



Designation: E 84 – 89a

AMERICAN SOCIETY FOR TESTING AND MATERIALS

1916 Race St., Philadelphia, Pa. 19103

Reprinted from the Annual Book of ASTM Standards, Copyright ASTM
If not listed in the current combined index, will appear in the next edition.

Standard Test Method for Surface Burning Characteristics of Building Materials¹

This standard is issued under the fixed designation E 84; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This test method for the comparative surface burning behavior of building materials is applicable to exposed surfaces, such as ceilings or walls, provided that the material or assembly of materials, by its own structural quality or the manner in which it is tested and intended for use, is capable of supporting itself in position or being supported during the test period. These tests are conducted with the material in the ceiling position.

1.2 The purpose of this test method is to determine the relative burning behavior of the material by observing the flame spread along the specimen. Flame spread and smoke density developed are reported. However, there is not necessarily a relationship between these two measurements.

1.3 The use of supporting materials on the underside of the test specimen may lower the flame spread index from that which might be obtained if the specimen could be tested without such support, and the test results do not necessarily relate to indices obtained by testing materials without such support.

1.4 This test method may not be appropriate for obtaining comparative surface burning behavior of some cellular plastic materials.

1.5 Testing of materials that melt, drip, or delaminate to such a degree that the continuity of the flame front is destroyed, results in low flame spread indices that do not relate directly to indices obtained by testing materials that remain in place.

1.6 The values stated in inch-pound units are to be regarded as the standard.

1.7 *This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use.*

1.8 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish*

appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 390 Specification for Zinc-Coated (Galvanized) Steel Poultry Netting (Hexagonal and Straight Line) and Woven Steel Poultry Fencing²

D 2016 Test Methods for Moisture Content of Wood³

E 69 Test Method for Combustible Properties of Treated Wood by the Fire-Tube Apparatus⁴

E 160 Test Method for Combustible Properties of Treated Wood by the Crib Test⁴

E 162 Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source⁴

E 286 Test Method for Surface Flammability of Building Materials Using an 8-ft (2.44-m) Tunnel Furnace⁴

3. Significance and Use

3.1 This test method is intended to provide only comparative measurements of surface flame spread and smoke density measurements with that of select grade red oak and inorganic reinforced cement board⁵ surfaces under the specific fire exposure conditions described herein.

3.2 This test method exposes a nominal 24-ft (7.32-m) long by 20-in. (508-mm) wide specimen to a controlled air flow and flaming fire exposure adjusted to spread the flame along the entire length of the select grade red oak specimen in 5½ min.

3.3 This test method does not provide for the following:

3.3.1 Measurement of heat transmission through the tested surface.

3.3.2 The effect of aggravated flame spread behavior of an assembly resulting from the proximity of combustible walls and ceilings.

3.3.3 Classifying or defining a material as noncombustible, by means of a flame spread index by itself.

4. Apparatus

4.1 *Fire Test Chamber*—See Figs. 1 and 2.

4.1.1 The fire test chamber shall consist of a horizontal duct having an inside width of $17\frac{3}{4} \pm \frac{1}{4}$ in. (451 ± 6.3 mm)

¹ This test method is under the jurisdiction of ASTM Committee E-5 on Fire Standards and is the direct responsibility of Subcommittee E05.22 on Surface Burning.

Current edition approved Sept. 6, 1989. Published November 1989. Originally published as E 84 – 50 T. Last previous edition E 84 – 89.

² Annual Book of ASTM Standards, Vol 01.06.

³ Annual Book of ASTM Standards, Vol 04.09.

⁴ Annual Book of ASTM Standards, Vol 04.07.

⁵ Chem-Fill 100S and 100H, nominal 100 to 110 lb/ft³ (1600 to 1760 kg/m³), available from CEM-FIL Corp., 120 Spence Lane, Nashville, TN 37210, has been found suitable for this purpose.



Documents

Document Sharing Hub

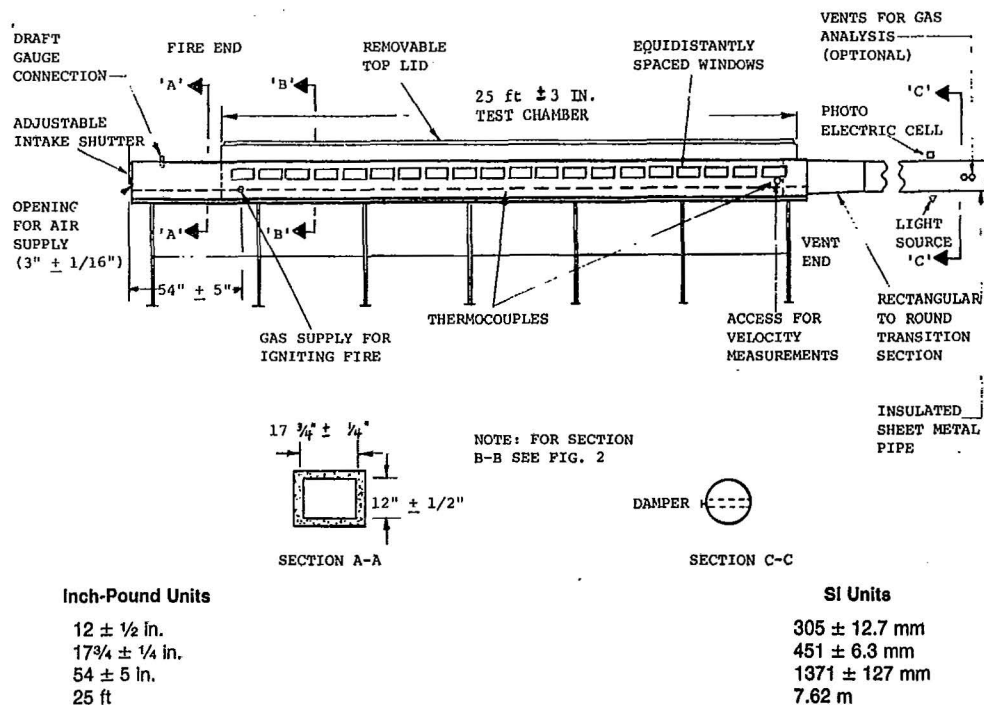


FIG. 1 Test Furnace, Showing Some Critical Dimensions (Not a Construction Drawing)

measured at ledge location along side walls and $17\frac{3}{8} \pm \frac{3}{8}$ in. (448 ± 10 mm) at all other points; a depth of $12 \pm \frac{1}{2}$ in. (305 ± 13 mm) measured from the bottom of the test chamber to the ledge of the inner walls on which the specimen is supported (including the $\frac{1}{8}$ -in. (3.2-mm) thickness of woven fiberglass⁶ gasketing tape); and a length of 25 ft (7.62 m). The sides and base of the duct shall be lined with an insulating masonry material as illustrated in Fig. 2, consisting of A. P. Green, G-26⁷ refractory fire brick. One side shall be provided with double observation windows⁸ with the inside pane flush mounted (See Fig. 2). Exposed inside glass shall be $2\frac{3}{4} \pm \frac{3}{8}$ by 11 ± 1 , - 2 in. (70 ± 10 by $279 \pm 25 - 50$ mm). The centerline of the exposed area of the inside glass shall be in the upper half of the furnace wall, with the upper edge not less than 2.5 in. (63 mm) below the furnace ledge. The window shall be located such that not less than 12 in. (305 mm) of the specimen width can be observed. Multiple windows shall be located along the tunnel so that the entire length of the test sample may be observed from outside the fire chamber. The windows shall be pressure tight in accordance with 6.2 and 6.2.1.

4.1.2 The ledges shall be fabricated of structural materials⁹ capable of withstanding the abuse of continuous testing, level with respect to the length and width of the chamber and each other, and maintained in a state of repair

⁶ Woven fiberglass tape, $1\frac{1}{2}$ by $\frac{1}{8}$ in., No. 8817K35, available from McMaster-Carr, P.O. Box 54960, Los Angeles, CA 90054 or an equivalent has been found suitable for this purpose.

⁷ This method is based on the use of G-26 fire brick, available from A. P. Green Refractories, Green Blvd., Mexico, MO 65265.

⁸ Heat-resistant glass, Vycor, 100 % silica glass, nominal $\frac{1}{4}$ in. thick, has been found suitable for the interior pane; Pyrex glass, nominal $\frac{1}{4}$ in. thick, has been found suitable for the exterior pane.

⁹ High-temperature furnace refractory. Zircon has been found suitable for this purpose.

commensurate with the frequency, volume, and severity of testing occurring at any time.

4.1.3 To provide air turbulence for proper combustion, turbulence baffling shall be provided by positioning six A. P. Green, G-26⁷ refractory fire bricks (long dimension vertical, $4\frac{1}{2}$ -in. (114-mm) dimension along the wall) along the side walls of the chamber at distances of 7, 12, and $20 \pm \frac{1}{2}$ ft (2.1, 3.7, and 6.1 ± 0.2 m) on the window side and $4\frac{1}{2}$, $9\frac{1}{2}$, and $16 \pm \frac{1}{2}$ ft (1.3, 2.9, and 4.9 ± 0.2 m) on the opposite side.

4.1.4 The top shall consist of a removable noncombustible (metal and mineral composite) structure, insulated with nominal 2 in. (51 mm) thick mineral composition material¹⁰ as shown in Fig. 2 and of a size necessary to cover completely the fire test chamber and the test samples. The lid shall be maintained in an unwarped and flat condition. The mineral composition material shall have physical characteristics comparable to the following:

Maximum effective use temperature of at least:	1200°F (650°C)
Bulk density	21 lb/ft ³ (336 kg/m ³)
Thermal conductivity at 300 to 700°F (149 to 371°C)	0.50 to 0.71 Btu·in./h·ft ² ·°F (0.072 to 0.102 W/m·K)
K _{ρC} product: ⁴	1 to 4 $\frac{\text{btu}^2 \cdot \text{in.}}{\text{ft}^5 \cdot \text{h} \cdot ^\circ\text{F}^2} \left(1 \times 10^4 \right)$ to 4 × 10 ⁴ $\frac{\text{W}^2 \cdot \text{S}}{\text{m}^4 \cdot \text{K}^2}$

⁴ K_{ρC} is equal to the thermal conductivity times the density times the specific heat.

The entire lid assembly shall be protected with flat sections of high-density (nominal 110 lb/ft³ or 1761 kg/m³) $\frac{1}{4}$ -in. (6.3-mm) inorganic reinforced cement board, maintained in

¹⁰ A. P. Green Castable Block Mix, 21 lb/ft³ density, available from A. P. Green Refractories, Green Blvd., Mexico, MO 65265, or an equivalent has been found suitable for this purpose.

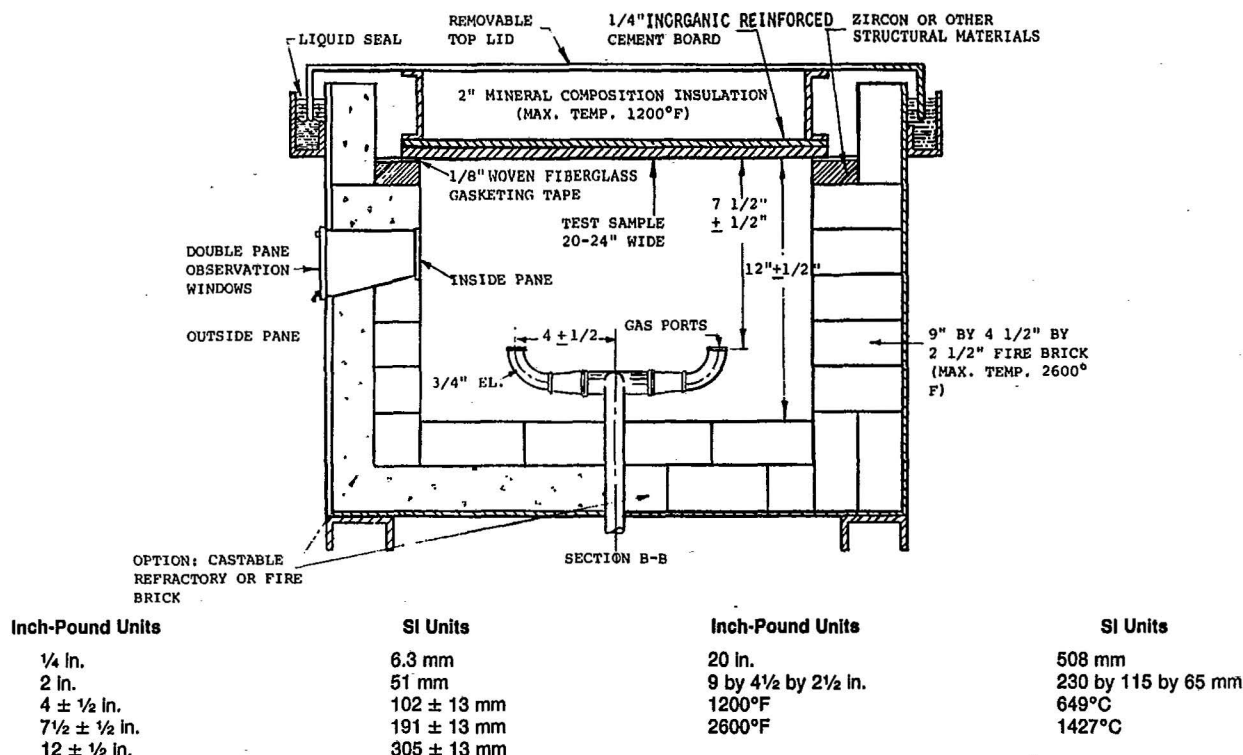


FIG. 2 Test Furnace Showing Some Critical Dimensions (Section "B-B" is not a Construction Drawing)

an unwarped and uncracked condition through continued replacement. This protective board may or may not be secured to the furnace lid. When in place the top shall be completely sealed against the leakage of air into the fire test chamber during the test.

4.1.5 One end of the test chamber, designated as the "fire end," shall be provided with two gas burners delivering flames upward against the surface of the test sample. The burners shall be spaced 12 in. (305 mm) from the fire end of the test chamber, and $7\frac{1}{2} \pm \frac{1}{2}$ in. (190 ± 13 mm) below the under surface of the test sample. The air intake shutter shall be located 54 ± 5 in. (1372 ± 127 mm) upstream of the burner, as measured from the burner centerline to the outside surface of the shutter. Gas to the burners shall be provided through a single inlet pipe, distributed to each port burner through a tee-section. The outlet shall be a $\frac{3}{4}$ -in. elbow. The plane of the port shall be parallel to the furnace floor, such that the gas is directed upward toward the specimen. Each port shall be positioned with its centerline $4 \pm \frac{1}{2}$ in. (102 ± 13 mm) on each side of the centerline of the furnace so that the flame is evenly distributed over the width of the exposed specimen surface (see Fig. 2). The controls used to assure constant flow of gas to the burners during period of use shall consist of a pressure regulator, a gas meter calibrated to read in increments of not more than 0.1 ft^3 (2.8 L), a manometer to indicate gas pressure in inches of water, a quick-acting gas shut-off valve, a gas metering valve, and an orifice plate in combination with a water manometer to assist in maintaining uniform gas flow conditions. An air intake fitted with a vertically sliding shutter extending the entire width of the test chamber shall be provided at the fire end. The shutter shall be positioned so as to provide an air

inlet port $3 \pm \frac{1}{16}$ in. (76 ± 2 mm) high measured from the floor level of the test chamber at the air intake point.

4.1.6 The other end of the test chamber, designated as the "vent end," shall be fitted with a gradual rectangular-to-round transition piece, not less than 20 in. (508 mm) in length, with a cross-sectional area of not less than 200 in.^2 (1290 cm^2) at any point. The transition piece shall in turn be fitted to a 16-in. (406-mm) diameter flue pipe. The movement of air shall be by an induced draft system having a total draft capacity of at least 0.15-in. (3.8-mm) water column with the sample in place, the shutter at the fire end open the normal $3 \pm \frac{1}{16}$ in. (76 ± 2 mm), and the damper in the wide open position. A draft gage tap to indicate static pressure shall be inserted through the top at the midwidth of the tunnel, 1 ± 0.5 in. (25 ± 12 mm) below the ceiling, 15 ± 0.5 in. (381 ± 12 mm) downstream from the inlet shutter.

4.1.7 Photometer System:¹¹

4.1.7.1 A photometer system consisting of a lamp and photocell shall be mounted on a horizontal section of the 16-in. (406-mm) diameter vent pipe at a point where it will be preceded by a straight run of pipe (at least 12 diameters or 16 ft (4.88 m) and not more than 30 diameters (40 ft (12.19 m)) from the vent end of the chamber, and with the light beam directed upward along the vertical axis of the vent pipe. The vent pipe shall be insulated with at least 2 in. (51 mm) of high-temperature mineral composition material, from the vent end of the chamber to the photometer

¹¹ A Weston Instruments No. 856BB. Photronic cell and 12-V sealed beam, clear lens, auto spot lamp (General Electric No. 4405 operated at 12 ± 0.05 VDC, with an overall light-to-cell path length of 36 ± 4 in. (914 ± 102 mm)) has been found suitable for this purpose.

location. The photoelectric cell of which the output is directly proportional to the amount of light received shall be mounted over the light source and connected to a recording device having a minimum operating chart width of 5 in. (127 mm) with an accuracy within $\pm 1\%$ of full scale, for indicating changes in the attenuation of incident light by the passing smoke, particulate, and other effluent. The distance between the light source lens and the photocell lens shall be 36 ± 4 in. (914 ± 102 mm). The cylindrical light beam shall pass through 3-in. (76-mm) diameter openings at the top and bottom of the 16-in. diameter duct, with the resultant light beam centered on the photocell.

4.1.7.2 Linearity of the photometer system shall be verified periodically by interrupting the light beam with calibrated neutral density filters. The filters shall cover the full range of the recording instrument. Transmittance values measured by the photometer, using neutral density filters, shall be within $\pm 3\%$ of the calibrated value for each filter.

4.1.8 Draft Regulating Device:

4.1.8.1 An automatically controlled damper to regulate the draft pressure shall be installed in the vent pipe downstream of the smoke-indicating attachment. The damper shall be provided with a manual override.

4.1.8.2 Other manual or automatic draft regulation devices, or both, may be incorporated to maintain fan characterization and air-flow control throughout test periods.

4.1.9 Thermocouples:

4.1.9.1 A No. 18 Awg (1.02-mm) thermocouple, with $\frac{3}{8} \pm \frac{1}{8}$ in. (9.5 ± 3.2 mm) of the junction exposed in the air, shall be inserted through the floor of the test chamber so that the tip is $1 \pm \frac{1}{32}$ in. (25.4 ± 0.8 mm) below the top surface of the gasketing tape and 23 ft $\pm \frac{1}{2}$ in. ($7.0 \text{ m} \pm 13$ mm) from the centerline of the burner ports at the center of its width.

4.1.9.2 A No. 18 Awg (1.02-mm) thermocouple embedded $\frac{1}{8}$ in. (3.2 mm) below the floor surface of the test chamber shall be mounted in refractory or portland cement, carefully dried to avoid cracking, at distances of 13 ft $\pm \frac{1}{2}$ in. ($3.96 \text{ m} \pm 13$ mm) and 23 ft $\pm \frac{1}{2}$ in. ($7.09 \text{ m} \pm 13$ mm) from the centerline of the burner ports.

4.1.9.3 The room in which the test chamber is located shall have provision for a free inflow of air during the test to maintain the room at atmospheric pressure during the entire test run.

5. Test Specimens

5.1 The test specimen shall be at least 2 in. (51 mm) wider (nominally $20\frac{1}{4} \pm \frac{3}{4}$ in. (514 ± 19 mm)) than the interior width of the tunnel and a total of 24 ft $\pm \frac{1}{2}$ in. ($7.32 \text{ m} \pm 13$ mm) in length. The specimen may consist of a continuous, unbroken length, or of sections joined end-to-end. A $14 \pm \frac{1}{8}$ -in. (356 ± 3 -mm) length of uncoated 16-gage (0.053 to 0.060 in.) steel sheet shall be placed on the specimen mounting ledge in front of and under the specimen in the upstream end of the tunnel. Specimens shall be truly representative of the materials for which test results are desired. Properties adequate for identification of the materials or ingredients, or both, of which the test specimen is made shall be recorded.

5.2 The test specimen shall be conditioned to a constant weight at a temperature of $73.4 \pm 5^\circ\text{F}$ ($23 \pm 2.8^\circ\text{C}$) and at a relative humidity of $50 \pm 5\%$.

6. Calibration

6.1 Place a $\frac{1}{4}$ -in. (6.3-mm) inorganic reinforced cement board on the ledge of the furnace chamber, then place the removable lid of the test chamber in position.

6.2 With the $\frac{1}{4}$ -in. (6.3-mm) inorganic reinforced cement board in position on top of the ledge of the furnace chamber and with the removable lid in place, establish a draft to produce a 0.15-in. (3.8-mm) water-column reading on the draft manometer, with the fire-end shutter open $3 \pm \frac{1}{16}$ in. (76 ± 1.6 mm), by manually setting the damper as a characterization of fan performance. Then close and seal the fire-end shutter, without changing the damper position. The manometer reading shall increase to at least 0.375 in. (9.53 mm), indicating that no excessive air leakage exists.

6.2.1 In addition, conduct a supplemental leakage test periodically with the tunnel sealed from the inlet end to beyond the photometer system, by placing a smoke bomb in the chamber. Ignite the bomb and pressurize the chamber to 0.375 ± 0.125 in. (9.53 ± 3.18 mm) water column. Seal all points of leakage observed in the form of escaping smoke particles.

6.3 Establish a draft reading within the range 0.055 to 0.100 in. (1.40 to 2.54 mm) water column. The required draft gage reading will be maintained throughout the test by the automatically controlled damper. Record the air velocity at seven points, 23 ft from the centerline of the burner ports, $6 \pm \frac{1}{4}$ in. (168 ± 7 mm) below the plane of the specimen mounting ledge. Determine these seven points by dividing the width of the tunnel into seven equal sections and recording the velocity at the geometrical center of each section. During the measurement of velocity, remove the turbulence bricks (see 3.3) and the exposed 23-ft thermocouple and place 24-in. (670-mm) long straightening vanes between 16 and 18 ft (4.88 and 5.49 m) from the burner. The straightening vanes shall divide the furnace cross section into nine uniform sections. Determine the velocity with furnace air temperature at $73.4 \pm 5^\circ\text{F}$ ($23 \pm 2.8^\circ\text{C}$), using a velocity transducer. The velocity, determined as the arithmetic average of the seven readings, shall be 240 ± 5 ft (7.32 ± 1.5 m)/min.

6.4 Maintain the air supply at a temperature of $73.4 \pm 5^\circ\text{F}$ ($23 \pm 2.8^\circ\text{C}$), and a relative humidity of $50 \pm 5\%$.

6.5 Supply the fire test chamber with natural (city) or methane (bottled) gas fuel of uniform quality with a heating value of nominally 1000 Btu/ft³ (37.3 MJ/m³). Adjust the gas supply initially at approximately 5000 Btu (5.3 MJ)/min. Record the gas pressure, the pressure differential across the orifice plate, and the volume of gas used in each test. Unless otherwise corrected for, when bottled methane is employed, insert a length of coiled copper tubing into the gas line between the supply and metering connection to compensate for possible errors in the flow indicated due to reductions in gas temperature associated with the pressure drop and expansion across the regulator. With the draft and gas supply adjusted as indicated in 6.3 and 6.4, the test flame shall extend downstream to a distance of $4\frac{1}{2}$ ft (1.37 m) over the specimen surface, with negligible upstream coverage.

6.6 Preheat the test chamber with the $\frac{1}{4}$ -in. (6.3-mm) inorganic reinforced cement board and the removable lid in place and with the fuel supply adjusted to the required flow. Continue the preheating until the temperature indicates

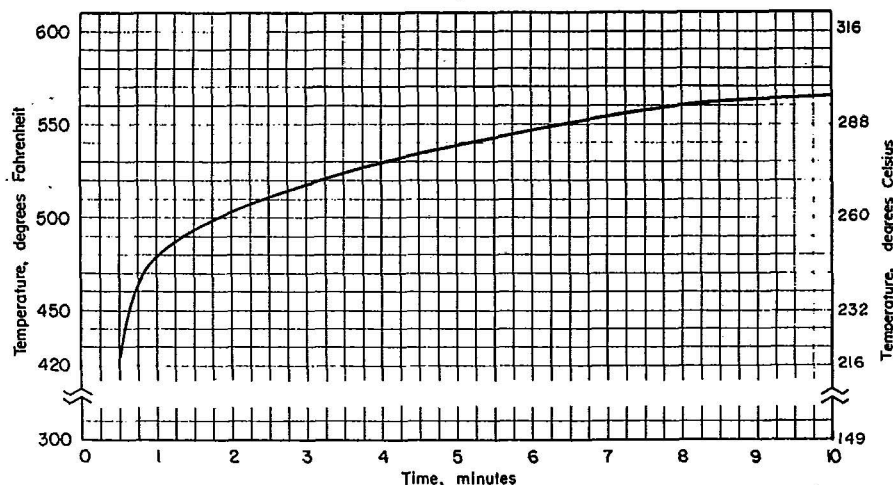


FIG. 3 Representative Time-Temperature Curve for Preheat Temperature

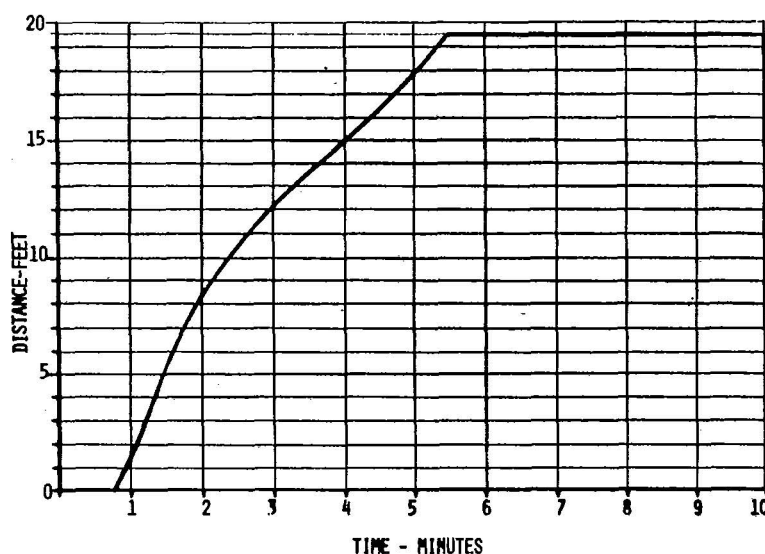


FIG. 4 Representative Time-Distance Curve for Flame Spread of Red Oak

the floor thermocouple at 23¼ ft (7.09 m) reaches $150 \pm 5^\circ\text{F}$ ($66 \pm 2.8^\circ\text{C}$). During the preheat test, record the temperatures indicated by the thermocouple at the vent end of the test chamber at intervals not longer than 15 s and compare these readings to the preheat temperature shown in the time-temperature curve in Fig. 3. This preheating is for the purpose of establishing the conditions that will exist following successive tests and for indicating the control of the heat input into the test chamber. If appreciable variation from the temperatures shown in the representative preheat curve is observed, suitable adjustments in the fuel supply may be necessary based on red oak calibration tests.

6.7 Allow the furnace to cool after each test. When the floor thermocouple at 13 ft (3.96 m) shows a temperature of $105 \pm 5^\circ\text{F}$ ($40.5 \pm 2.8^\circ\text{C}$), place the next specimen in position for test.

6.8 With the test equipment adjusted and conditioned as described in 6.2, 6.3, 6.4, and 6.6, make a test or series of tests, using nominal 23/32-in. (18.3-mm) select-grade red oak flooring as a sample, conditioned to 6 to 8 % moisture

content as determined by the 221°F (105°C) oven-dry method described in Test Methods D 2016. Make observations at distance intervals not in excess of 2 ft (0.6 m) and time intervals not in excess of 30 s, and record the time when the flame reaches the end of the specimen, that is, 19½ ft (5.94 m) from the end of the ignition fire. The end of the ignition fire shall be considered as being 4½ ft (1.37 m) from the burners. The flame shall reach the end point in $5\frac{1}{2}$ min ± 15 s. Automatically record the temperatures measured by the thermocouple near the vent end at least every 15 s. Automatically record the photoelectric cell output immediately prior to the test and at least every 15 s during the test.

NOTE 1—The flame may be judged to have reached the end point when the vent-end thermocouple registers a temperature of 980°F (527°C).

6.9 Plot the flame spread distance, temperature, and change in photoelectric cell readings separately on suitable coordinate paper. Figures 4, 5, and 6 are representative curves for red oak flame spread distance, time-temperature