1.6 mm) asbestos paper gasket, three stainless steel reflectors are mounted behind the heating element. A ⅜ in. (9.5 mm) asbestos millboard disc, provided with ventilation and lead wire holes, is positioned behind the heating element and used to center the assembly with respect to front ⅜ in. (9.5 mm) asbestos millboard ring by means of a 6-32 stainless steel screw. The adjustment nuts on the end of the centering screw provide proper spacing of the furnace components. The cavities adjacent to the heating element assembly are to be packed with glass wool. The furnace assembly is housed in a 4 in. (102 mm) o.d. by 0.083 in. (2.1 mm) wall by 4⅛ in. (10.5 cm) long stainless steel tube. Two additional ⅜ in. (9.5 mm) asbestos board spacing rings and a rear cover of ⅜ in. (9.5 mm) asbestos board complete the furnace. The furnace is to be located centrally along the long axis of the chamber with the opening facing toward and about 12 in. (305 mm) from the right wall. The centerline of the furnace is about 7¾ in. (195 mm) above the chamber floor.

A-1.2 Specimen Holder *(see 2-4).* The specimen holder is to conform in shape and dimension to Figure 2-4 and to be fabricated by bending and brazing (or spot welding) 0.025 in. (0.6 mm) thick stainless steel to provide a 1½ in. (38.1 mm) depth, and to expose a 2 9/16 in. by 2 9/16 in. (65.1 mm by 65.1 mm) specimen area. As described in 2-5 the holder is to have top and bottom guides to permit accurate centering of the exposed specimen area in relation to the furnace opening. A 3 in. by 3 in. (76.2 mm by 76.2 mm) sheet of ½ in. (12.7 mm) asbestos millboard, having a

nominal density of 50 ± 10 lb/ft.^{3} (0.85 ± 0.17 g/cm^3), is to be used to back the specimen. A spring bent from 0.010 in. (approximately 0.25 mm) thick phosphor bronze sheet is to be used with a steel retaining rod to securely hold the specimen and millboard backing in position during testing.

A-1.3 Support of Furnace and Specimen Holder *(see 2-5).* The framework as shown in Figure 2-5 has welded to it a 5 in. (12.7 cm) o.d., ¼ in. (6.4 mm) wall, 2 in. (50.8 mm) long horizontally oriented steel tube to support the radiant heat furnace described in 2-3. This support tube is to have provision to accurately align the furnace opening so that it is: (1) 1½ in. ± 1/16 in. (38.1 mm ± 1.6 mm) away from, (2) parallel to and (3) centered horizontally and vertically to within ± 1/16 in. (1.6 mm) with respect to the exposed specimen area. Three tapped holes with screws equidistantly positioned around the furnace support tube, or one screw at the top of the support in conjunction with two adjustable (vertically along the support tube) metal guide strips mounted horizontally inside to the tube, are to provide adequate alignment.

The framework is to have two ⅜ in. (9.5 mm) diameter transverse rods of stainless steel to accept the guides of the specimen holder described in A-1.2. The rods are to support the holder so that the exposed specimen area is parallel to the furnace opening. Spacing stops are to be mounted at both ends of each rod to permit quick and accurate lateral positioning of the specimen holder.

A-1.4 Photometric System *(see 2-6).* The photometric system is to consist of a tungsten-filament light source (Type 1630 6.5 volt lamp, maintained at 4 ± 0.2V) and a photodetector with an S-4 spectral sensitivity response. The photometer is to be oriented vertically to reduce variations in measurement brought about by stratification of the smoke generated by the specimens under test. The system is shown in Figures 2-6.A and 2-6.B. The window in the chamber floor through which the light beam passes is provided with an electric heater to maintain a temperature of at least 125°F (52°C) to minimize smoke condensation. The collimated beam inside the chamber is to have a path length of 36 ± ⅛ in. (914 ± 3 mm). The approximately circular light "spot" is centered entirely within the sensing area of the detector. A typical photomultiplier photometer system will require a high-voltage D.C. power supply and a neutral density filter of sufficient optical density to produce a convenient signal level for the indicator or recorder. The photometer system used is to be capable of permitting the recording of reliable optical densities of at least 6.0, corresponding to transmittance values of 0.0001 percent of the incident light. *(See A-2.1.1.)*

The two optical platforms and their housings shall be kept in alignment with three metal rods, ½ in. (12.7 mm) in diameter, fastened securely into 5/16 in. (7.9 mm) thick externally mounted top and bottom plates and symmetrically arranged about the collimated light beam.

A-1.5 Radiometer *(see 2-7).* The body temperature of the radiometer shall be monitored with a 100-220°F (38-100°C) thermometer in a ½ in. by ½ in. by 1½ in. long (12.7 mm by 12.7 mm by 38.1 mm) brass well drilled to accept the thermometer with a close fit. Silicone grease may be used to provide good thermal contact.

The circular receiving surface of the radiometer shall be spray-coated with an infrared-absorbing black paint containing a silicone vehicle. The radiometer is to be calibrated calorimetrically in accordance with the procedure summarized in A-2.2.

A-1.6 Chamber Wall Thermocouple *(see 2-8).* A thermocouple is mounted with its junction secured to the geometric center of the inner rear wall panel of the chamber using a ¼ in. (6.4 mm) thick polystyrene foam disk cover and epoxy cement.

A-1.7 Burner *(see 2-11).* The multiple flamelet burner is a six-tube burner, with construction details as shown in Figure 2-4. The vertical tubes of the six-tube burner are made from ⅛ in. (3.2 mm) o.d. by 0.031 in. (0.8 mm) thick-wall stainless steel tubing.

The vertical tubes of the six tube burner are made from ⅛ in. (3.2 mm) o.d. by 0.031 in. (0.8 mm) thickness stainless steel tubing (two tubes are bent 180° into the trough, two tubes are bent 135° from the vertical, and two tubes are bent 90° from the vertical).

All tubes should be crimped at the tip to reduce the opening diameter to 0.055 in. (1.4 mm). The horizontal manifold section of the burner consists of ¼ in. (6.4 mm) o.d. by 0.035 in. (0.9 mm) wall stainless steel tubing. The other end is attached to a fitting in the chamber floor.

A-1.8 Chamber Pressure Regulator. A simple pressure regulator consists of an open, water-filled bottle and a length of flexible tubing, one end of which is connected to a sampling port on the top of the chamber. The other end of the tubing is inserted 4 in. (10 mm) below the water surface. The bottle is located at the same level as the floor of the chamber.

A-2 Calibration of Test Equipment

A-2.1 Photometric System

A-2.1.1 When first assembled and as necessary following use or when suspicious of a malfunction, calibration of the photometer should be checked by interrupting the light beam with calibrated neutral density filters. The filters should cover the full range of the instrument. Optical density values measured by the photometer are to be within ± 3 percent of the calibrated values.

A-2.1.2 Shifts in dark current levels between tests, excessive zero shifts during test, or lack of calibration indicate the need for inspection of the photometer system.

A-2.1.3 The optical density of a supplementary filter used to extend the measuring range of the photometer is to be known to an accuracy of ± 3 percent.

A-2.2 Radiometer. Calibration of the radiometer is accomplished by placing it at suitable distances from a radiant energy source, while maintaining its body temperature at 200 ± 5°F (93 ± 3°C) with controlled air flow through the rear-mounted cooler, and measuring its electrical output as a function of the irradiance level. The irradiance level is determined calorimetrically by measuring the rate of temperature rise of a blackened thin copper disk of known weight, area (1½ in., 38.1 mm dia.), specific heat, and absorptivity in place of the radiometer. The measured millivolt output of the radiometer, at a body temperature of 200°F (93°C), corresponding to an irradiance level of 2.2 ± .04 Btu/sec. ft.^{2} (2.5 ± .05 W/cm^2) is used to establish the furnace control settings discussed in 2-3, 4-3.1, and 4-3.2.

A-2.3 Chamber Pressure Manometer — Leak Rate Test. For purposes of standardization, a leakage rate test should be periodically conducted using the manometer and tubing described in 2-10. The chamber is pressurized to 3 in. (approximately 76 mm) of water by introducing compressed air through a gas sampling hole in the top. The decrease in pressure from 3 in. to 2 in. (approximately 76 to 50 mm) of water is timed with a stop watch. This time should not be less than 5.0 minutes.

A-2.4 Standard Smoke Generating Materials. For checking operational and procedural details of the equipment and method described herein, two standard materials may be used. Under nonflaming conditions, a single layer of alphacellulose (cotton linters) paper and under flaming conditions, plastic sheet should provide repeatable maximum specific optical density values in two portions of the measuring range.[1] Use of these standard materials does not obviate the need for following the calibration and standardization procedure outlined in this standard.

[1]These reference samples, designated SRM 1006 and SRM 1007, may be purchased from the Office of Standard Reference Materials, National Bureau of Standards, Washington, D.C. 20234

Appendix B

This Appendix is not a part of this standard, but is presented here for guidance only.

Suggested Report Form — Smoke Density Chamber

Sample Code _____ **Test No.** _____ **Date** _____

Lab Code _____ **Operator** _____ **Time** _____

Recorded Data or Curve

Time, min.	% Trans.	D_s

Operating Conditions

Radiometer Reading _____ mV;
Irradiance _____ W/cm^2
Furnace Voltage _____ V
Burner Fuel _____ cc/min air;
_____ cc/min propane
Thermal Exposure: flaming smoldering
Chamber Pressure _____ inch H_2O
Chamber Wall Temp. _____ °C
Chamber Surface Condition _____
_____
Burner: ☐ Standard ☐ Special

Sample

Description - _____
Manufacturer - _____
Preconditioning: Temp. _____ °C;
Duration _____ hr.
Conditioning: Temp. _____ °C;
RH _____ %; Duration. _____
Thickness - _____ in.; Density _____ g/cm^3 or lb/ft^3
Initial Wt. _____; Final Wt. _____;
% Loss _____
Special Conditions - _____
_____

Results

Min. Trans. _____ % at _____ min
Max. Specific Optical Density, D_m = _____
Clear Beam Reading = _____ %;
Equiv. D_c _____
D_m (corr.) = $D_m - D_c$ = _____

Remarks