



Standard Test Method for Behavior of Materials in a Tube Furnace with a Cone-shaped Airflow Stabilizer, at 750°C¹

This standard is issued under the fixed designation E2652; 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 fire-test-response test method covers the determination under specified laboratory conditions of combustion characteristics of building materials.

1.2 Limitations of this fire-test response test method are shown below.

1.2.1 This test method does not apply to laminated or coated materials.

1.2.2 This test method is not suitable or satisfactory for materials that soften, flow, melt, intumesce or otherwise separate from the measuring thermocouple.

1.2.3 This test method does not provide a measure of an intrinsic property.

1.2.4 This test method does not provide a quantitative measure of heat generation or combustibility; it simply serves as a test method with selected (end point) measures of combustibility.

1.2.5 This test method does not measure the self-heating tendencies of materials.

1.2.6 In this test method materials are not being tested in the nature and form used in building applications. The test specimen consists of a small, specified volume that is either (1) cut from a thick sheet; (2) assembled from multiple thicknesses of thin sheets; or (3) placed in a container if composed of granular powder or loose fiber materials.

1.2.7 Results from this test method apply to the specific test apparatus and test conditions and are likely to vary when changes are made to one or more of the following: (1) the size, shape, and arrangement of the specimen; (2) the distribution of organic content; (3) the exposure temperature; (4) the air supply; (5) the location of thermocouples.

1.3 This test method references notes and footnotes that provide explanatory information. These notes and footnotes, excluding those in tables and figures, shall not be considered as requirements of this test method.

¹ This test method is under the jurisdiction of ASTM Committee E05 on Fire Standards and is the direct responsibility of Subcommittee E05.23 on Combustibility.

Current edition approved July 1, 2012. Published August 2012. Originally approved in 2009. Last previous edition approved in 2009 as E2652-09a. DOI: 10.1520/E2652-12.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.5 This test method is technically equivalent to **ISO 1182**.

1.6 *This standard 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.*

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

1.8 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E136 Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C

E176 Terminology of Fire Standards

2.2 *ISO Standards:*³

ISO 1182 Reaction to Fire Tests for Building Products – Non-combustibility Test

ISO 13943 Fire Safety — Vocabulary

ISO 5725-2:1994 Accuracy (trueness and precision) of Measured Methods and Results – Part 2: Basic Method for the Determination of Repeatability and Reproducibility of a Standard Measurement Method

2.3 *Other Standards:*⁴

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

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁴ Available from International Maritime Organization, 55 Victoria St., London, SW1H0EU, United Kingdom, <http://www.imo.org>.

IMO Fire Test Procedures Code

3. Terminology

3.1 *Definitions*—For definitions of terms found in this test method, refer to Terminology E176 and ISO 13943. In case of conflict, the definitions given in Terminology E176 shall prevail.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *homogeneous product, n*—a product with nominally uniform density and composition.

3.2.2 *non-homogeneous product, n*—a product that does not satisfy the requirements of a homogeneous product.

3.2.2.1 *Discussion*—Non-homogeneous products are often composed of more than one component.

3.2.3 *sustained flaming (for testing at 750°C), n*—sustained flaming for testing at 750°C (1382°F) is the persistence of a flame on or over any part of the visible part of the test specimen lasting 5 s or longer.

4. Summary of Test Method

4.1 This test method uses a furnace to expose building materials for at least 30 min to a temperature of 750°C (1382°F).

4.2 The furnace consists of an enclosed refractory tube surrounded by a heating coil with a cone-shaped airflow stabilizer.

4.3 Thermocouples are used to assess the temperature increases resulting from combustion of the product.

4.4 Weight loss and flaming combustion of the product is also assessed.

5. Significance and Use

5.1 While actual building fire exposure conditions are not duplicated, this test method will assist in indicating those materials which do not act to aid combustion or add appreciable heat to an ambient fire.

5.2 This test method does not apply to laminated or coated materials.

5.3 This test method is technically equivalent to ISO 1182.

6. Test Apparatus

6.1 *General:*

6.1.1 The apparatus shall consist of a refractory tube furnace insulated and surrounded by a heating coil. A cone-shaped airflow stabilizer shall be attached to the base of the furnace and a draft shield to its top. Details are shown in Fig. 1.

6.1.2 Thermocouples shall be provided for measuring the furnace temperature and the furnace wall temperature. Optional additional thermocouples shall be used if the specimen surface temperature and the specimen center temperature are required.

6.1.3 A thermal sensor shall be used to measure the furnace temperature along its central axis.

6.1.4 Unless stated otherwise, all dimensions shall have a 5 % tolerance.

6.2 *Test Furnace:*

6.2.1 The test furnace shall consist primarily of the follow-

6.2.2 The furnace tube shall be constructed of a refractory material, as specified in Table 1, of density $2800 \pm 300 \text{ kg/m}^3$ ($175 \pm 19 \text{ lb/ft}^3$).

6.2.3 The furnace shall be $150 \pm 1 \text{ mm}$ ($5.9 \pm 0.04 \text{ in.}$) high with an internal diameter of $75 \pm 1 \text{ mm}$ ($2.9 \pm 0.04 \text{ in.}$) and a wall thickness of $10 \pm 1 \text{ mm}$ ($0.4 \pm 0.04 \text{ in.}$).

6.2.4 The furnace tube shall be surrounded by an annular space of the following dimensions: 150 mm ($5.9 \pm 0.04 \text{ in.}$) high and of 10 mm ($0.4 \pm 0.04 \text{ in.}$) wall thickness.

6.2.4.1 The annular space shall be fitted with top and bottom plates, recessed internally to locate the ends of the furnace tube.

6.2.4.2 The annular space shall be insulated with a 25 mm (1 in.) mm layer of an insulating material having a thermal conductivity of $0.04 \pm 0.01 \text{ W/(m K)}$ ($0.00077 \pm 0.00019 \text{ BTU in./(s ft}^2\text{°F)}$) at a mean temperature of 20°C (68°F). Magnesium oxide powder of a nominal bulk density of $170 \pm 30 \text{ kg/m}^3$ ($10.6 \pm 1.9 \text{ lb/ft}^3$) is a suitable material for this use.

6.2.5 The furnace tube shall be provided with a single winding of 80/20 nickel/chromium electrical resistance tape, $3 \text{ mm} \pm 0.1 \text{ mm}$ ($0.12 \pm 4/1000 \text{ in.}$) wide and $0.2 \pm 0.01 \text{ mm}$ ($8/1000 \pm 0.4/1000 \text{ in.}$) thick.

6.2.5.1 Wind the electrical resistance tape as specified in Fig. 2.

6.2.5.2 Cut grooves into the furnace tube so as to allow accurate winding of the electrical tape.

6.2.6 An open-ended cone-shaped air-flow stabilizer shall be attached to the underside of the furnace.

6.2.6.1 The air-flow stabilizer shall be 500 mm (19.7 in.) long and shall be reduced uniformly from an internal diameter of $75 \pm 1 \text{ mm}$ ($2.9 \pm 0.04 \text{ in.}$) at the top to an internal diameter of $10.0 \pm 0.5 \text{ mm}$ ($0.4 \pm 0.4 \text{ in.}$) at the bottom.

6.2.6.2 The air flow stabilizer shall be manufactured from 1 mm thick sheet steel, with a smooth finish on the inside. The joint between the air flow stabilizer and the furnace shall have an airtight fit, with an internal smooth finish.

6.2.6.3 The upper half of the air flow stabilizer shall be insulated with a 25 mm (1 in.) layer of an insulating material having a thermal conductivity of $0.04 \pm 0.01 \text{ W/(m K)}$ ($0.00077 \pm 0.00019 \text{ BTU in./(s ft}^2\text{°F)}$) at a mean temperature of 20°C (68°F). Mineral fiber insulating material with a nominal thermal conductivity of $0.04 \pm 0.01 \text{ W/(m K)}$ ($0.00077 \pm 0.00019 \text{ BTU in./(s ft}^2\text{°F)}$) at a mean temperature of 20°C (68°F) is a suitable material for this use.

6.2.7 A draft shield, constructed of the same material as the air flow stabilizer, shall be provided at the top of the furnace. It shall be 50 mm (2 in.) high and have an internal diameter of $75 \pm 1 \text{ mm}$ ($2.9 \pm 0.04 \text{ in.}$).

6.2.7.1 The draft shield and its joint with the top of the furnace shall have smooth internal finish.

6.2.7.2 The exterior shall be insulated with a 25 mm (1 in.) layer of an insulating material having a thermal conductivity of $0.04 \pm 0.01 \text{ W/(m K)}$ ($0.00077 \pm 0.00019 \text{ BTU in./(s ft}^2\text{°F)}$) at a mean temperature of 20°C (68°F). Mineral fiber insulating material with a nominal thermal conductivity of $0.04 \pm 0.01 \text{ W/(m K)}$ ($0.00077 \pm 0.00019 \text{ BTU in./(s ft}^2\text{°F)}$) at a mean temperature of 20°C (68°F) is a suitable material for this use.

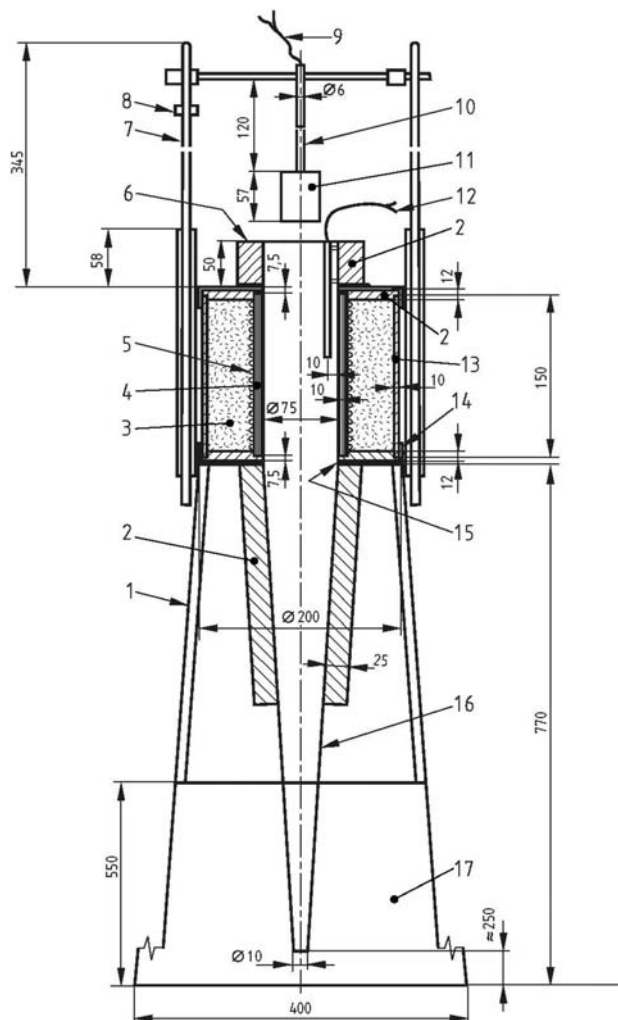


FIG. 1 Test Apparatus

Key to numbers in Fig. 1

- | | | |
|--------------------------|---|-------------------------------|
| 1 Stand | 7 Heat resisting steel rod for insertion device | 13 External insulating wall |
| 2 Insulation | 8 Stop | 14 Mineral fiber cement |
| 3 Magnesium oxide powder | 9 Specimen thermocouples (optional) | 15 Seal |
| 4 Furnace tube | 10 Stainless steel tube | 16 Stabilizer cone |
| 5 Heating coils | 11 Specimen holder | 17 Draft screen (metal sheet) |
| 6 Draft shield | 12 Furnace thermocouple | |

TABLE 1 Furnace Tube Refractory Material for Apparatus

Material	Composition % (kg/kg mass)
Alumina (Al_2O_3)	>89
Silica and alumina (SiO_2 , Al_2O_3)	>98
Ferric oxide (Fe_2O_3)	<0,45
Titanium dioxide (TiO_2)	<0,25
Manganese oxide (Mn_3O_4)	<0,1
Other trace oxides (sodium, potassium, calcium and magnesium oxides)	The balance

6.2.8 The assembly, consisting of the furnace, air flow stabilizer cone and draft shield, shall be mounted on a firm horizontal stand, with a base and draft screen attached to the stand, to reduce drafts around the bottom of the stabilizer cone. The draft screen shall be 550 mm (21.7 in.) high and the

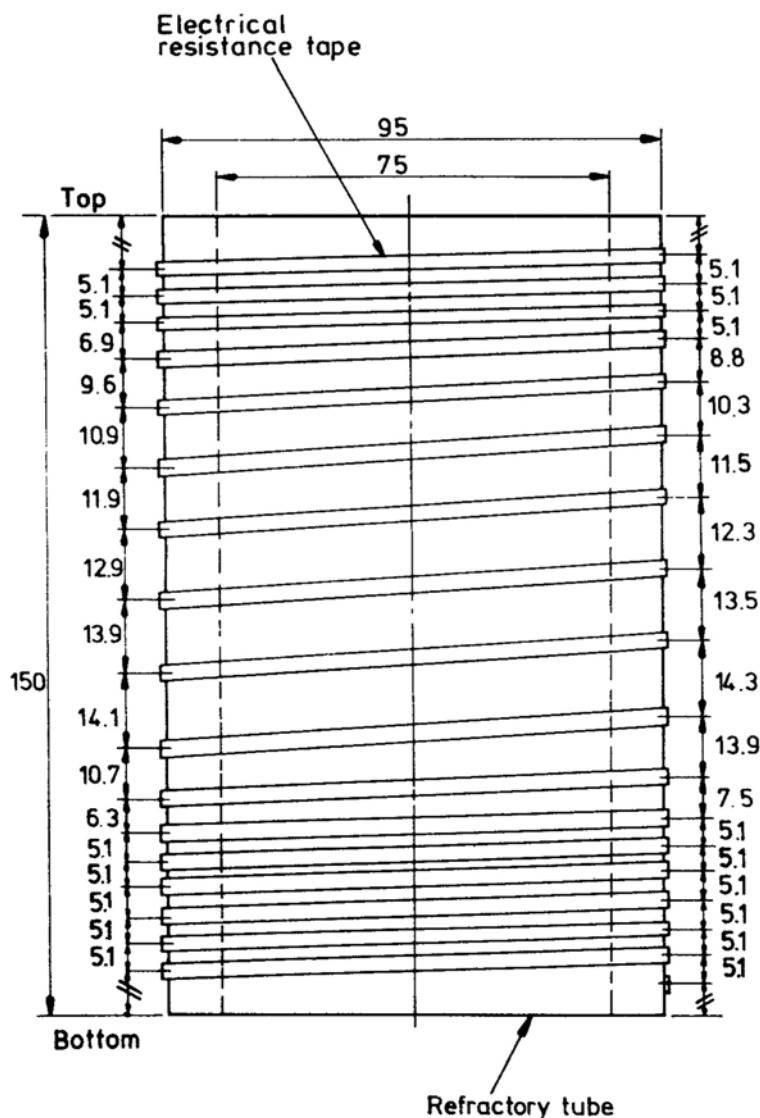
bottom of the air flow stabilizer cone shall be located 250 mm (9.8 in.) above the base plate.

6.3 Test Specimen Holder and Insertion Device:

6.3.1 The test specimen holder shall be made of nickel/chromium or of an alternate heat-resisting steel wire. A fine metal gauze tray of heat-resisting steel shall be placed in the bottom of the holder. The weight of the holder shall be 15 ± 2 g (0.53 ± 0.07 oz).

6.3.2 The test specimen holder shall be capable of being suspended from the lower end of a stainless steel tube with a 6 mm ($\frac{1}{4}$ in.) outside diameter and a 4 mm (0.15 in.) bore, as shown in Fig. 3.

6.3.3 The test specimen holder shall be provided with a suitable insertion device for lowering it down the axis of the furnace tube without shock, so that the geometric center of the



All dimensions in millimetres.

FIG. 2 Furnace Winding for Test Apparatus

specimen during the test is located at the geometric center of the furnace, with a ± 3 mm ($\pm \frac{1}{8}$ in.) tolerance. The insertion device shall consist of a metallic sliding rod moving freely within a vertical guide fitted to the side of the furnace.

6.3.4 The test specimen holder for loose fill materials shall be cylindrical and shall have the same inner dimensions as the outer dimensions of the test specimen. It shall be made of fine metal wire gauze, constructed of heat resisting steel similar to the wire gauze used at the bottom of the test specimen holder specified in 6.3.1. The specimen holder shall have an open end at the top. The weight of the holder shall not exceed 30 g (1.06 oz).

6.4 Thermocouples:

6.4.1 Thermocouples shall have a wire diameter of 0.3 mm (0.01 in.) and an outer diameter of 1.5 mm (0.06 in.). The hot junction shall be insulated and not earthed. The thermocouples

shall be of either type K or type N. The thermocouple insulating material shall be either stainless steel or a nickel based alloy.

6.4.2 All new thermocouples shall be exposed to a Bunsen burner yellow flame for not less than 60 s before use.

NOTE 1—This will reduce thermocouple reflectivity.

6.4.3 The furnace thermocouple shall be located with its hot junction 10.0 ± 0.5 mm (0.4 ± 0.04 in.) from the tube wall and at a height corresponding to the geometric center of the furnace tube. A locating guide is a useful tool to set the position of the thermocouple. The correct position shall be maintained with the help of a guide attached to the draft shield.

6.4.4 In addition to the thermocouple for the measurement of the furnace temperature, a similar thermocouple shall be provided for measuring the furnace wall temperature during calibration.

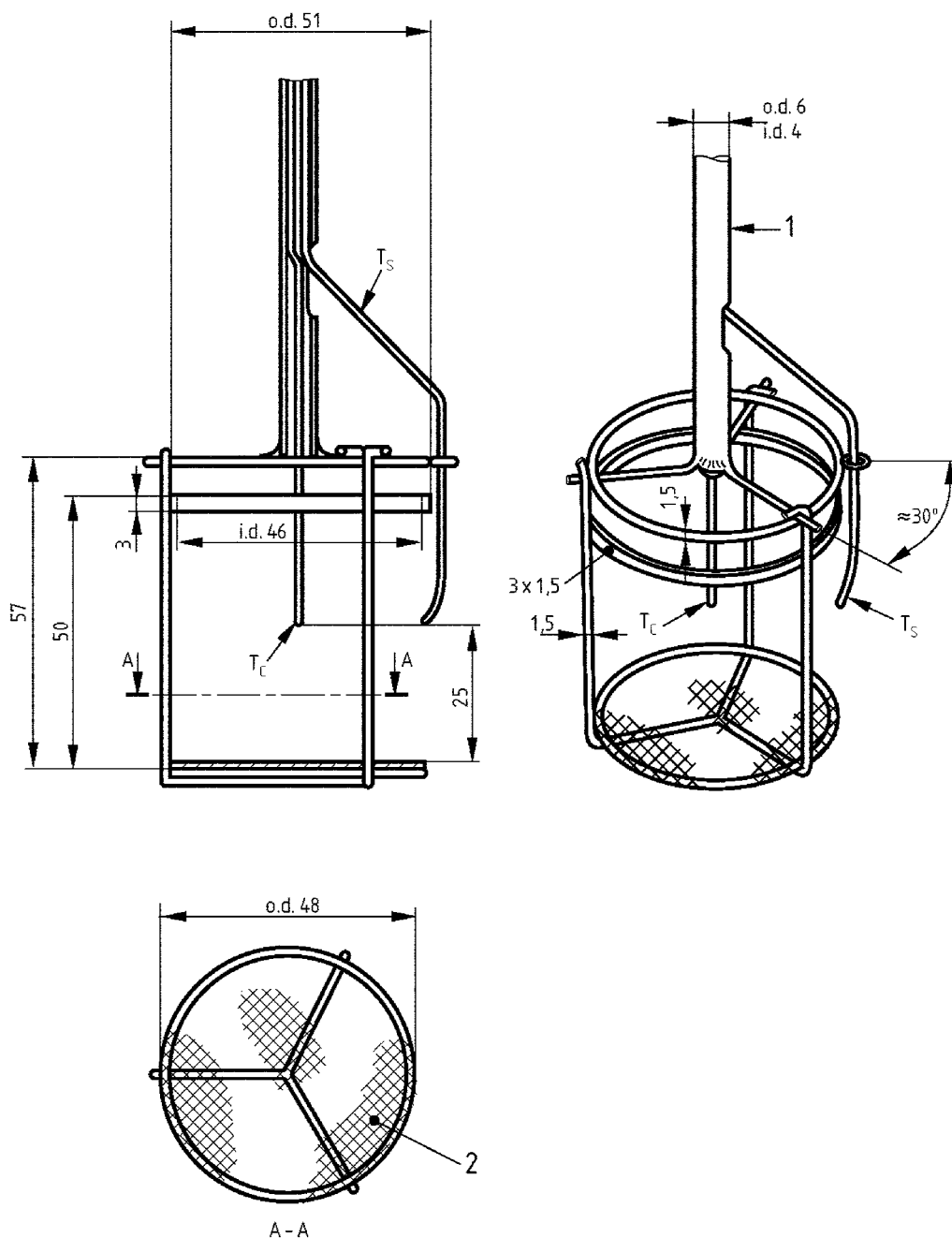


FIG. 3 Specimen Holder for Solid Specimens

Key

- 1 Stainless steel tube
- 2 Aperture mesh 0,9 mm diameter of wire 0,4 mm

Dimensions in millimetres

- T_c Specimen centre thermocouple
- T_s Specimen surface thermocouple
- Note – use of T_c and T_s is optional

6.4.5 Optional thermocouples are described in [Annex A2](#).

6.4.6 An optional mirror is described in [Annex A2](#).

6.4.7 *Optional Test Specimen Center Thermocouple*—The optional test specimen center thermocouple shall be positioned so that its hot junction is located at the geometric center of the test specimen. This shall be achieved by drilling a 2 mm (0.08 in.) diameter hole axially in the top of the test specimen.

6.4.8 *Optional Test Specimen Surface Thermocouple*—The optional test specimen surface thermocouple shall be positioned so that its hot junction is in contact with the test specimen at mid-height of the test specimen at the start of the test. It shall be located diametrically opposite the furnace thermocouple.

6.4.9 When the apparatus of Test Method E2652 is used to assess the behavior of building materials in accordance with Test Method E136, measurements shall be made using both of the optional thermocouples specified in 6.4.7 (test specimen center thermocouple) and 6.4.8 (test specimen surface thermocouple) of Test Method E2652. The values shall be reported as required in Section 15 of Test Method E136.

6.5 *Thermal Sensor*—The thermal sensor shall be constructed of a thermocouple of the type specified in 6.4, brazed to a copper cylinder 10.0 ± 0.2 mm (0.4 ± 0.001 in.) in diameter and 15.0 ± 0.2 mm (0.6 ± 0.001 in.) high.

6.6 *Mirror*—To facilitate observation of sustained flaming and for operator safety, it is advisable to provide a mirror above the apparatus, positioned so that it will not affect the test. A square mirror, 300 mm (11.8 in.) per side, at an angle of 30° to the horizontal, and placed 1 m (1.1 yd) above the furnace has been found suitable.

6.7 *Balance*—A balance with an accuracy of 0.01 g (0.004 oz) is required.

6.8 *Voltage Stabilizer*—A single-phase automatic voltage stabilizer, with a rating of not less than 1.5 kVA, shall be provided. It shall be capable of maintaining the accuracy of the output voltage within $\pm 1\%$ of the rated value, from zero to full load.

6.9 *Variable Transformer*—A voltage transformer capable of handling at least 1.5 kVA and of regulating the voltage output from zero to a maximum value equal to that of the input voltage shall be provided. The voltage output shall vary linearly over the range.

6.10 *Electrical Input Monitor*—An ammeter and a voltmeter or wattmeter, shall be provided to enable rapid setting of the furnace to approximately the operating temperature.

6.11 *Power Controller*—A power controller shall be provided for use as an alternative to the voltage stabilizer, variable transformer and electrical input monitor specified above. It shall be of the type which incorporates phase-angle firing and shall be linked to a thyristor unit capable of supplying 1.5 VA. The maximum voltage shall not be greater than 100 V and the current limit shall be adjusted to give “100 % power” equivalent to the maximum rating of the heater coil. The stability of the power controller shall be approximately 1 % and the set point repeatability shall be $\pm 1.0\%$. The power output shall be linear over the set point range.

6.12 *Temperature Indicator and Recorder*—A temperature indicator shall be provided which is capable of measuring the output from the thermocouple to the nearest 1°C (0.5°F) or the millivolt equivalent. It shall produce a permanent record of this at intervals of not greater than 1 second.

NOTE 2—A digital device or a multirange chart recorder with an operating range of 10 mV full scale deflection with a “zero” of approximately 700°C (1292°F) have been found suitable instruments.

6.13 *Timing Device*—A timing device shall be provided, which is capable of recording elapsed time to the nearest second and accurate to within 1 s in 1 h.

6.14 *Desiccator*—A desiccator shall be provided for storing the conditioned test specimens.

7. Test Specimens

7.1 All test specimens shall be taken from a sample which is sufficiently large to be representative of the product.

7.2 *Dimensions*—The test specimens shall be cylindrical and each shall be 50 ± 3 mm (2.0 ± 0.1 in.) high and have a volume of $76\,000 \pm 8\,000$ mm³ (4.6 ± 0.5 in.³) and a diameter of $45 + 0/-2$ mm ($1.8 + 0/-0.08$ in.).

7.3 Test Specimen Preparation:

7.3.1 If the material is under 50 ± 3 mm (2.0 ± 0.1 in.) thick, cylindrical test specimens of the required thickness shall be created by using multiple layers of material to obtain a test specimen that is 50 ± 3 mm (2.0 ± 0.1 in.) thick.

7.3.2 If the material is over 50 ± 3 mm (2.0 ± 0.1 in.) thick, material thickness shall be reduced to obtain a cylindrical test specimen that is 50 ± 3 mm (2.0 ± 0.1 in.) thick.

7.3.3 The layers shall be placed horizontally in the specimen holder and held together by means of two wires of nickel/chromium or of an alternate heat-resisting steel, to prevent air gaps between layers. The maximum wire diameter shall be 0.5 mm (0.2 in.).

7.3.4 Test specimens of loose fill materials shall be fully representative of the material in its actual use.

7.3.5 The test specimens shall be dried in a ventilated oven maintained at $60 \pm 5^\circ\text{C}$ ($140 \pm 9^\circ\text{F}$), for between 20 and 24 h, and cooled to ambient temperature in a desiccator prior to testing. The weight of each specimen shall be determined to an accuracy of 0.01 g (0.004 oz) prior to test and recorded.

7.3.6 Not less than four identical specimens shall be tested.

8. Procedure

8.1 Test Setup:

8.1.1 Conduct the test at room conditions of $21 \pm 3^\circ\text{C}$ ($70 \pm 5^\circ\text{F}$).

8.1.2 The test apparatus shall not be exposed to drafts or any form of strong direct sunlight or artificial illumination which would adversely affect the observation of flaming inside the furnace.

8.1.3 The room temperature shall not change by more than 3°C (5°F) during a test.

8.2 Furnace Wall Temperature Calibration:

8.2.1 When the furnace temperature is stabilized, measure the temperature of the furnace wall using the contact thermocouple (see 8.2.1.1) and the temperature indicator specified. Make measurements on three vertical axes of the furnace wall (at 0, 120 and 240 degrees from the vertical axis) such that the distances separating each of the axes are the same. Record the temperatures on each axis at a position corresponding to the mid-height point of the furnace tube and at positions both 30 mm (1.2 in.) above and 30 mm (1.2 in.) below the mid-height point.

8.2.1.1 The contact thermocouple shall be of the type described in 6.4.1. A typical arrangement is for the thermocouple end to be bent to allow a horizontal contact with the interior of the furnace wall (as shown in Fig. 4). The contact thermocouple shall be supported along its length, for example by placing it within a porcelain sheath.

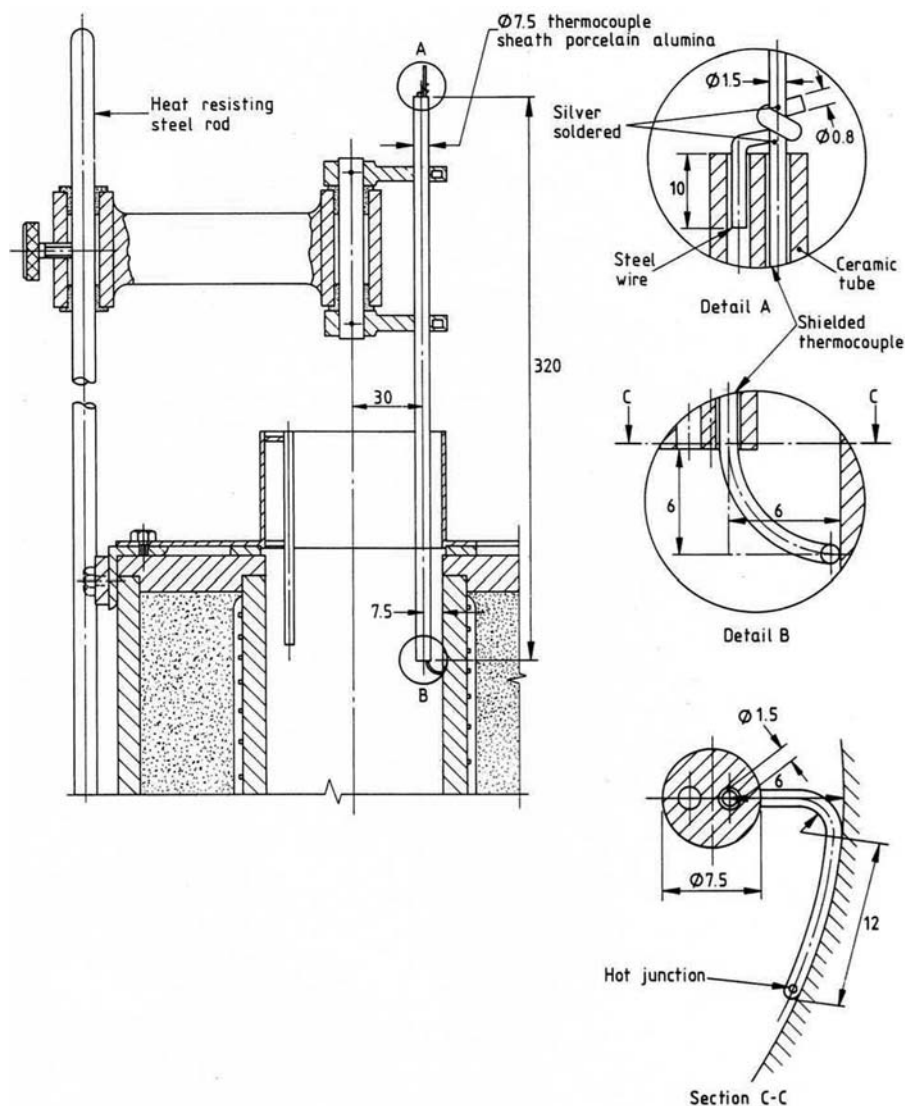


FIG. 4 Typical Contact Thermocouple and Support

8.2.2 Conduct this procedure by using a thermocouple scanning device with the thermocouple and insulating tubes in the positions specified above. Pay particular attention to the contact between thermocouple and furnace wall which, if poor, will lead to low temperature readings. At each measurement point the temperature recorded by the thermocouple shall be stable before a temperature reading is taken.

8.2.3 Obtain nine temperature readings $T_{i,j}$ (i = axis 1 to 3; j = level a to c for +30 mm; 0 mm and -30 mm) as shown in Table 2.

8.2.4 Temperature Calculations:

8.2.4.1 Calculate and record the arithmetic mean of the nine temperature readings recorded in 8.2.3 as the average furnace wall temperature, T_{avg} .

$$T_{avg} = \frac{T_{1;a} + T_{1;b} + T_{1;c} + T_{2;a} + T_{2;b} + T_{2;c} + T_{3;a} + T_{3;b} + T_{3;c}}{9} \quad (1)$$

8.2.4.2 Calculate the arithmetic means of the temperature readings on the three axes recorded in 8.2.3 as the three vertical axes average furnace wall temperatures.

$$T_{avg,axis1} = \frac{T_{1;a} + T_{1;b} + T_{1;c}}{3} \quad (2)$$

$$T_{avg,axis2} = \frac{T_{2;a} + T_{2;b} + T_{2;c}}{3} \quad (3)$$

$$T_{avg,axis3} = \frac{T_{3;a} + T_{3;b} + T_{3;c}}{3} \quad (4)$$

8.2.4.3 Calculate the absolute percentage value of the deviations of the temperature on the three axes from the average furnace wall temperature.

TABLE 2 Position of Furnace Wall Temperature Readings

Vertical axis	a, at +30 mm	Level b at 0 mm	c, at -30 mm
1 (at 0°)	$T_{1;a}$	$T_{1;b}$	$T_{1;c}$
2 (at 120°)	$T_{2;a}$	$T_{2;b}$	$T_{2;c}$
3 (at 240°)	$T_{3;a}$	$T_{3;b}$	$T_{3;c}$

$$T_{dev.axis1} = 100 \times \frac{|T_{avg} - T_{avg.axis1}|}{T_{avg}} \quad (5)$$

$$T_{dev.axis2} = 100 \times \frac{|T_{avg} - T_{avg.axis2}|}{T_{avg}} \quad (6)$$

$$T_{dev.axis3} = 100 \times \frac{|T_{avg} - T_{avg.axis3}|}{T_{avg}} \quad (7)$$

8.2.4.4 Calculate and record the average deviation (arithmetic mean) of the average temperature on each of the three axes and the average furnace wall temperature.

$$T_{avg.dev.axis} = \frac{T_{dev.axis1} + T_{dev.axis2} + T_{dev.axis3}}{3} \quad (8)$$

8.2.4.5 Calculate the arithmetic means of the temperature readings on the three levels recorded in 8.2.3 as the three level average furnace wall temperatures.

$$T_{avg.level a} = \frac{T_{1;a} + T_{2;a} + T_{3;a}}{3} \quad (9)$$

$$T_{avg.level b} = \frac{T_{1;b} + T_{2;b} + T_{3;b}}{3} \quad (10)$$

$$T_{avg.level c} = \frac{T_{1;c} + T_{2;c} + T_{3;c}}{3} \quad (11)$$

8.2.4.6 Calculate the absolute percentage value of the deviations of the temperature on the three levels from the average furnace wall temperature.

$$T_{dev.level a} = 100 \times \frac{|T_{avg} - T_{avg.level a}|}{T_{avg}} \quad (12)$$

$$T_{dev.level b} = 100 \times \frac{|T_{avg} - T_{avg.level b}|}{T_{avg}} \quad (13)$$

$$T_{dev.level c} = 100 \times \frac{|T_{avg} - T_{avg.level c}|}{T_{avg}} \quad (14)$$

8.2.4.7 Calculate and record the average deviation (arithmetic mean) of the average temperature on each of the three levels and the average furnace wall temperature.

$$T_{avg.level c} = \frac{T_{dev.level a} + T_{dev.level b} + T_{dev.level c}}{3} \quad (15)$$

8.2.4.8 The average deviation of the temperature on the three vertical axes from the average furnace wall temperature $T_{avg.dev.axis}$ (Eq 8) shall be less than 0.5 %.

8.2.4.9 The average deviation of the temperature on the three levels from the average furnace wall temperature $T_{avg.dev.level}$ (Eq 15) shall be less than 1.5 %.

8.2.5 Check that the average wall temperature at level +30 mm $T_{avg.dev.level a}$ (Eq 9) is less than the average wall temperature at level -30 mm, $T_{avg.dev.level c}$ (Eq 11).

8.3 Furnace Temperature Calibration:

8.3.1 Once the furnace temperature is stabilized and the furnace wall temperature has been checked, measure the temperature of the furnace along its central axis using the thermal sensor and the temperature indicator specified. Use a positioning device to precisely locate the thermal sensor. The reference for the vertical positioning shall be the top surface of the copper cylinder of the thermal sensor.

8.3.2 Record the temperature of the furnace along its central axis at a position corresponding to the mid height point of the furnace tube.

8.3.3 From this position, move the thermal sensor downwards in steps of no more than 10 mm (0.4 in.) until the bottom of the furnace tube is reached. Record the temperature at each position once it has stabilized.

8.3.4 Move the thermal sensor from the lowest position upwards in steps of no more than 10 mm (0.4 in.) until the top of the furnace is reached. Record the temperature in each position once it has stabilized.

8.3.5 From the top of the furnace move the thermal sensor downwards in 10 min (0.4 in.) steps until the mid point of the furnace is reached. Record the temperature in each position once it has stabilized.

8.3.6 For each position, record two temperatures: one going upwards and one downwards. Report also the arithmetic mean of these temperature records with distance.

8.3.7 The calculated mean temperature at each level used shall fall inside the limits specified as follows:

$$T_{min} = 541\,653 + (5901 \times x) - (0067 \times x^2) + (3375 \times 10^{-4} \times x^3) - (8553 \times 10^{-7} \times x^4)$$

$$T_{max} = 613\,906 + (5333 \times x) - (0081 \times x^2) + (5779 \times 10^{-4} \times x^3) - (1767 \times 10^{-6} \times x^4)$$

TABLE 3 Furnace Temperature Profile Values

Furnace Height (mm)	Furnace Height (in.)	T min (°C)	T min (°F)	T Max (°C)	T Max (°F)
145	5.7	639.4	1182.9	671.0	1239.8
135	5.3	663.5	1226.3	697.5	1287.5
125	4.9	682.8	1261.0	716.1	1321.0
115	4.5	697.9	1288.2	728.9	1344.0
105	4.1	709.3	1308.7	737.4	1359.3
95	3.7	717.3	1323.1	742.8	1369.0
85	3.3	721.8	1331.2	745.9	1374.6
75	3.0	722.7	1332.9	747.0	1376.6
65	2.6	719.6	1327.3	746.0	1374.8
55	2.2	711.9	1313.4	742.5	1368.5
45	1.8	698.8	1289.8	735.5	1355.9
35	1.4	679.3	1254.7	723.5	1334.3
25	1.0	652.2	1206.0	705.0	1301.0
15	0.6	616.2	1141.2	677.5	1251.5
5	0.2	569.5	1057.1	638.5	1181.3

where x is the furnace height, in mm and $x = 0$ mm corresponds to the bottom of the furnace. The appropriate temperature values are given in **Table 3**.

8.4 Frequency of Calibration—The calibration procedures in **8.2** and **8.3** shall be carried out on a new furnace and whenever any major component of the equipment (namely the furnace tube, winding, insulation or power supply) has been replaced.

8.5 Test Setup:

8.5.1 Remove the test specimen holder and its support from the furnace. Position the furnace thermocouple as specified in **6.4.3**. If additional thermocouples are required, position them as specified in **6.4**. All thermocouples shall be connected to the temperature indicator using compensating cables.

8.5.2 Connect the heating element of the furnace either to the voltage stabilizer, variable transformer and the electrical input monitor or to the power controller. Automatic thermostat control of the furnace shall not be used during testing.

NOTE 3—The heating element normally draws a current of between 9 and 10 A at approximately 100 V, under steady state conditions. In order not to overload the winding, it is recommended that the maximum current not exceed 11 A.

NOTE 4—Subject any new furnace tube to slow heating initially. A suitable procedure has been found to be increasing the furnace temperature in steps of approximately 200°C (392°F), allowing 2 h heating at each temperature.

8.5.3 Adjust the power input to the furnace so that the average furnace temperature, as indicated by the furnace thermocouple, is stabilized for at least 10 min at $750 \pm 5.5^\circ\text{C}$ ($1382 \pm 10^\circ\text{F}$). The drift (linear regression) shall not exceed 2°C (3.6°F) during these 10 min. The maximum deviation from the average temperature shall not exceed 10°C (18°F) in 10 min.

8.5.4 Record the temperature continuously.

9. Test Procedure

9.1 Stabilize the furnace as described in **8.5.3**. The stabilized temperature shall be considered the initial temperature. If the recorder used does not allow a real-time calculation, check the temperature stabilization afterwards. If the conditions specified were not satisfied, repeat the test.

9.2 Before starting the test, ascertain that the whole equipment is in good working order, for example, that the stabilizer is clean, the specimen insertion device is working smoothly and the specimen holder exactly occupies the required position in the furnace.

9.3 Insert one test specimen into the test specimen holder suspended on its support.

9.4 Place the test specimen holder in the furnace in the position specified, taking not more than 5 s to complete this operation.

9.5 Start the timing device immediately following the insertion of the test specimen into the furnace.

9.6 Record the temperature measured by the furnace thermocouple throughout the test. If the optional surface thermocouple and center thermocouple are provided, their temperature shall also be recorded throughout the test.

9.7 Conduct the test for a period of 30 min. If final temperature equilibrium, which is achieved when the tempera-

ture drift (linear regression) as measured by the furnace thermocouple does not exceed 2°C (4°F) over a period of 10 min, has been reached by the thermocouple at the end of 30 min, terminate the test. If final temperature equilibrium has not been reached by the thermocouple at 30 min, continue the test, checking for final temperature equilibrium at 5 min intervals thereafter. Terminate the test once equilibrium is established by the thermocouple or after 60 min test duration. Note the test duration. Then remove the specimen from the furnace. The end of the test is the end of the final 5 min interval or 60 min (whichever comes first).

9.8 If additional thermocouples are used, terminate the test when final temperature equilibrium is achieved for all thermocouples used or after 60 min, whichever comes first.

9.9 Weigh the test specimen after cooling it to ambient temperature in a desiccator. Recover any char, ash or other debris which breaks off the test specimen and falls down the tube, either during or following the test, and include this as a part of the unconsumed test specimen being weighed. Record the weight to the nearest 1 %.

9.10 Use this procedure for all test specimens to be tested.

9.11 Throughout the test make and record visual observations on the test specimens.

9.12 Note the occurrence of any flaming and record the duration of such flaming in seconds.

NOTE 5—Flaming is sometimes difficult to identify. Some test specimens exhibit only flame as a steady blue-colored luminous gas zone. do not ignore this and note it under “observations during test” in the test report.

9.13 Record the initial temperatures, the maximum temperature (or temperatures) and the final temperature, as measured by the appropriate thermocouples.

10. Calculations

10.1 Calculate the weight loss for each of the test specimens, expressed as a percentage of the initial weight of the test specimen, to the nearest 1 %.

10.2 Calculate and record the temperature rise, in $^\circ\text{C}$, for each of the test specimens.

10.3 Calculate the temperature rise as the difference between the maximum temperature and the final temperature.

11. Report

11.1 Report the following information for each material tested:

11.1.1 Test specimen identification code or number.

11.1.2 Manufacturer or submitter.

11.1.3 Date of test.

11.1.4 Operator.

11.1.5 Composition or generic identification.

11.1.6 Test specimen thickness (including thickness of each layer for multi-layer materials).

11.1.7 Test specimen weight.

11.1.8 Color of the test specimens.

11.1.9 Other relevant details of test specimen.

11.1.10 Weight loss for each of the test specimens, both in weight and expressed as a percentage of the initial weight of the test specimen to the nearest 1 %.

11.1.11 Initial temperature, maximum temperature and final temperature, for each of the test specimens.

11.1.12 Whether flaming occurred and the duration of flaming, in s, for each of the test specimens.

11.1.13 Temperature rise for each of the test specimens.

12. Precision and Bias

12.1 Information on precision of this test method was developed by the European Committee for Standardization,

Technical Committee 127 (Fire Safety in Buildings; CEN/TC 127 [CEN, 36 rue de Stassart, B, 1050 Brussels, Belgium) and is presented in **Appendix X4**.

13. Keywords

13.1 building materials; combustion; conical stabilizer; heated tube; tube furnace

ANNEXES

(Mandatory Information)

A1. COMPARISON OF THIS TEST METHOD WITH TEST METHOD **E136**

A1.1 The key difference between the apparatuses in this test method and in Test Method **E136** is that the furnace tube in this test method has a conical air-flow stabilizer section attached at its bottom.

A1.2 Both test methods use cylindrical furnace tubes.

A1.3 The furnace tube in Test Method **E136** has an inner diameter of approximately 75 mm (3 in.) and a length of 210

to 250 mm (8½ to 10 in.). The furnace tube in this test method has a similar inner diameter, but a length of approximately 150 mm (6 in.). An open-ended cone-shaped air-flow stabilizer is attached to the underside of the furnace in this test method. The conical stabilizer is approximately 500 mm (20 in.) long, and reduced uniformly from a diameter of approximately 75 mm (3 in.) to one of approximately 10 mm (0.4 in.).

A1.4 The air-flow stabilizer has an insulated upper half.

A2. OPTIONAL EQUIPMENT

A2.1 Optionally, thermocouples shall also be provided for measurement of the temperature in the geometric center of the test specimen and on the surface of the test specimen.

A2.2 Optional Test Specimen Center Thermocouple—The optional test specimen center thermocouple shall be positioned so that its hot junction is located at the geometric center of the test specimen. This shall be achieved by drilling a 2 mm (0.08 in.) diameter hole axially in the top of the test specimen.

A2.3 Optional Test Specimen Surface Thermocouple—The optional test specimen surface thermocouple shall be posi-

tioned so that its hot junction is in contact with the test specimen at mid-height of the test specimen at the start of the test. It shall be located diametrically opposite the furnace thermocouple.

A2.4 Mirror—To facilitate observation of sustained flaming and for operator safety, it is advisable to provide a mirror above the apparatus, positioned so that it will not affect the test. A square mirror, 300 mm (11.8 in.) per side, at an angle of 30° to the horizontal, and placed 1 m (1.1 yd) above the furnace has been found suitable.

APPENDIXES

(Nonmandatory Information)

X1. OPTIONAL IMO CRITERIA FOR REPORTING PASS OR FAIL INFORMATION

X1.1 In the IMO criteria, a material is reported as passing the test if the criteria in (i) through (iv) are met by all of the individual specimens:

(i) the average furnace thermocouple temperature rise does not exceed 30°C (54°F) at any time during the test;

(ii) the average surface thermocouple temperature rise does not exceed 30°C (54°F) at any time during the test;

(iii) the mean duration of sustained flaming does not exceed 10 s at any time during the test, and

(iv) the average of the weight loss of all tested specimens does not exceed 50 % during the test.

X1.2 As shown above, in some cases, materials will meet the above criteria in spite of exhibiting limited flaming and other indications of combustion.

X2. OPTIONAL TEST METHOD E136 CRITERIA FOR REPORTING PASS OR FAIL INFORMATION

X2.1 In Test Method E136 a material is reported as passing the test if at least three of the four specimens tested meet the individual specimen criteria detailed in X2.2 or in X2.3. The three specimens do not need to meet the same individual specimen criteria.

X2.2 If the weight loss of the specimen is 50 % or less, the material passes the test when the criteria in X2.2.1 and X2.2.2 are met:

X2.2.1 The recorded temperatures of the surface and interior thermocouples do not at anytime during the test rise more than 30°C (54°F) above the stabilized furnace temperature measured at T_2 prior to the test.

X2.2.2 There is no flaming from the test specimen after the first 30 s.

X2.3 If the weight loss of the specimen exceeds 50 %, the material passes the test when the criteria in X2.3.1 and X2.3.2 are met:

X2.3.1 The recorded temperature of the surface and interior thermocouples do not, at any time during the test, rise above the stabilized furnace temperature measured at T_2 prior to the test.

X2.3.2 There is no flaming from the specimen at any time during the test.

X3. COMPARISON OF RESULTS OBTAINED WITH THIS TEST METHOD AND WITH TEST METHOD E136

X3.1 Three laboratories tested 13 materials with the apparatuses of Test Method E136 and with this test method. The results were compared in terms of the surface temperature rise and in terms of the classification of pass or fail (using the information from Test Method E136 and the information shown in X3.2). The variation in peak surface temperature rise typically ranged from 15 to 20°C (27 to 36°F) for temperature rises near the limiting value, for example, $30 \pm 20^\circ\text{C}$ ($54 \pm 36^\circ\text{F}$) rise. In terms of classification, the three laboratories agreed on a pass classification for four materials and on a fail classification for eight materials. One material was classified fail by one laboratory and pass by two laboratories. However, agreement would probably have been attained if the tests had not been terminated prematurely.

X3.2 In the study above, the material was reported as passing this test if at least three of the four test specimens tested met the individual specimen criteria detailed in (i) through (iii):

- (i) the weight loss of the test specimen is 50 % or less;
- (ii) the recorded temperature rise of the test specimen is not, at any time during the test, higher than 30°C above the stabilized furnace temperature, and
- (iii) there is no flaming from the test specimen after the first 30 s.

X3.3 One laboratory performed a sensitivity study on the results from the apparatus in this test method and concluded that the peak surface temperature rise was not sensitive to a change in furnace temperature level ranging from 730 to 750°C or in specimen location (mid-height of furnace versus 20 mm ($\frac{3}{4}$ in.) below mid-height).

X3.4 Results of the studies above were described in an unpublished NBS report entitled: “Evaluation of two test methods for noncombustibility: ASTM 136E136 and ISO R1182 authored by D. Gross, R. A. Lindauer and R. Willard, in 1973.

X4. PRECISION OF TEST METHOD

X4.1 An interlaboratory round robin was conducted by CEN/TC 127. The test procedure used was essentially the same as described in this test method. The products tested in this round robin were as described in Table X4.1. Values in this section are presented in SI units only.

X4.2 The values of the statistical average ($\bar{A}_{vg}$), the standard deviations for repeatability (S_r and S_R), the values of repeatability (r) and reproducibility (R) at 95 % confidence level are shown in Table X4.2 and were all calculated in accordance with the equations in ISO 5725-2 for the three key properties measured: temperature increase (ΔT , in °C), weight loss (Δm , in %) and duration of flaming (t_f , in s). Note that the values for r and R are calculated to be 2.8 times the values of the corresponding standard deviation. The calculations were

TABLE X4.1 Products Evaluated in the Interlaboratory Evaluation

Product	Density (kg/m ³)	Thickness (mm)
Glass wool	10.9	100
Stone wool	145	50
Calcium silicate board with cellulose	460	50.8
Wood fiber board	50	25
Gypsum fiber board (10 wt%-paper fiber)	1100	25
FR cellulose loose fill	30	—
Mineral wool loose fill	30	—
Vermiculux	190	50.1
Polystyrene concrete board	50	25

made by including results which were identified as “stragglers” but by excluding results which were identified as “outliers.”

X4.3 A linear model was obtained for each one of the

TABLE X4.2 Statistical Results of the Interlaboratory Evaluation

	ΔT (°C)	Δm (%)	t_f (s)
Average (Avg)	from 1.60 to 144.17	From 2.12 to 90.13	from 0.0 to 251.22
Standard deviation for repeatability (S_r)	from 1.13 to 20.17	From 0.25 to 1.68	from 0.0 to 37.05
Standard deviation for reproducibility (S_R)	from 1.13 to 54.26	From 0.33 to 3.06	from 0.0 to 61.75
repeatability (r)	from 3.15 to 56.47	From 0.71 to 4.70	from 0.0 to 103.75
Reproducibility (R)	from 3.15 to 151.94	From 0.93 to 8.57	from 0.0 to 172.90
S_r /Avg %	from 9.37 to 70.36	From 0.55 to 3064	from 9.19 to 43.37
S_R /Avg %	from 0.64 to 0.36	From 21.64 to 70.36	from 23.94 to 136.19
Linear models			
Standard deviation for repeatability (S_r)	$= 1.26 + 0.10 \times \Delta T$	$= 0.00 + 0.09 \times \Delta m$	$= 0.00 + 0.14 \times t_f$
Standard deviation for reproducibility (S_R)	$= 0.96 + 0.26 \times \Delta T$	$= 0.00 + 0.11 \times \Delta m$	$= 0.00 + 0.32 \times t_f$
repeatability (r)	$= 3.53 + 0.29 \times \Delta T$	$= 0.00 + 0.24 \times \Delta m$	$= 0.00 + 0.38 \times t_f$
Reproducibility (R)	$= 2.68 + 0.73 \times \Delta T$	$= 0.00 + 0.30 \times \Delta m$	$= 0.00 + 0.89 \times t_f$

properties measured, for S_r , S_R , r , and R . The linear equation coefficients are also presented in Table X4.2. It is possible that

the data could be approximated better by non linear models but this was not attempted.

X5. OPTIONAL THERMOCOUPLES IN TEST METHOD E2652

X5.1 Test Method E2652 does not required the use of the test specimen center thermocouple or of the test specimen surface thermocouple; they are optional, as indicated in 6.4.7 and 6.4.8. However, measurements using these thermocouples are required in Section 15 of Test Method E136.

X5.2 The apparatus used for Option B of Test Method E136 is the apparatus of Test Method E2652.

X5.3 Therefore, Section 10.2 of Test Method E136 and

6.4.9 of Test Method E2652 explain that when the apparatus of Test Method E2652 is used to assess the behavior of building materials in accordance with Test Method E136, measurements need to be made using both of the optional thermocouples specified in 6.4.7 (test specimen center thermocouple) and 6.4.8 (test specimen surface thermocouple) of Test Method E2652. The sections also explain that the values of these measurements must be reported as required in Section 15 of Test Method E136.

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