Designation: E 2405 – 05

An American National Standard

# Standard Test Method for Determination of Fire and Thermal Parameters of Materials Using an Intermediate Scale Test with Vertically Oriented Specimen[1]

This standard is issued under the fixed designation E 2405; 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 standard determines fire properties related to piloted ignition of a vertically oriented specimen exposed to an external graduated radiant heat flux as shown in Fig. 1. This test method provides data suitable for comparing the performance of materials, which are used as the exposed surfaces of walls or other vertically orientated products in construction applications.

NOTE 1—This test method has been prepared to closely follow the test procedure of ISO 5658-4, however with additional provisions for heat release and smoke development measurements that are optional.

1.2 The fire characteristics determined by this test method include time-to-ignition, vertical flame spread rate and lateral flame spread rate. Optional measurements include heat release rates and visible smoke development rates.

1.3 The optional heat release rate is determined by the principle of oxygen consumption calorimetry, via measurement of the oxygen consumption as determined by the oxygen concentration and flow rate in the exhaust product stream (exhaust duct).

1.4 The values stated in SI units are to be regarded as the standard.

1.5 *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.*

1.6 *Fire testing of products and materials is inherently hazardous, and adequate safeguards for personnel and property shall be employed in conducting these tests. This test method may involve hazardous materials, operations, and equipment.* Specific information about hazard is given in Section 7.

1.7 *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]

E 176 Terminology of Fire Standards

E 2257 Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies

2.2 *ISO Standards:*

ISO 5658-4 Reaction to Fire Tests—Spread of Flame—Part 4: Intermediate Scale Test with Vertically-orientated Specimen[3]

ISO/TR 14697 Fire Tests—Guidance Rules for the Choice of Substrates for Building Products[3]

## 3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology E 176.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *backing board*, *n*—a board with the same dimensions as the specimen and used to back the specimen so as to represent end-use conditions.

3.2.2 *flashing*, *n*—existence of flame on or over the surface of the specimen for periods of less than 1 s.

3.2.3 *irradiance*, *n*—quotient of the radiant flux incident on an infinitesimal element of surface containing the point, by the area of that element.

3.2.4 *product*, *n*—material, composite or assembly about which information is required.

3.2.5 *specimen*, *n*—representative piece of the product which is to be tested together with any substrate or treatment. The specimen may include an air gap. The specimen may also be tested as a stand-alone product without substrates if this is representative of end-use conditions.

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

Current edition approved Jan. 1, 2005. Published March 2005.

[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.

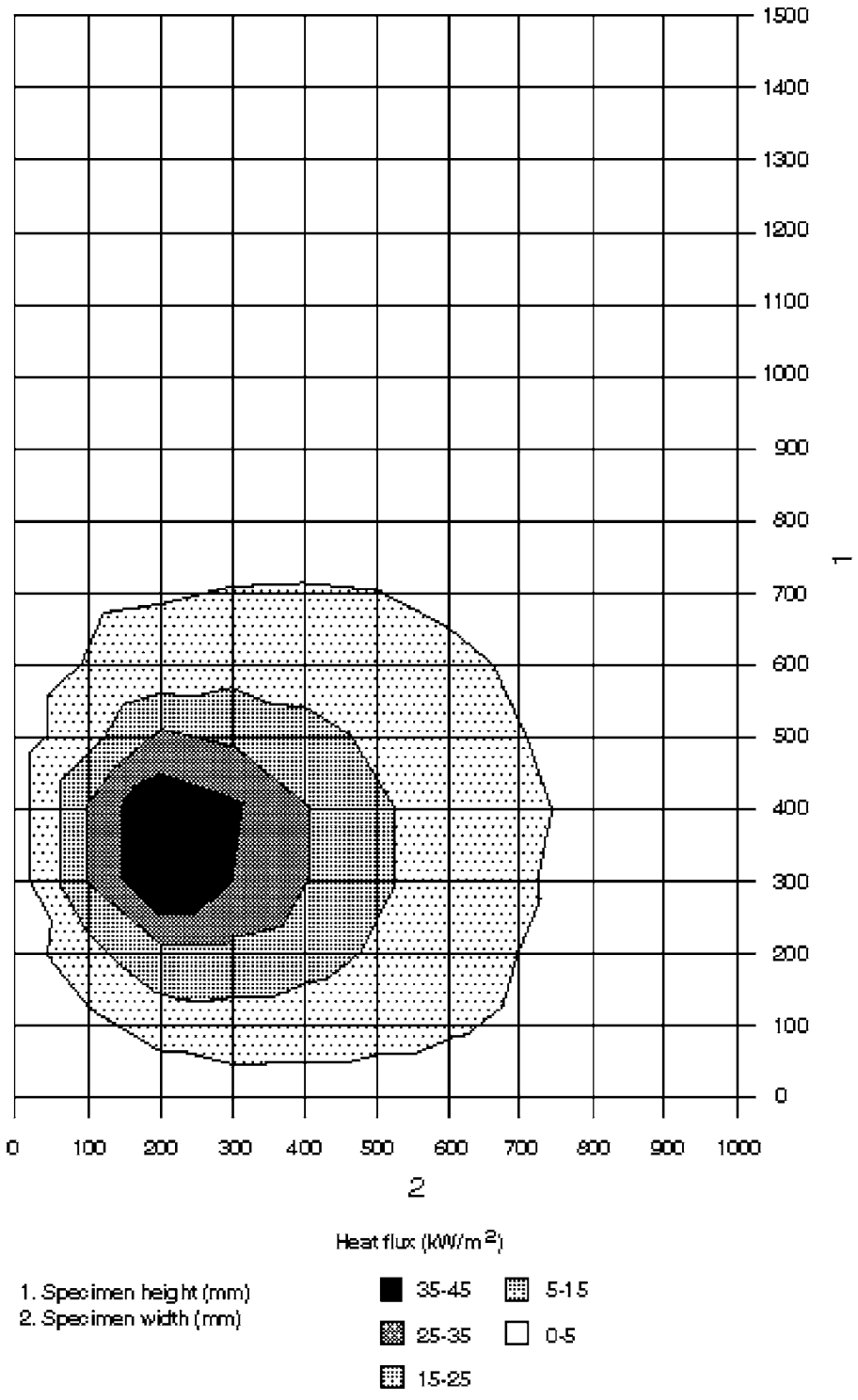



**FIG. 1 Heat Flux Distribution on the Calibration Board**

3.2.6 *substrate*, *n*—a material which is used or is representative of that used, immediately beneath a surface product in end-use, for example, skimmed plasterboard beneath a wall-covering.

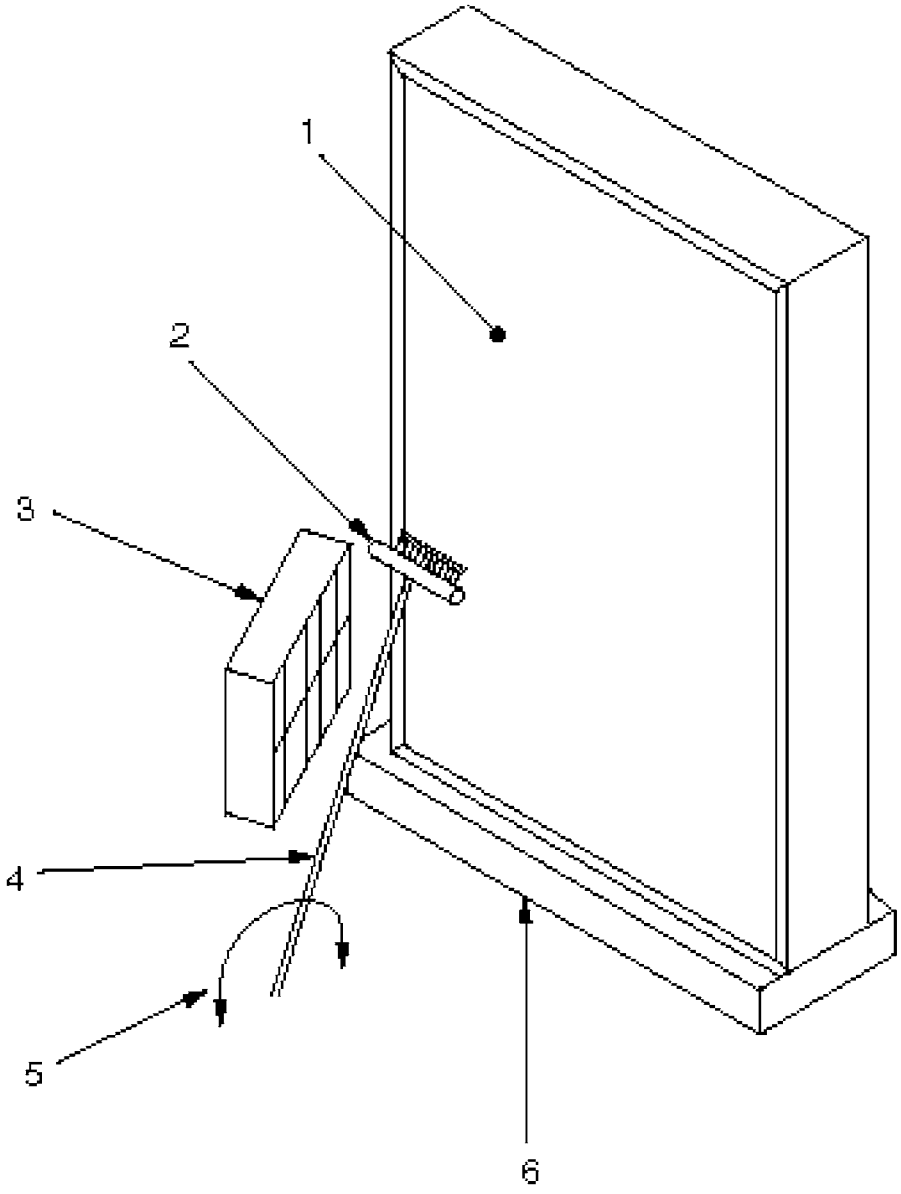
3.2.7 *sustained flaming*, *n*—existence of flame on or over most of the specimen surface for periods of more than 4 s.

3.2.8 *transitory flaming*, *n*—existence of flame on or over most of the specimen surface for periods between 1 and 4 s.

## 4. Summary of Test Method

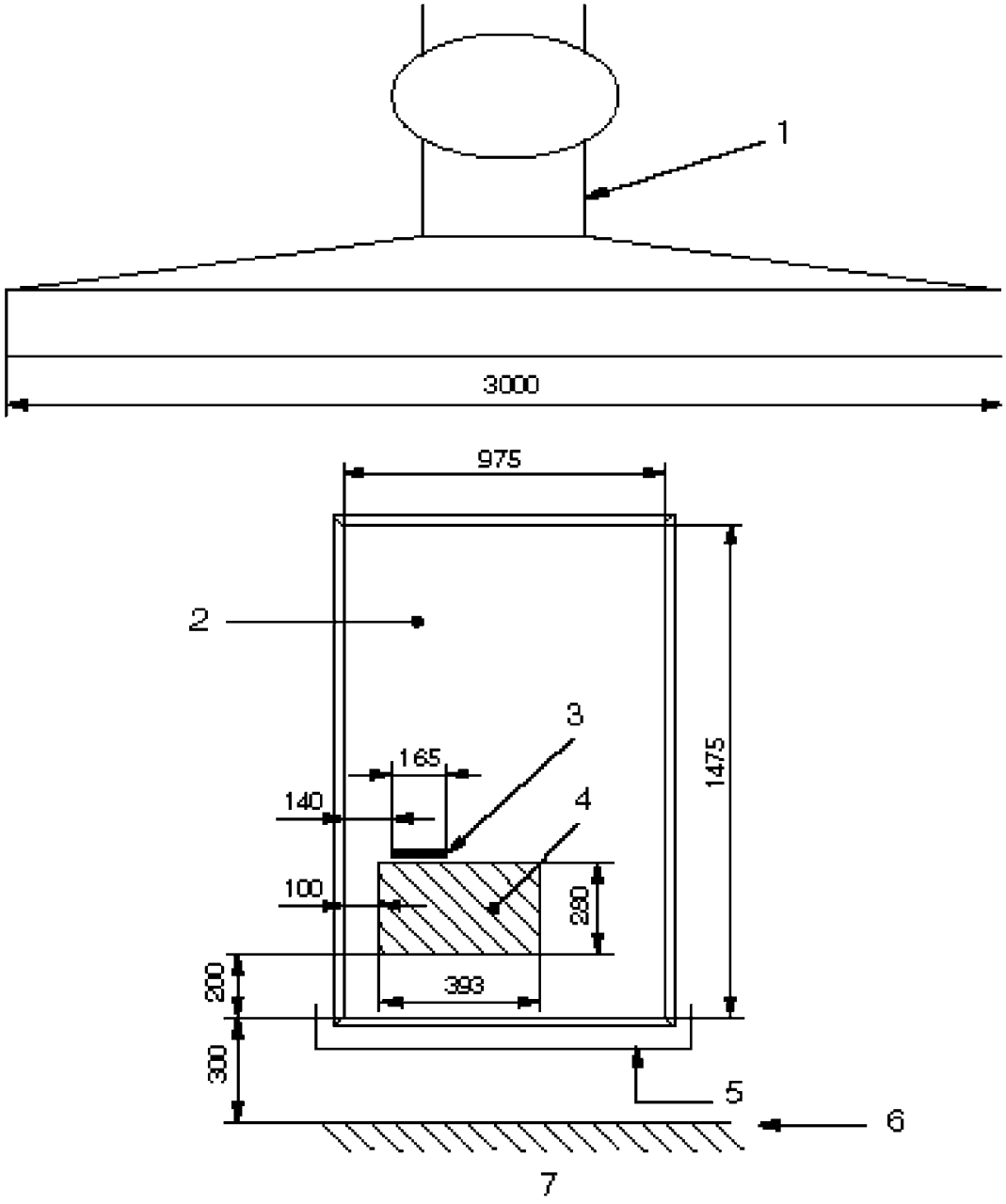
4.1 This test method is designed to measure time-to-ignition and vertical and lateral rates of flame spread of a specimen in

a vertical orientation. The test specimen is exposed to a graduated radiant heat flux supplied by an adjacent gas-fired radiant panel (see Fig. 2). A non-impinging line burner placed above the radiated area of the specimen (see Figs. 2 and 3) provides piloted ignition. Following ignition, the flame front progression along the horizontal and vertical lengths of the specimen is tracked as a function of time.




1. Test specimen
2. Pilot flame burner
3. Vertical radiant panel at an angle of 35¡ to the specimen
4. Supply pipe
5. Direction of rotation of supply pipe
6. Debris collection tray

**FIG. 2 Schematic of the Test (a)**




1. Exhaust hood
2. Exposed area of specimen
3. Pilot flame burner
4. Radiant panel
5. Debris collection tray
6. Floor level
7. (a) Elevation view
8. Specimen
9. Radiant panel
10 (b) Plan view

**FIG. 3 Schematic of the Test (b)**

4.2 The test results are reported in terms of time-to-ignition and flame spread distance as a function of time.

NOTE 2—Other fire spread effects such as flaming drips or debris can also be measured.

4.3 Optional measurements include heat release rate and smoke development rate. For these measurements however, the apparatus shall be positioned underneath a calibrated hood/duct facility as detailed in Annex A1.

## 5. Significance and Use

5.1 This test method is used primarily to determine time-to-ignition, vertical flame spread rate, and lateral flame spread rate of materials, products and assemblies in a vertical orientation when exposed to a graduated radiant heat flux.

5.2 Optionally, this test method is suitable to measure the heat release rate and smoke development rate of materials, products and assemblies in a vertical orientation when exposed to a graduated radiant heat flux.

5.3 This test method is suitable to test materials that have a planar or nearly planar exposed surface. This test method is not intended to test materials with surface cracks, fissures or holes exceeding 8 mm in width or 10 mm in depth. Also, the total area of such cracks, fissures or holes at the surface shall not exceed 30 % of the exposed surface area of the specimen.

## 6. Apparatus

6.1 *General*:

6.1.1 The test apparatus consists of four main components: a radiant panel assembly, a specimen support trolley assembly, a specimen holder, and a pilot flame burner.

6.2 *Radiant Panel Assembly*:

6.2.1 The radiant panel assembly consists of a radiant panel support framework and an assembly of porous refractory tiles at the front of a plenum chamber to provide a flat radiating surface (see Fig. 2).

6.2.2 The assembled radiant panel shall provide a flat radiating surface of dimensions 480 ± 5 mm by 280 ± 5 mm. The plenum chamber shall contain baffle plates and diffusers to distribute the gas/air mixture evenly over the radiating surface.

6.2.3 The radiant panel support framework holds the refractory tiles in place and connects the air and gas pipe work to the refractory tiles. It also holds safety devices, regulators and flow meters. This support framework shall have its lower edge at least 500 mm above floor level to ensure sufficient ventilation during panel operation. The radiating face of the panel shall be vertical and the angle between the panel face and the exposed surface of the specimen shall be 35 ± 3°, as shown in Figs. 2 and 3.

NOTE 3—A wire screen fixed immediately in front of the radiating face of the panel has been found to increase the irradiance and to protect the panel from falling debris. A typical wire screen may be made from 3 mm diameter stainless steel rods to form a screen of 480 ± 5 mm by 280 ± 5 mm. A screen with 20 horizontally orientated equally-spaced rods and 4 vertically orientated equally-spaced rods, welded at all contacts and placed 15 mm from the face of the radiant panel has been found to be satisfactory.

6.3 *Specimen Support Trolley Assembly*:

6.3.1 This assembly incorporates the trolley and the guide rail, which are used to locate the specimen holder at the required test position in relation to the radiant panel and the pilot flame burner as shown in Fig. 4.

6.3.2 The trolley, as shown in Fig. 4, shall be provided to hold the specimen holder and allow the specimen to be readily moved and positioned at the required angle of orientation with respect to the radiant panel.

6.3.3 The trolley shall also have a debris collection tray fixed below the lower edge of the specimen holder. This tray shall be 1100 ± 5 mm long by 300 ± 5 mm wide by 100 ± 5 mm deep. It shall be made of 1 mm thick steel and shall be fixed to the specimen support trolley so that the base of the tray is 50 mm below the bottom edge of the specimen holder. The tray shall contain 10 mm calcium silicate board lined with aluminum foil and with a strip of 40 mm thick by 40 mm by 1095 mm calcium silicate board wrapped in aluminum foil (see Figs. 4 and 5.

6.3.4 The trolley shall be moved by sliding on a guide rail to consistently achieve the required tolerances (see Fig. 4).

NOTE 4—The specimen holder transport system may be manually or automatically operated to achieve this requirement.

6.4 *Specimen Holder*:

6.4.1 The specimen holder assembly is shown in Fig. 6. Make the specimen holder from 2 ± 0.5 mm thick stainless steel to the dimensions given in Fig. 6 so that the exposed surface of the specimen is 1475 ± 25 mm high by 975 ± 25 mm wide. The test specimen shall be held pressed against the front flanges of the specimen holder by use of a quick action clamping device.

NOTE 5—To test specimens thicker than 200 mm, a modified specimen holder and a wider debris tray is required. The debris tray should extend 100 mm in front of the specimen base (see Fig. 5).

6.5 *Pilot Flame Burner*:

6.5.1 The pilot burner shall be a 160 ± 5 mm long stainless steel tube with an internal diameter of 10 ± 1 mm and an external diameter of 12 ± 1 mm. The tube shall have 15 evenly spaced 1 mm diameter holes positioned radially along the centerline (see Fig. 7).

6.5.2 The pilot burner shall be mounted so that its position relative to the face of the test specimen is in line with the top of the radiant panel (see Fig. 3). The distance between the burner tube and the face of the specimen shall be 25 ± 1 mm (see Fig. 8).

6.5.3 The gas used for the pilot burner shall be commercial grade propane with a heating value of approximately 83 $MJ/m^3$.

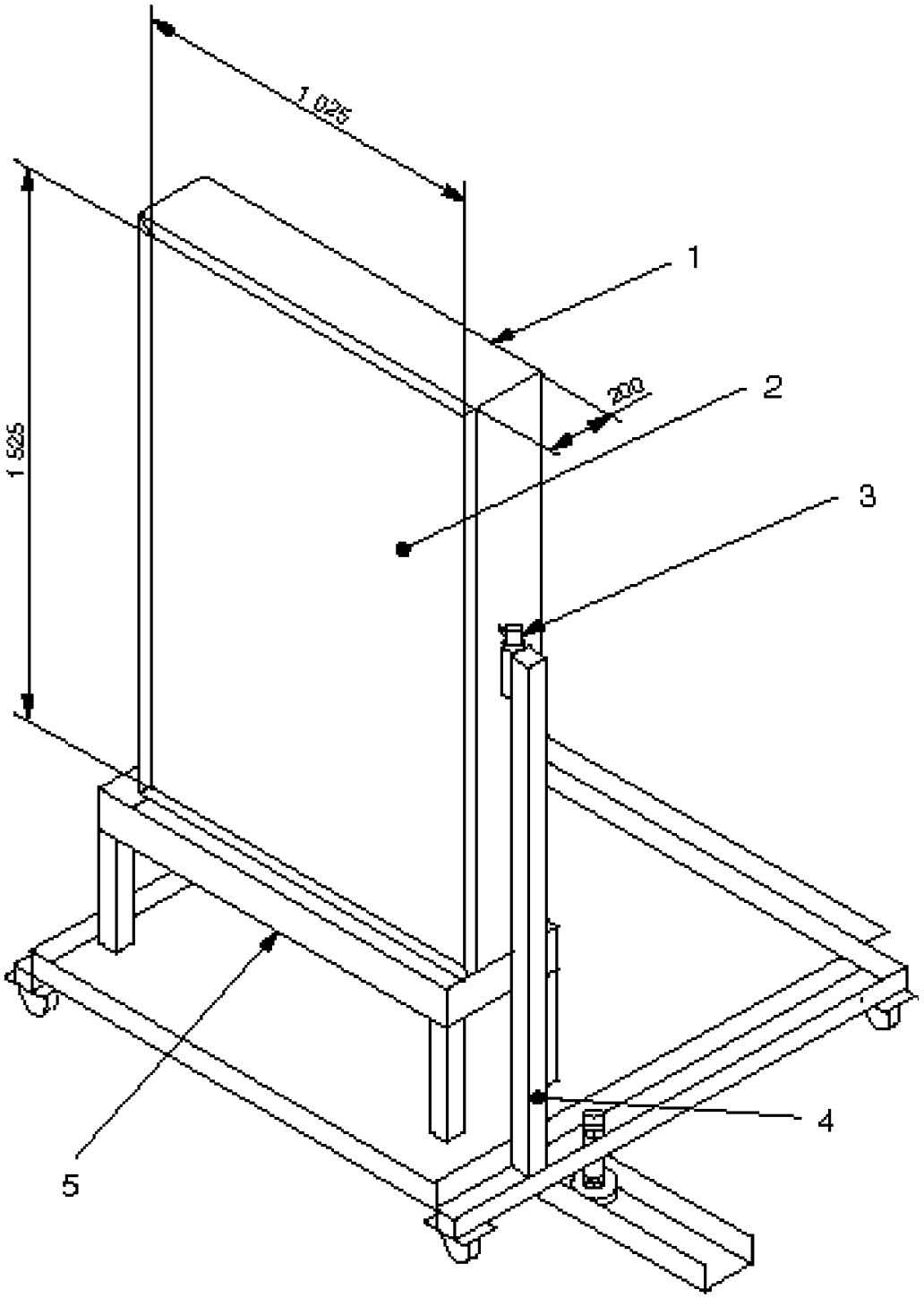
6.5.4 The flow rate to the pilot burner shall be adjusted to about 0.6 l/min.

6.6 *Gas and Air Supplies*:

6.6.1 The combustion gas and air shall be fed to the radiant panel via suitable pressure and flow regulators, and flow meters. A suitable supply system includes the following:

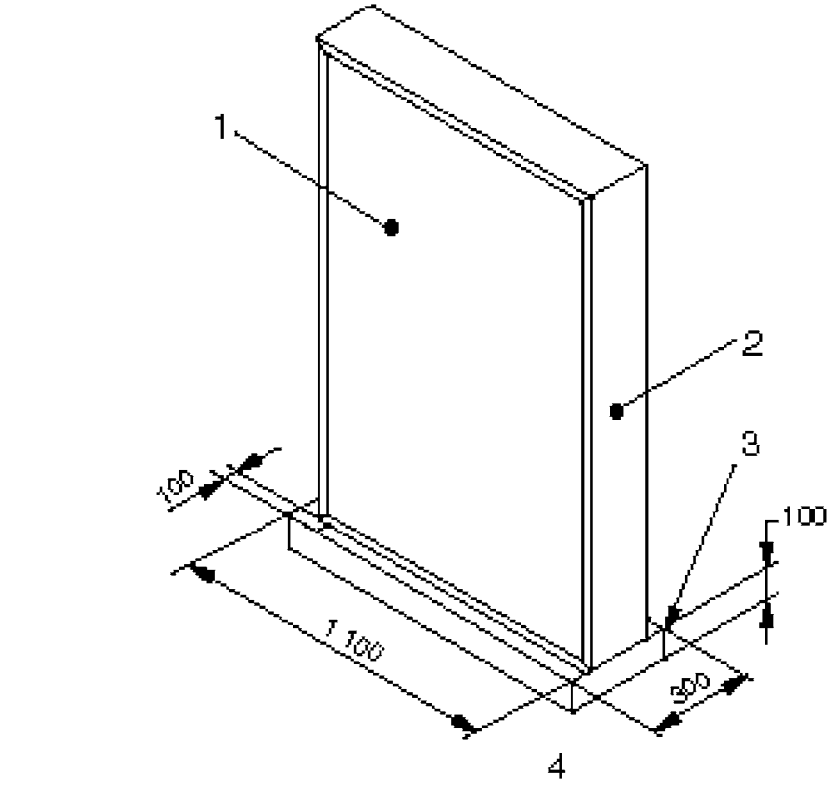
6.6.1.1 A supply of natural gas, methane or propane with a flow rate of at least 0.3 l/s at a pressure sufficient to overcome friction losses through the supply lines and the radiant panel,

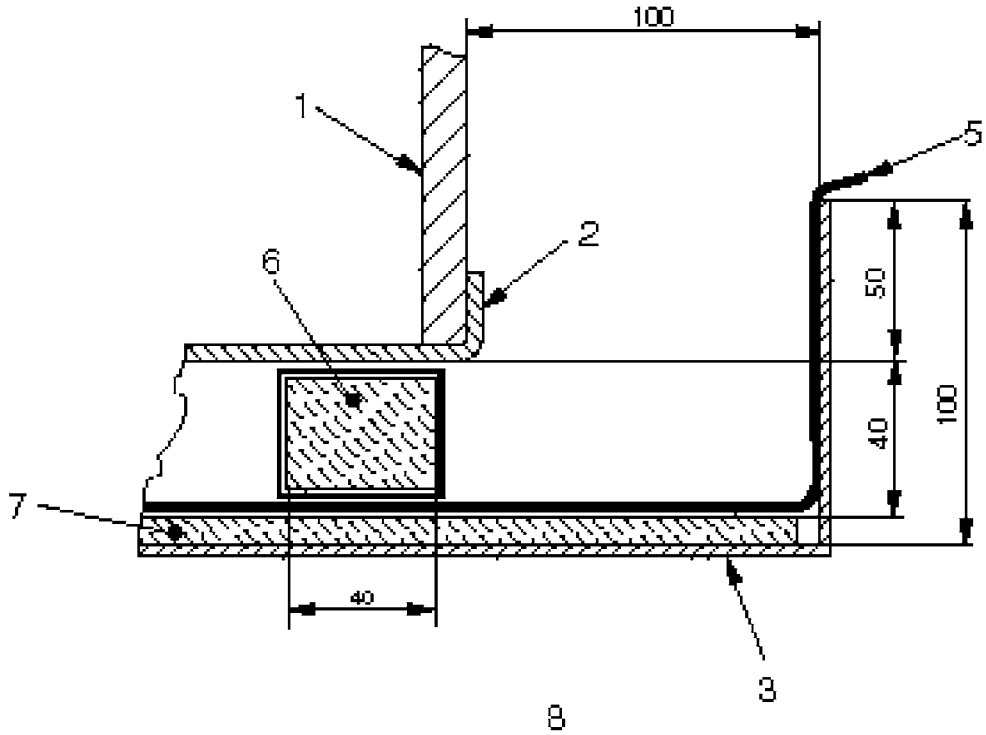
6.6.1.2 An air supply with a flow rate of at least 5 l/s at a pressure sufficient to overcome the friction losses through the supply lines and the radiant panel,




1. Specimen holder
2. Test specimen
3. Tapered fitting on each side of specimen holder locates with sockets on the trolley framework
4. Trolley framework supporting the specimen holder
5. Debris collection tray

**FIG. 4 Typical Specimen Holder and Trolley Assembly**




1. Specimen
2. Specimen holder
3. Debris collection tray
4. (a) General arrangement of debris collection tray
5. Aluminium foil
6. Calcium silicate board wrapped in aluminium foil
7. Calcium silicate board
8. (b) Position of debris collection tray and showing lining to tray

**FIG. 5 Debris Collection Tray**

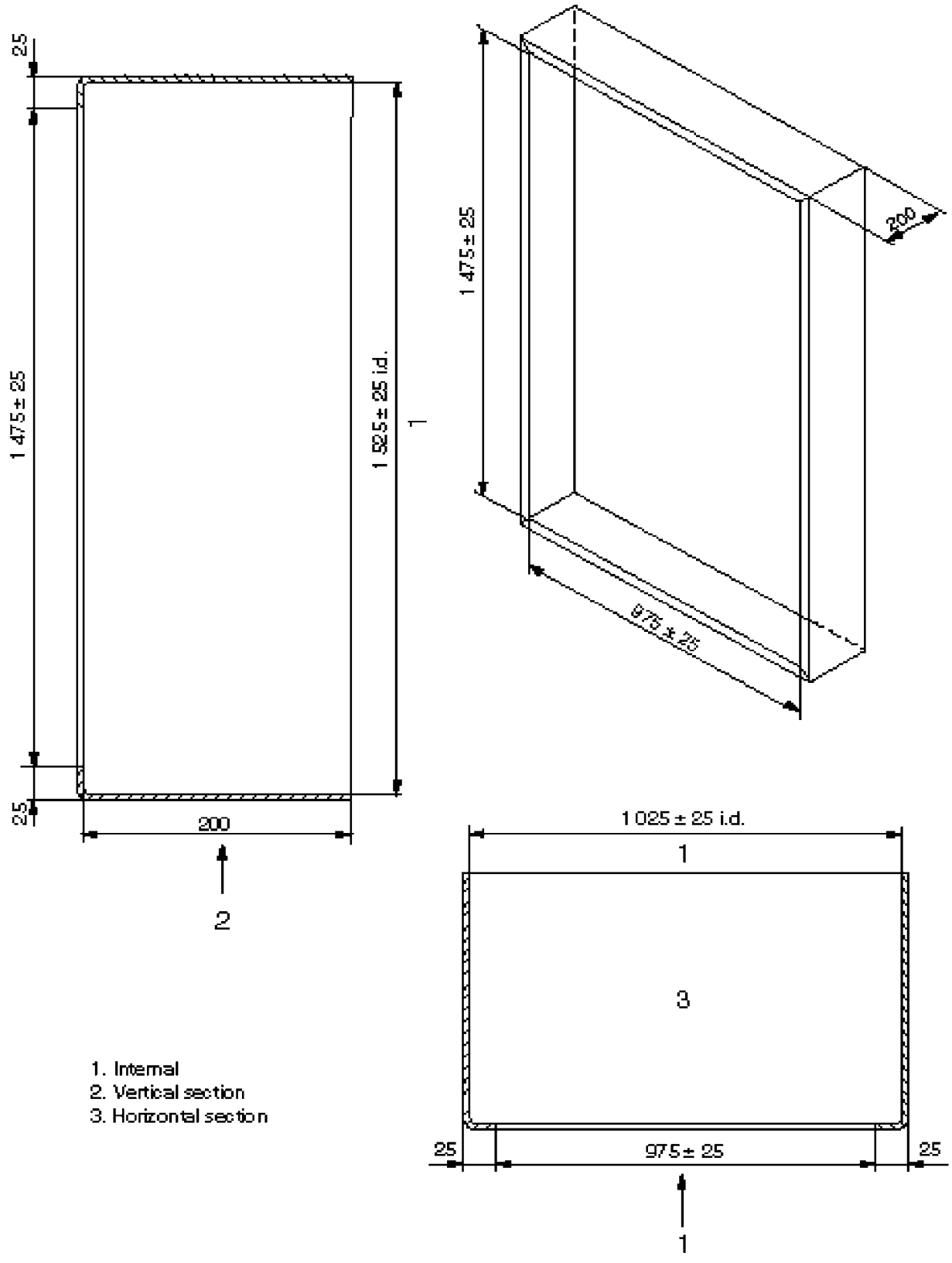
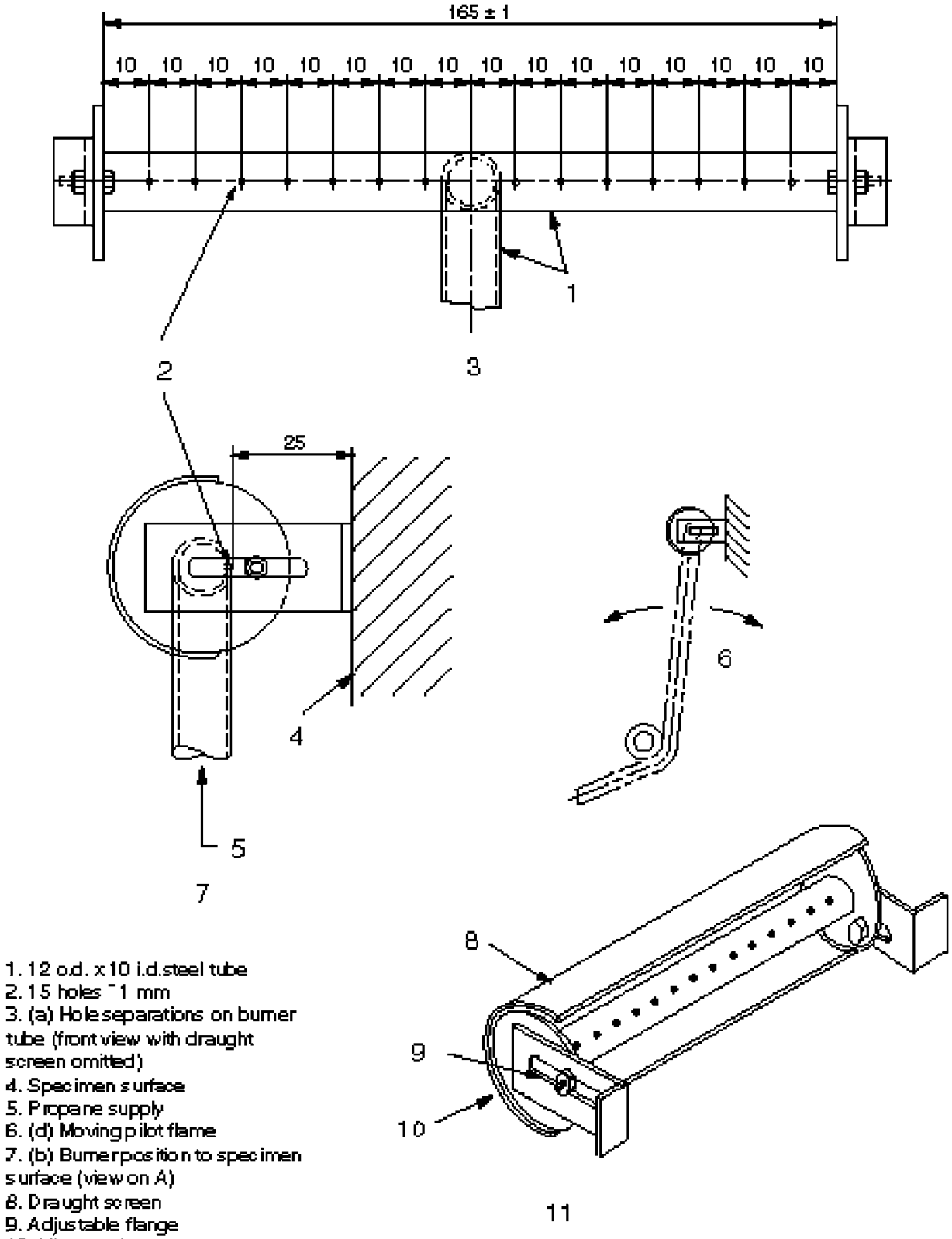



**FIG. 6 Typical Specimen Holder**




1. 12 o.d. x 10 i.d. steel tube
2. 15 holes ¯1 mm
3. (a) Hole separations on burner tube (front view with draught screen omitted)
4. Specimen surface
5. Propane supply
6. (d) Moving pilot flame
7. (b) Burner position to specimen surface (view on A)
8. Draught screen
9. Adjustable flange
10. View on A
11. (c) General arrangement of pilot flame burner

**FIG. 7 Pilot Flame Burner**

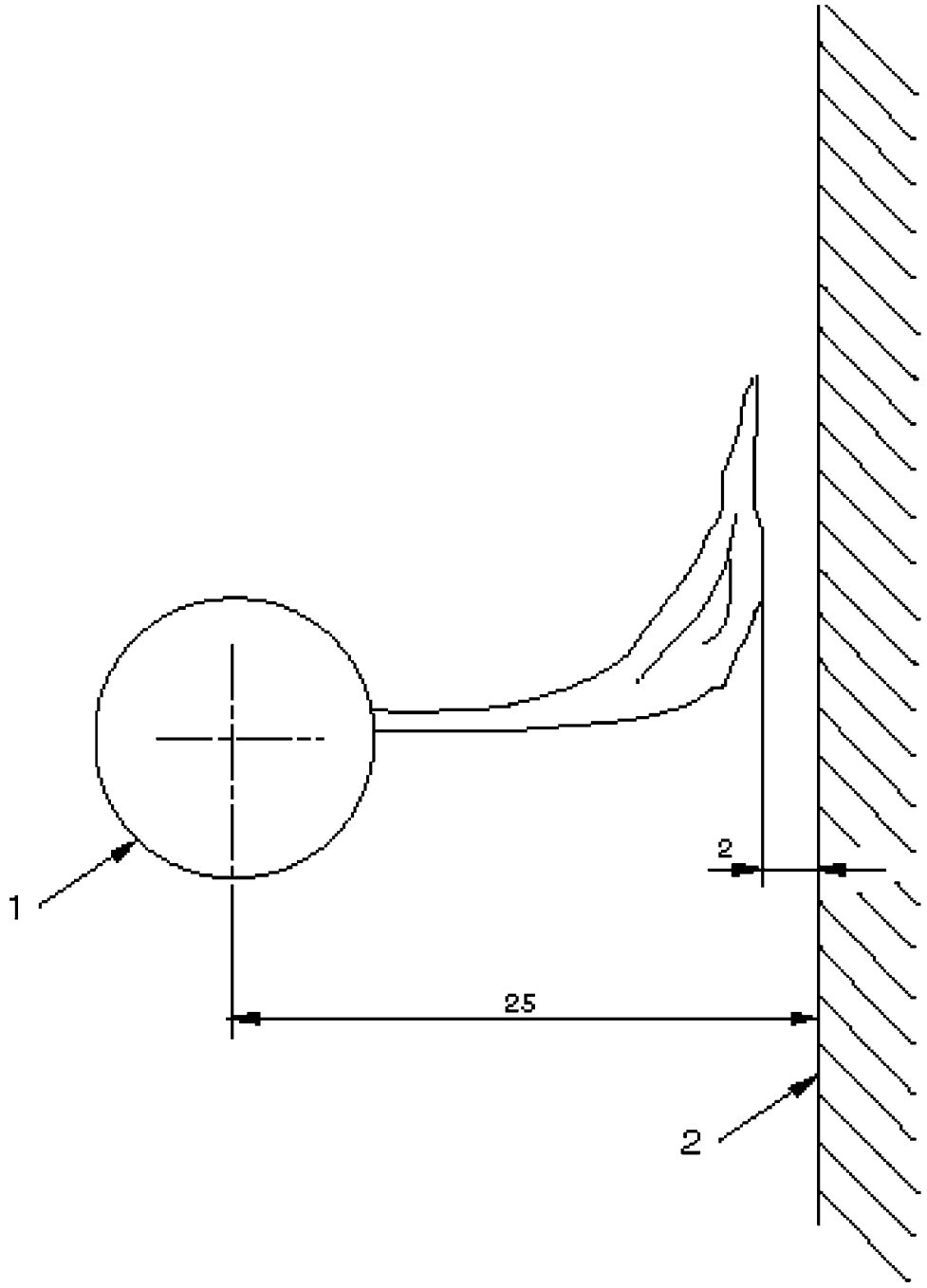



**FIG. 8 Position of Non-impinging Pilot Burner Flame to Specimen**

6.6.1.3 Separate isolation valves for gas and air,

6.6.1.4 A non-return valve and pressure regulator in the gas supply line,

6.6.1.5 An electrically operated valve to shut off the gas supply automatically in the event of air pressure loss, power failure or a sharp drop in temperature at the burner surface,

6.6.1.6 A particulate filter and a flow control valve in the air supply,

6.6.1.7 A flow meter for natural gas, methane or propane with a range of 0.3 l/s to 1.5 l/s at ambient temperature and pressure and a resolution capability of 1 % or better, and

6.6.1.8 A flow meter for air with a range of 1 l/s to 12 l/s at ambient temperature and pressure to a resolution capability of 1 % or better.

6.7 *Test Enclosure*:

6.7.1 The apparatus shall be sited in an enclosure substantially free from draughts with a clearance of at least 1 m between it and the walls of the test room. The radiant heat source shall not be located within 2 m of combustible material on ceiling, walls or floor.

6.7.2 The exterior air supply to replace that removed by the fume exhaust system shall be arranged in such a way that the ambient temperature remains reasonably stable and within the range 10 to 30°C.

6.7.3 Measurements shall be taken of air speeds near a dummy specimen while the fume exhaust system is operating but with the radiant panel and its air supply turned off. The air flow perpendicular to the lower edge and at the mid point of the specimen shall not exceed 0.3 m/s in any direction, when measured at a distance of 100 mm from the specimen.

6.8 *Other Major Components*:

6.8.1 *Heat Flux Meter*:

6.8.1.1 A Schmidt-Boelter (thermopile) type heat flux meter with a nominal range of 0 to 50 kW/m$^2$ and a time constant of not more than 3 s (corresponding to a time to reach 95 % of final output of not more than 10 s) shall be provided. The heat flux meter's sensing surface shall be flat, be less than 10 mm diameter, be coated with a durable matt black finish, and shall not be closed with a transparent cover.

NOTE 6—Commercially available heat flux meters are commonly referred to as "heat flux transducers" or "heat flux gages."

6.8.2 *Recorder*—The output from the heat flux meter shall be recorded by a strip chart recording millivoltmeter, computer data logger, or other comparable method.

NOTE 7—A digital voltmeter capable of indicating signal changes of 10 μV has been found to be convenient for monitoring changes in operating conditions of the radiant panel. A strip chart recorder with a paper speed of 5 mm/s has been found to be suitable.

6.8.3 *Timing Devices*—A chronograph and either an electric clock with a sweep second hand or a digital clock shall be used to measure time to ignition and to track the advancement of the flame front with time.

6.8.4 *Video Camera*—A video camera, placed at a location (see 10.1.4) to provide a clear view of the whole test specimen, along with an appropriate video recording device shall be used.

6.8.5 *Pyrometer*—A radiation pyrometer with a range of 700 to 850°C (black body temperature) and an accuracy of ±5°C suitable for viewing a circular area 30 ± 5 mm in diameter at a distance of about 750 mm shall be used to control the thermal output of the radiant panel. The sensitivity of the pyrometer shall be substantially constant between the wave lengths of 1 and 9 mm. Position the pyrometer on the dummy specimen trolley (see Fig. 9) for convenience of operations.

## 7. Hazards

7.1 The test procedures involve the generation of high irradiances, which are capable of igniting extraneous objects or clothing following even brief exposures. Take precautions to avoid accidental ignition of this type.

7.2 The exhaust system must be so designed and operated that the laboratory environment is protected from smoke and gas. The operator must minimize exposure to combustion products.

7.3 The operator must use protective gloves and clothing while moving the specimen trolley toward or away from the radiant panel.

7.4 Hazards can exist for the violent ejection of molten hot material or sharp fragments from some specimens during the test. Therefore, eye protection must be used by the operator.

## 8. Test Specimens

8.1 *The Exposed Surface*—The specimen selected for testing shall be tested on that face which will normally be exposed in its end-use, subject to the following:

8.1.1 Asymmetric product specimens that have either face or both faces exposed in end-use shall be tested on both surfaces.

8.1.2 Product specimens that contain directional surface irregularities which in end-use conditions run horizontal or vertical, for example, corrugations, grain or machine-induced irregularities, shall be subject to two sets of tests with the irregularities in the horizontal and vertical directions.

8.1.3 Product specimens that contain distinct areas of different surface finish or texture shall be tested separately for each distinct finish or texture.

8.1.4 If the product is a pile carpet or other surface which is compressible by the flange of the pilot burner, a check shall be made by presenting the specimen to the pilot burner without gas in the test position. If necessary, the flange shall be adjusted so that the distance between the burner tube and the specimen is 25 mm.

8.2 *Specimen Size*:

8.2.1 The specimen shall be cut or joined, or both, to be 1525 ± 25 mm long by 1025 ± 25 mm wide to fit within the specimen holder and shall be representative of the product. Materials and assemblies of normal thickness 300 mm or less shall be tested using their full end-use thickness.

8.2.2 For specimens containing one or more vertical joints, one joint shall be placed at a distance of 250 mm from the left (hot) edge of the exposed specimen. For specimens containing one or more horizontal joints, one joint shall be placed at a distance of 350 mm from the lower edge of the exposed specimen.

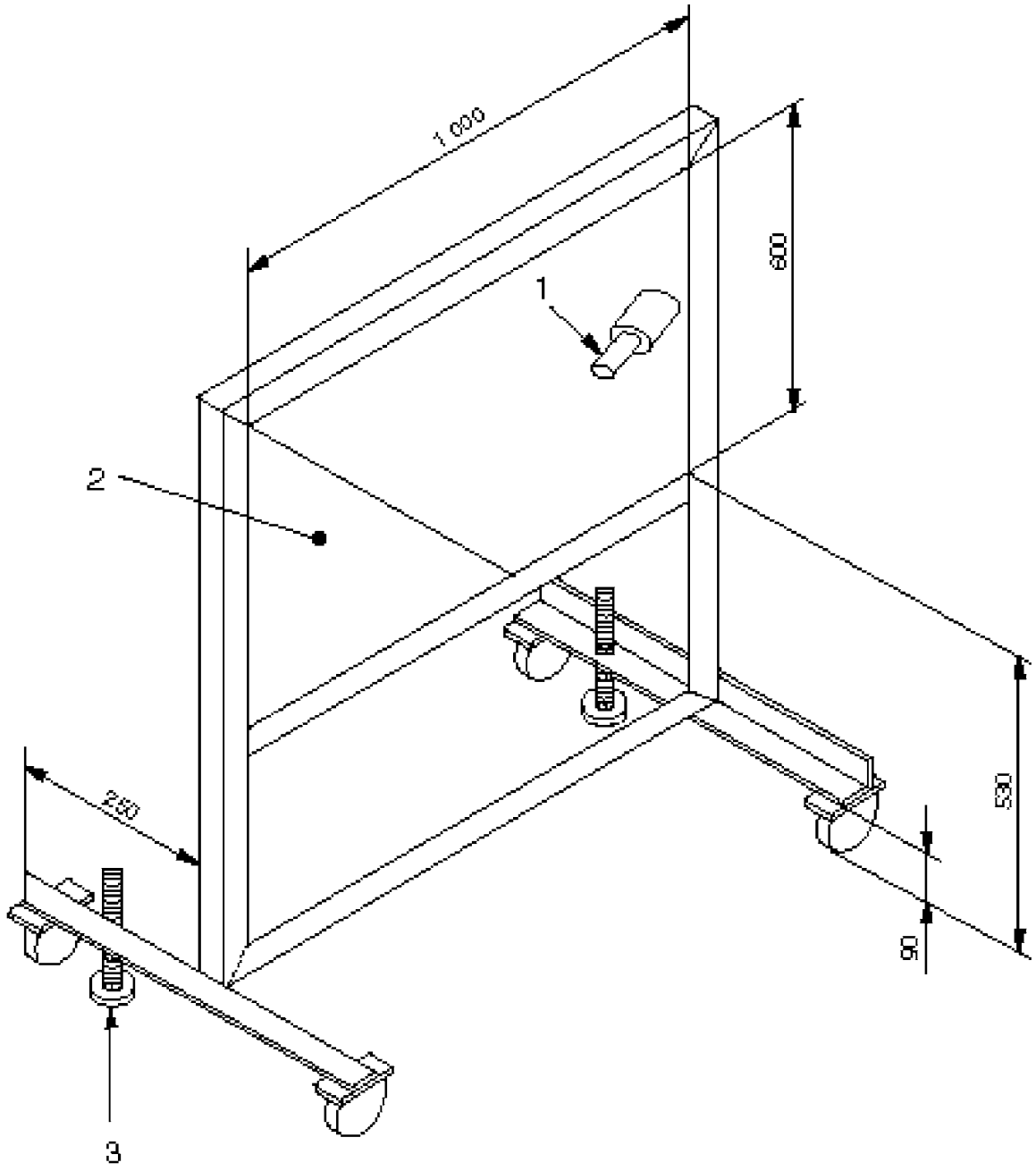
8.3 *Number Required*—Three specimens of the product evaluated shall be tested for each different exposed surface and specimen orientation.

8.4 *Specimen Assemblies*:

8.4.1 For thin materials or composites used in the fabrication of an assembly, the presence of an air gap or the nature of any underlying construction, or both, can significantly affect the characteristics of the exposed surface. Assemble layered materials, including those that contain an air gap, in the test specimen holder to ensure that the test specimen represents its end-use conditions.

NOTE 8—Place materials that are bulky or heavy, such as brick wall substrates, directly on the floor with the exposed surface at the appropriate height above the floor. Present radiant panel to such specimens according to the principles shown in Fig. 3.

8.4.2 If the product is a surface coating it shall be applied on a suitable substrate to represent its end-use conditions using an application method recommended by its manufacturer (see Appendix X1).




1. Pyrometer
2. Dummy specimen mounted from rear
3. ~42 bearings for guide rail

**FIG. 9 Typical Dummy Specimen Trolley**

8.4.3 Products that would normally be attached to a substrate shall be tested with the substrate attached using an attachment method recommended by its manufacturer (see Appendix X1). The procedure for fixing the specimens to the substrate shall be clearly stated in the test report.

8.4.4 Products intended for use as freestanding structural products, such as partitioning and sandwich panels, shall be tested without a substrate with the specimen inserted by itself into the specimen holder.

NOTE 9—A suitable arrangement to test thin flexible materials is to staple the specimen to the backing board.

8.4.5 A product intended for use with an air gap behind it shall be tested with a backing board and inserted together into the specimen holder (see Fig. 10).

8.4.6 A product intended for use with an air gap behind it shall be placed over conditioned spacers positioned around its perimeter. It shall then be mounted on a backing board so that a 25 ± 2 mm air gap is provided between the unexposed face of the specimen and the backing board. Both specimen and the backing board shall be inserted into the specimen holder (see Fig. 10).

8.4.7 *Backing Boards and Spacers*—Backing boards shall be cut from non-combustible board (for example, calcium silicate board) 11 ± 2 mm thick with the same dimensions as the test specimen and an oven-dry density of 750 ± 100 kg/m$^3$ (see ISO/TR 14697). Spacers used to create the air gap specified in 8.4.6 shall be made of the same material as the backing board, cut into 25 ± 2 mm wide strips, and attached to the whole perimeter of the backing board.

8.5 *Dummy Specimen*—A dummy specimen shall be used to correctly configure the radiant panel as shown in Fig. 2. The dummy specimen shall be cut from a non-combustible board (for example, calcium silicate board of oven-dry density 950 ± 100 kg /m$^3$). It shall measure 1025 ± 25 mm wide, 650 ± 5 mm high, and 25 ± 2 mm thick. The dummy specimen shall remain in the specimen position for at least 600 s after the radiant panel reaches the specified heat flux, and shall be removed only when a test specimen is to be inserted in front of the radiant panel. The dummy specimen can be mounted on a support trolley (see Fig. 9).

8.6 *Conditioning*:

8.6.1 All test specimens shall be conditioned for a minimum of four days before testing to moisture equilibrium (constant weight) at an ambient temperature of 23 ± 3°C and a relative humidity of 50 ± 5 %. Constant weight is achieved when two weighings differ by no more than 0.2 % in 24 h.

8.6.2 Test specimens shall be arranged within the conditioning environment to allow for air circulation around each specimen.

8.6.3 Backing boards and spacers shall be conditioned for at least two days before use under the same temperature and humidity conditions as the test specimens.

8.6.4 When the test specimen requires a backing board, they are permitted to be conditioned separately or as a mounted specimen. Specimens that are glued to the backing board shall be glued before conditioning.

8.6.5 The total test procedure shall be carried out within 2 h after removal of the specimen from the conditioned environment.

8.7 *Reference Lines*:

8.7.1 Two lines shall be marked on the specimen, at the lower horizontal edge and the left vertical edge, to identify the edges of the specimen to be exposed by the radiant panel. These lines shall correspond to the specific overlap edge of the specimen holder (see Fig. 11).

8.7.2 Two additional lines shall be marked on the surface of the specimen: *(1)* a horizontal line at 480 mm above the horizontal line drawn in 8.6.1 and shall be referred to as the YO line, and *(2)* a vertical line at 200 mm from the vertical line drawn in 8.6.1 and shall be referred to as the XO line. The intersection of XO and YO shall be referred to as the zero point (see Fig. 12).

8.7.3 Additional horizontal lines shall be marked on the specimen surface at heights of 80 mm, 680 mm, 880 mm, 1080 mm, and 1280 mm from the horizontal line XO (see Fig. 13).

8.7.4 Additional vertical lines shall be marked on the specimen surface at distances of 400 mm, 600 mm, and 800 mm from the vertical line YO (see Fig. 13).

NOTE 10—Care should be taken to avoid the possibility of the line influencing the performance of the specimen, for example by damaging the surface, or increasing its radiation absorbency. Some materials discolor on thermal exposure so that the lines or marks, or both, may be obscured. Other reference lines may be added to allow the flame spread to be recorded.

## 9. Calibration

9.1 *Calibration Board*:

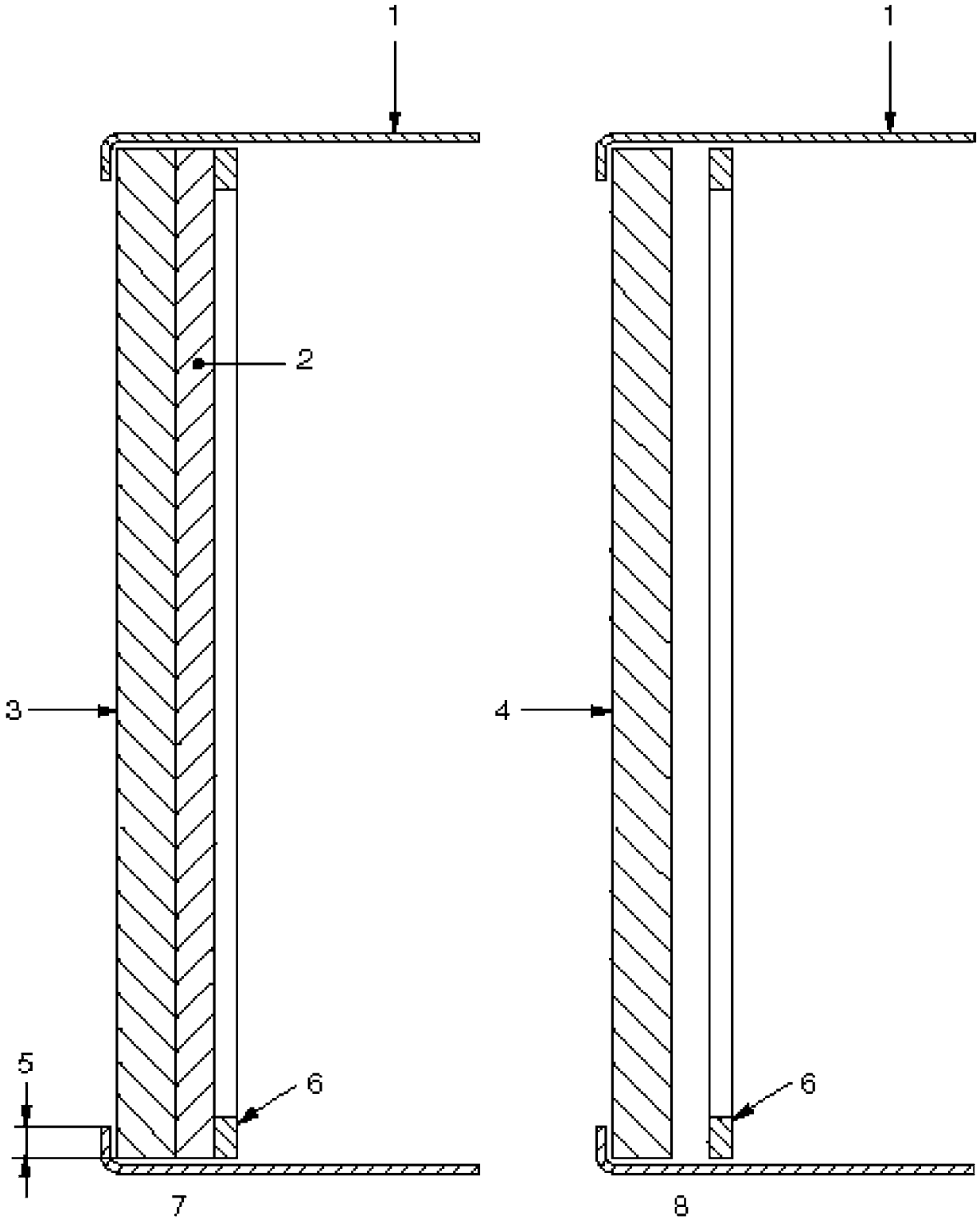
9.1.1 A calibration board shall be made of non-combustible board (for example, calcium silicate board) of dimensions 1025 ± 25 mm by 650 ± 5 mm by 11 ± 2 mm thick and of oven-dry density 750 ± 100 kg/m$^3$. The calibration board shall be provided with five holes at the positions given in Fig. 14 to accommodate a heat flux meter for measuring the irradiance in the plane corresponding to the exposed surface of a specimen. The five holes in the calibration board shall align with the center line of the radiant panel (positioned 640 mm above floor-level in the arrangement shown in Fig. 3). A single heat flux meter can be used, inserted in each hole in turn. Alternately, multiple heat flux meters can be used. Holes which are not occupied by a heat flux meter shall be filled with removable plugs of the same material as the calibration board.

9.1.2 The receiving face(s) of the heat flux meter(s) shall (all) be in the plane of the exposed surface of the calibration board.

9.1.3 The calibration board (see Fig. 15) shall be mounted in a dummy specimen holder and located on a specimen support trolley.

9.2 The working heat flux meter shall be calibrated every two months against the two reference standard heat flux meters. One of the reference heat flux meters shall be fully calibrated at an accredited laboratory annually.

9.3 *Monthly Verification*—The heat flux distribution (Table 1) on the calibration board shall be confirmed by measuring the heat flux at positions 1, 2, 3, 4, and 5 (see Fig. 14).




1. Specimen holder
2. Backing board
3. Specimen (which may include a substrate)
4. Specimen
5. Overlap edge of specimen holder
6. Pushing frame
7. (a) with backing board
8. (b) without substrate or backing board

**FIG. 10 Typical Mounting of Specimen**

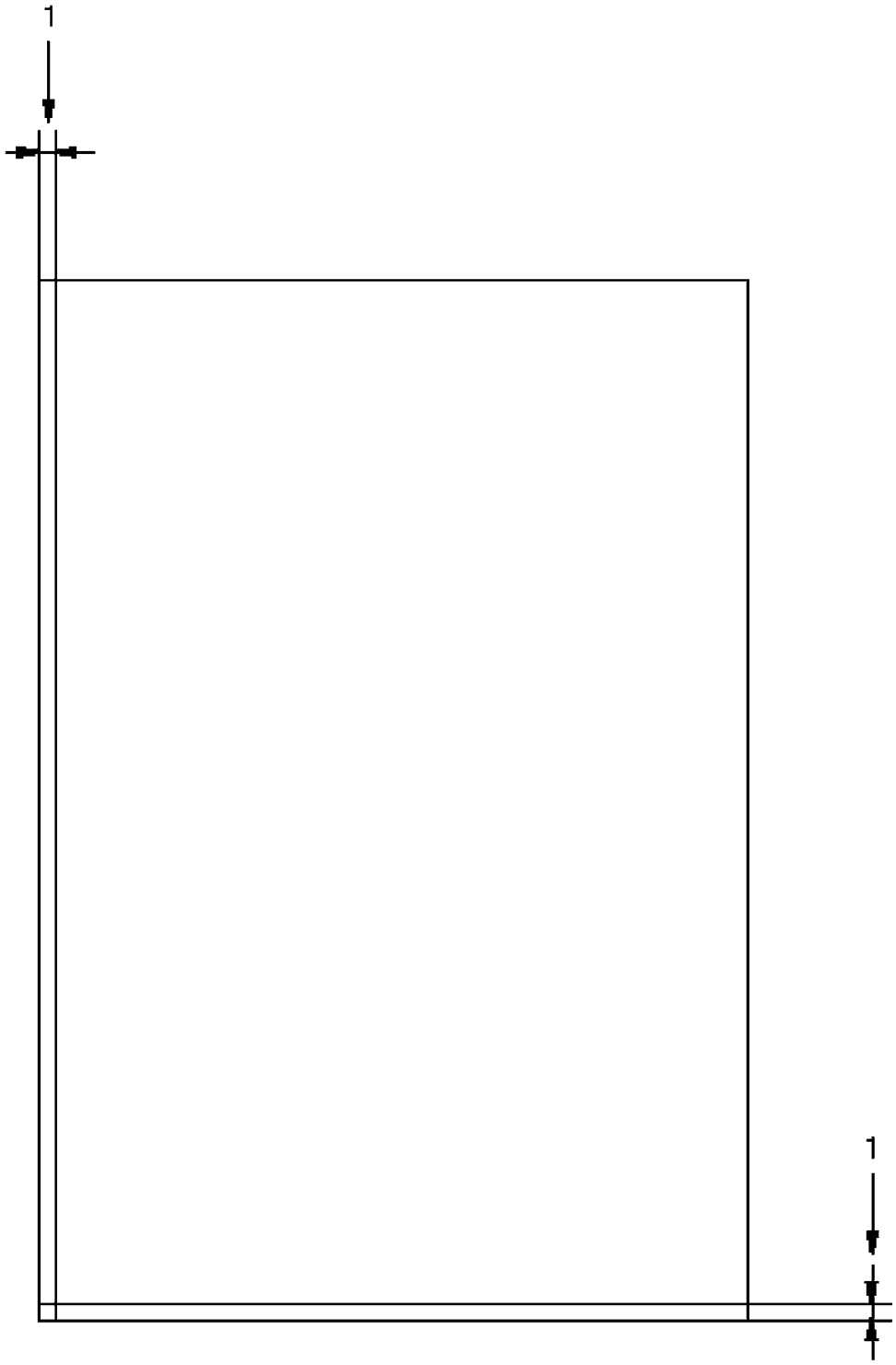
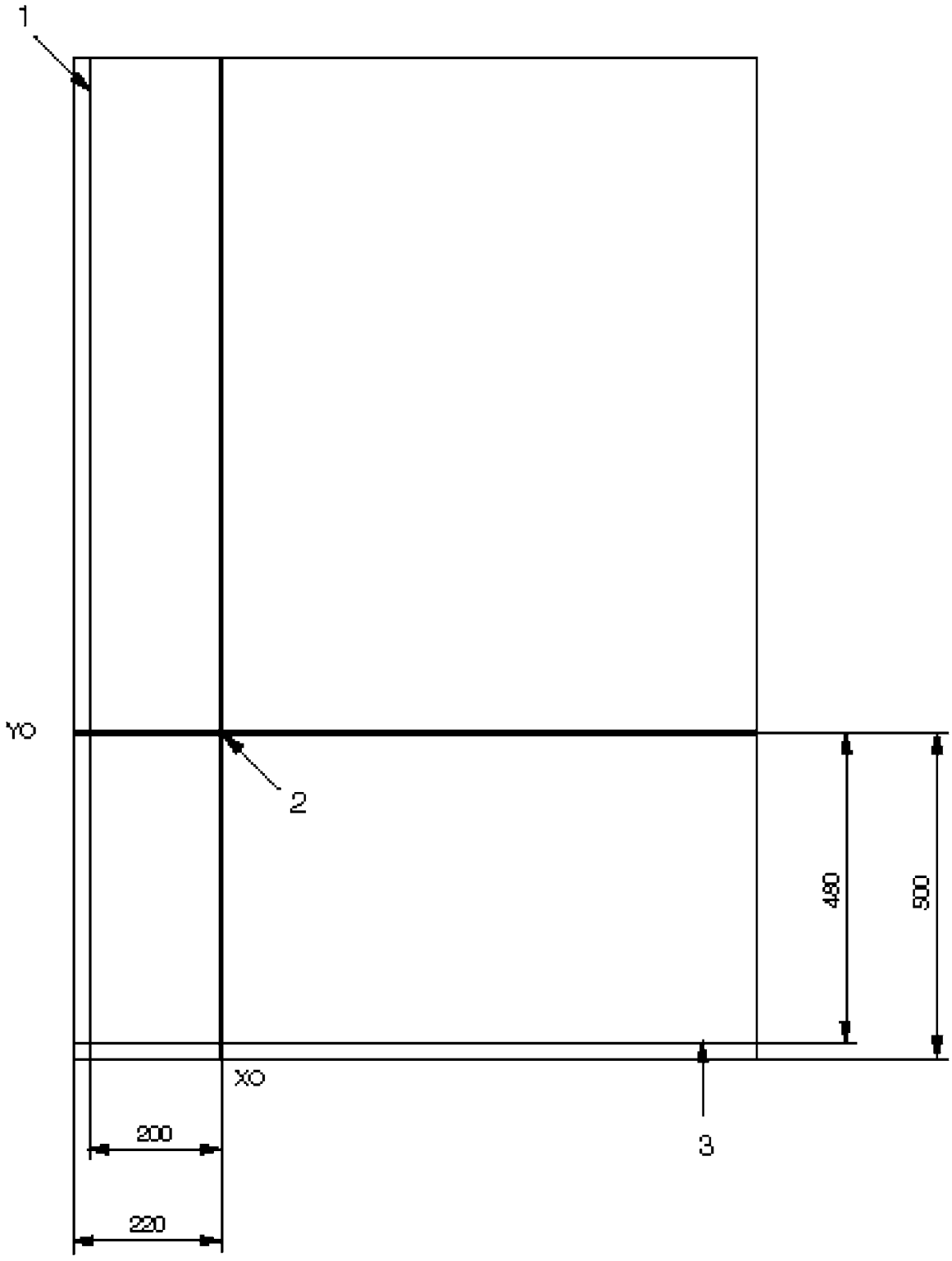



**FIG. 11 Location of Areas Overlapped by the Specimen Holder on Test Specimen**

9.4 *Daily Verification*—The heat flux at positions 1 and 2 on the calibration board shall be verified with the heat flux distribution of Table 1.

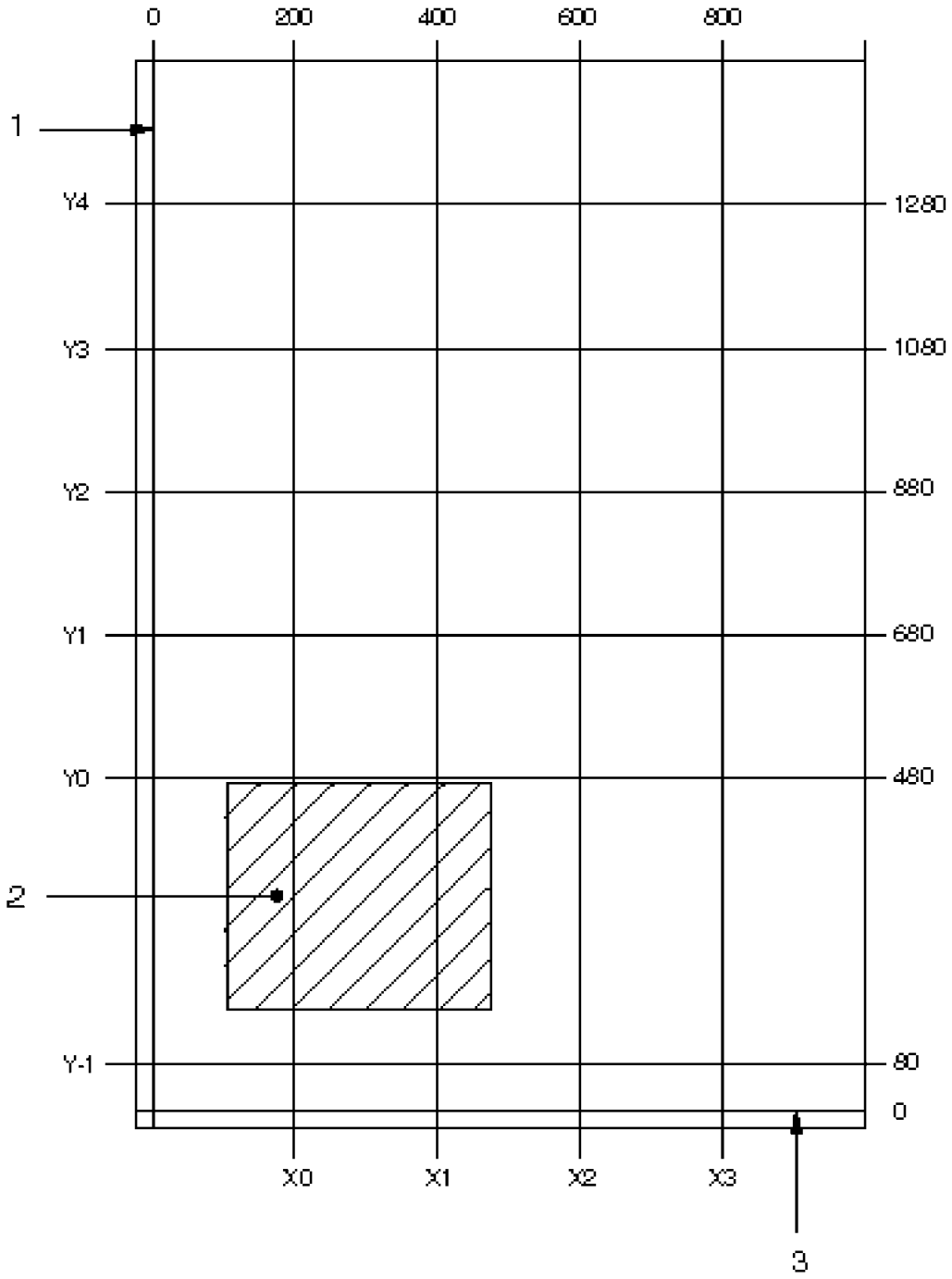
9.5 *Adjustment of the Pilot Flame*:

9.5.1 The spacing of the pilot burner nozzles from a dummy non-combustible specimen surface shall be adjusted to 25 ± 1




1. Exposed side edge of specimen
2. Zero-point
3. Lower exposed edge of specimen

**FIG. 12 Location of Zero Point on Test Specimen**




1. Exposed side edge of specimen
2. Position of radiant panel
3. Lower exposed edge of specimen

**FIG. 13 Location of Reference Lines on Test Specimen**

mm (see Fig. 8). There are two means of adjusting the spacing: *(1)* insert a dummy specimen into a specimen holder, or *(2)* use the dummy specimen trolley.

9.5.2 Adjust the propane supply so that the flames along the burner tube are about 2 mm separated from the surface of the dummy specimen, and note the propane flow rate. Check the adjustment of the pilot flames at least every day.

NOTE 11—For readily compressible materials such as high-pile carpets (see 8.1.4), the flange spacers on the pilot burner can be adjusted to leave

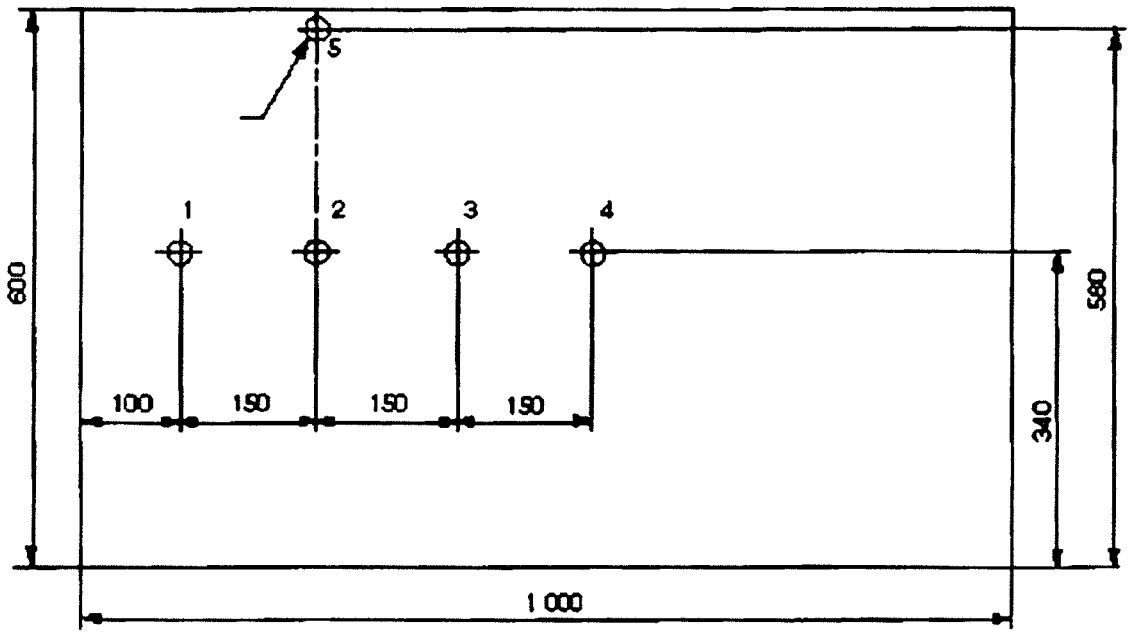



**FIG. 14 Positions of Heat Flux Meter in Exposed Area of Calibration Board**

a gap of 25 ± 1 mm between the surface of the specimen and the burner tube. This adjustment shall be done with the specimen in the test position, with no propane supply to the burner.

## 10. Procedure

NOTE 12—The initial position of the refractory surface of the radiant panel with respect to the specimen shall correspond with the dimensions shown in Fig. 3.

10.1 *Preparation*:

10.1.1 Set an air flow rate of about 5 1/s through the radiant panel. Turn on the combustion gas supply, ignite the radiant panel and allow it to come to thermal equilibrium as indicated by steady temperatures measured by the pyrometer.

NOTE 13—When operating correctly there should be no visible flaming from the panel except when viewed parallel to the surface from one side. From this direction a thin blue flame very close to the surface of the panel will be observed. An oblique view of the panel after a 15 min warm-up period should show a bright orange radiating surface.

10.1.2 Adjust the combustion gas or air flow rates, or both, until the heat flux measured with the heat flux meter(s) mounted in the calibration board at positions 1 and 2 correspond to Table 1. After each adjustment, allow the radiant panel to reach temperature equilibrium before measuring the radiant heat fluxes.

10.1.3 Once the heat flux values shown for positions 1 and 2 have been achieved, confirm that the heat flux for each of the other positions are as given in Table 1.

10.1.4 Position the video camera at a distance of approximately 3 m in front of the test specimen so that the full area of the specimen will be in focus without moving the camera during the test. Check that all the reference lines on the test specimen can be clearly seen on the video-recorder.

10.2 Mount the specimen in a specimen holder located on the specimen support trolley and start the fume exhaust system.

10.3 When the radiant panel has attained thermal equilibrium, light the pilot burner with the propane flow rate at 0.6 l/min.

10.4 Remove the calibration board, move the specimen support trolley smoothly and slowly into the test position (see Fig. 3), and position the pilot burner as shown in Fig. 8. Immediately start the clock, the chronograph, and the video camera clock.

10.5 Record time-to-ignition for the specimen as the time to sustained flaming. Record any other flaming effects, such as transitory flaming and formation of flaming drips or debris, and whether any flaming debris continues to burn after its collection in the debris tray.

10.6 Throughout the exposure of the specimen make no change in the fuel supply rate to the radiant panel to compensate for variations in its operating level.

10.7 Operate the event marker of the chronograph to indicate the time of arrival of any sustained flame front at the reference lines on the specimen surface and the edges of the specimen (see Fig. 13).

10.8 Maintain the pilot flame for the duration of the test.

10.9 *Duration of Test*—Withdraw the specimen trolley if:

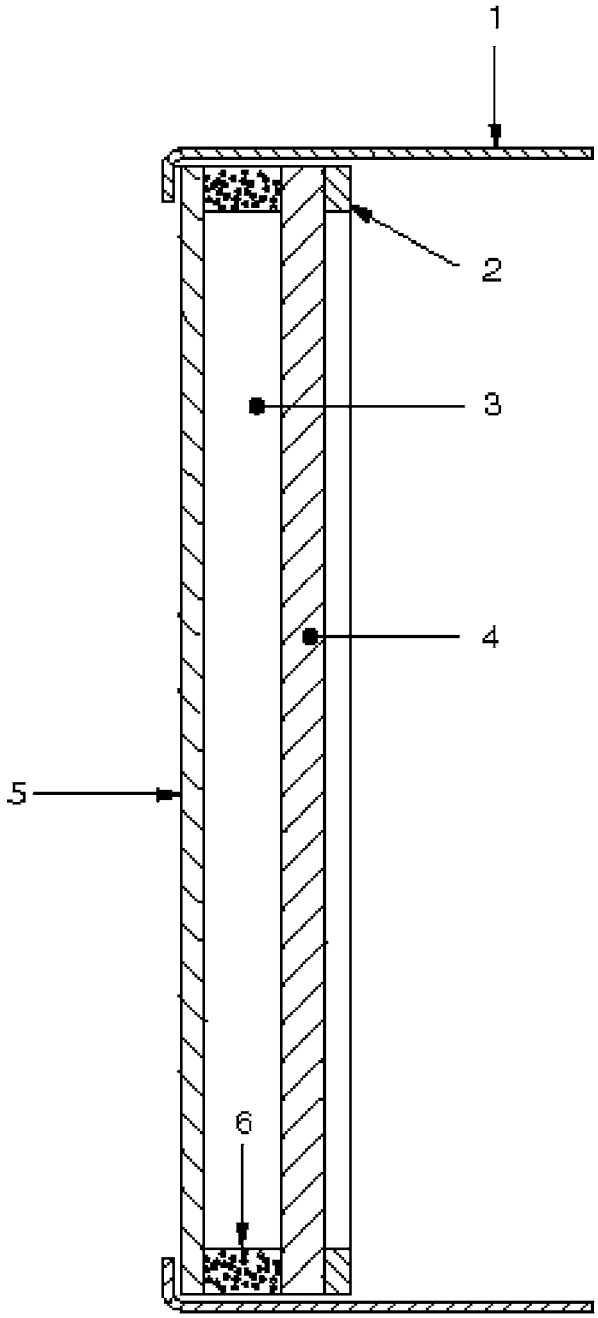
10.9.1 The specimen fails to ignite after a 20 min exposure, or

10.9.2 Flame ceases to spread along the specimen and goes out and no further flaming of any type ensues within the next 5 min, or

10.9.3 The specimen has been totally consumed, or

10.9.4 Thirty minutes have elapsed since the start of the test and flaming is still observable.

10.10 Record the burned area and type of damage to the specimen both photographically and with a detailed sketch (see Fig. 16).




1. Specimen holder
2. Pushing frame
3. Air gap
4. Backing board
5. Specimen
6. Spacer

**FIG. 15 Typical Mounting of Specimen with Backing Board and Spacers Forming an Air Gap**

NOTE 14—When the term "damaged area" is used, it is necessary to specify the types of damage observed. Discolorations, soot and changes in structure such as distortions, sintering, curling of the edge area, formation of bubbles etc., are not taken into consideration. For specimens with protective intumescing agents or layers, changes in these intumescents as a result of carbonization are not taken into account. To determine a

**TABLE 1 Heat Flux Along the Calibration Board**

| Heat Flux Position (Fig. 14) | Heat Flux (kW/m$^2$) |
|---|---|
| 1 | 25 ± 3 |
| 2 | 40 ± 3 |
| 3 | 25 ± 3 |
| 4 | 15 ± 3 |
| 5 | 13 ± 3 |

residual undamaged length of a protected building material (see Fig. 16), the protective layers are removed (for example, by scratching or washing off).

10.11 Repeat the above procedure for two additional specimens, allowing the radiant panel to attain temperature equilibrium before each test.

## 11. Calculation

11.1 Determine average flame spread rates (vertical and lateral) according to the appropriate method as indicated below where the flame spread distances are measured from the XO and YO reference lines:

11.2 *Method 1*—Where the specimen burns for more than 180 s,

$$(a) \qquad R_V = \frac{d}{180} \tag{1}$$

$$(b) \qquad R_L = \frac{d}{180} \tag{2}$$

where:
$R_V$ = vertical rate in mm/s,
$R_L$ = lateral rate in mm/s, and
$d$ = distance (mm) of the flame front furthest from X0 (or Y0), 180 s after ignition.

11.3 *Method 2 (a)*—Where the specimen burns to the Y4 reference line before 180 s,

$$R_V = \frac{800}{t_V - t_{ig}} \tag{3}$$

where:
$R_V$ = vertical rate in mm/s,
$t_V$ = time (s) for the flame front to reach the 800 mm reference line, and
$t_{ig}$ = ignition time (s).

11.4 *Method 2 (b)*—Where the specimen burns to the X3 reference line before 180 s,

$$R_L = \frac{600}{t_L - t_{ig}} \tag{4}$$

where:
$R_L$ = lateral rate in mm/s,
$t_L$ = time (s) for the flame front to reach the 600 mm reference line, and
$t_{ig}$ = ignition time (s).

11.5 *Method 3*—Where the maximum distance reached is less than the distance to the Y4 or X3 reference line of the specimen in under 180 s,

$$R_V = \frac{d_V\text{max}}{t_V\text{max} - t_{ig}} \tag{5}$$

where:
$R_V$ = vertical rate in mm/s,
$d_V$max = distance (mm) of the furthest Y reference line reached by the flame front,
$t_V$max = time (s) for the flame front to reach the furthest Y reference line, and
$t_{ig}$ = ignition time (s).

$$R_L = \frac{d_L\text{max}}{t_L\text{max} - t_{ig}} \tag{6}$$

where:
$R_L$ = lateral rate in mm/s,
$d_L$max = distance (mm) of the furthest X reference line reached by the flame front,
$t_L$max = time (s) for the flame front to reach the furthest X reference line, and
$t_{ig}$ = ignition time (s).

## 12. Report

12.1 *Descriptive Information*—The report shall include the following:

12.1.1 Name and address of testing laboratory,

12.1.2 Name and address of test sponsor,

12.1.3 Details of specimen preparation including substrate used, and method of fixing the specimen onto the substrate,

12.1.4 Number of specimens tested,

12.1.5 Conditioning of the specimen, and

12.1.6 Date of test.

12.2 *Test Results*—The test results shall include:

12.2.1 Time-to-ignition,

12.2.2 Table of numerical results containing flame front arrival times at vertical and horizontal marked lines on specimen surface, and

NOTE 15—The video record of the test may be used by the testing laboratory to verify the times of the flame front at the reference lines. The video film is not regarded as a mandatory part of the test report; it may be retained optionally as a further record of any unusual behavior (see Appendix X2).

12.2.3 Derived flame spread rates in the vertical and lateral directions, according to the calculations in Section 11.

12.3 *Descriptive Results*—Report the following observations if any:

12.3.1 Flashing, transitory flaming (unstable flame front), smoldering and after glow,

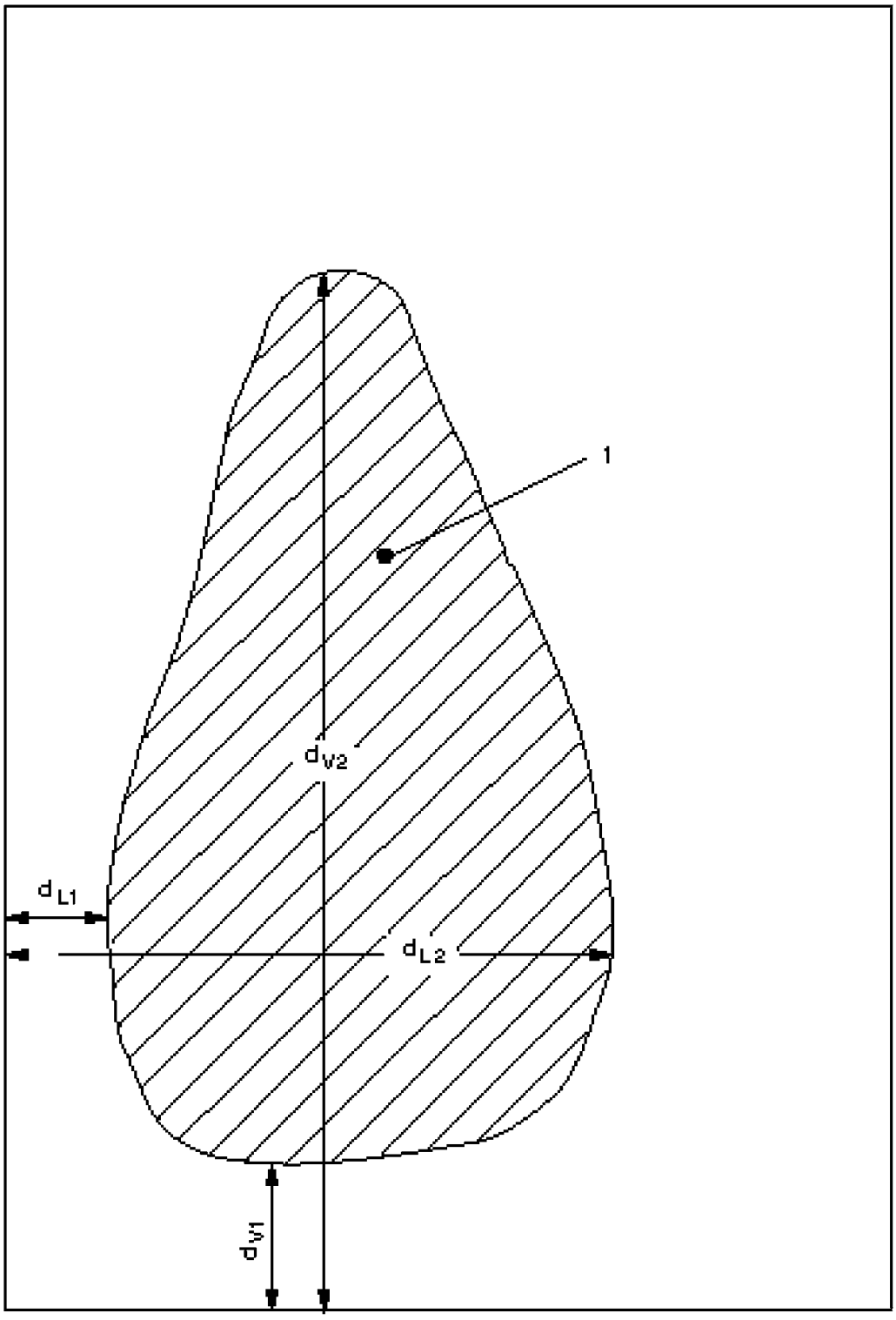
12.3.2 Drips or debris falling away from the specimen and whether or not it is flaming or glowing as defined by a duration of 4 s, intumescence or deformation of the specimen, or both, separations, spalling, fissures and cracks, sparks, melting, changes in form etc.,

12.3.3 Unusual behavior as outlined in Appendix X2, and

12.3.4 A sketch and photograph of the specimen damage (see 10.10).

## 13. Precision

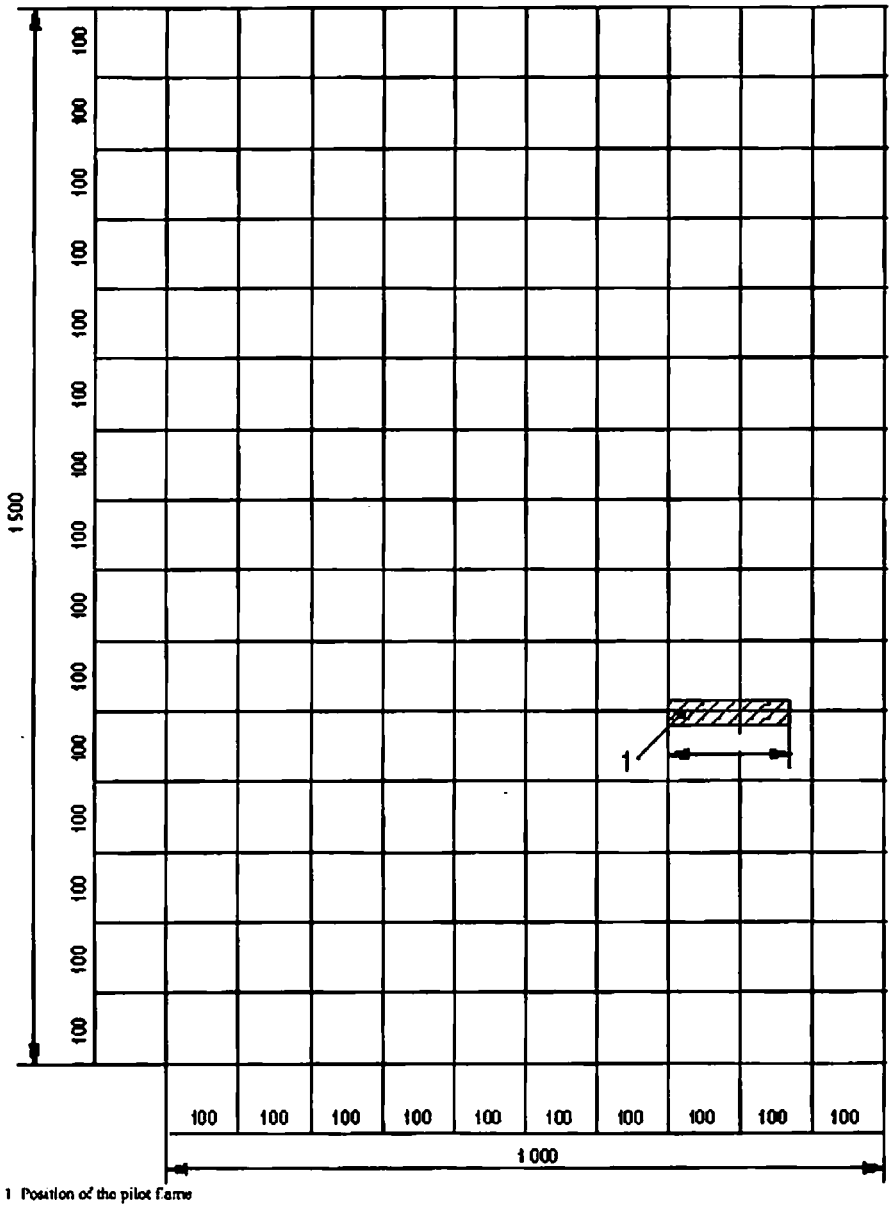
13.1 The variability in the ignition time and flame spread measurements during tests has been investigated in an interlaboratory trial (see Appendix X3).




1. Burned area

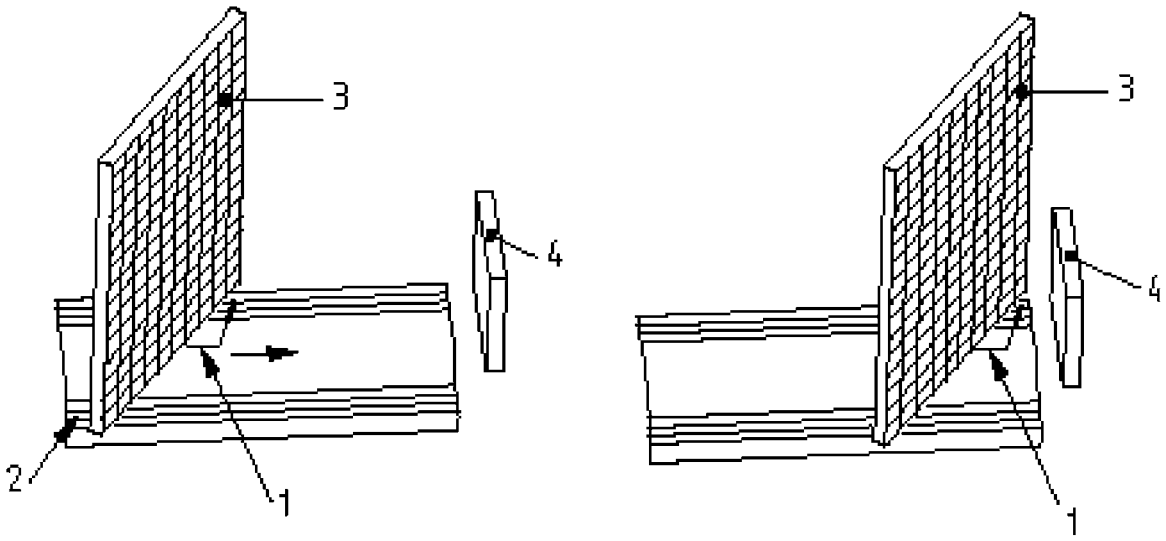
Maximum vertical burned length = $d_{v2} - d_{v1}$
Maximum lateral burned length = $d_{L2} - d_{L1}$

**FIG. 16 Damage Measurements to be Taken on All Specimens**




1 Position of the pilot flame

**FIG. 17 Reference Lines on Specimen (Optional)**




(a) Specimen advance to radiant panel
1 Start temperature thermocouple
2 Guide rails
3 Specimen
4 Radiant panel

(b) Test position

**FIG. 18 Schematic of Test Showing Use of Optional Thermocouple to Initiate Software for Start of Test**

## ANNEX

**(Mandatory Information)**

## A1. HEAT RELEASE RATE MEASUREMENT

### A1.1 Canopy Hood and Exhaust Duct

A1.1.1 *Location and Design*—The heat release rate shall be measured by placing the test apparatus, including the test specimen holder directly under a canopy hood and exhaust duct capable of collecting all of the exhaust gases. The face dimensions of the hood shall be at least 2440 by 2440 mm, and the depth shall be at least 1050 mm. The hood shall feed into a plenum having a 914 by 914 mm cross section (see Fig. A1.1). The plenum shall have a minimum height of 914 mm. The maximum height is 1830 mm. The exhaust duct connected to the plenum shall be 406 mm (16 in.) in diameter, horizontal, and shall have a circular aperture of 305 mm or guide vanes at its entrance.

A1.1.2 The hood shall have a draft sufficient to collect all of the combustion products leaving the room by moving at least a standard 2.5 $m^3$/s. Provisions shall be made to vary the draft to change the flow from 1 to 2.5 standard $m^3$/s. Mixing vanes shall be required in the duct if concentration gradients are found to exist.

A1.1.3 An alternative exhaust system design is permitted, provided it has been shown to produce equivalent results. (Equivalency is shown by meeting the requirements of A1.1.2.)

### A1.2 Instrumentation in the Exhaust Duct

A1.2.1 *Duct Gas Velocity Specification*—A bi-directional probe or an equivalent measuring system shall be used to measure gas velocity in the duct. The probe shown in Fig. A1.2 consists of a short stainless steel cylinder 44 mm long and 22 mm inside diameter with a solid diaphragm in the center. The pressure taps on either side of the diaphragm support the probe. The axis of the probe shall be along the centerline of the duct 3350 mm downstream from the entrance. The taps shall be connected to a pressure transducer that shall be able to resolve pressure differences of 0.25 Pa. Differential pressure measurements shall be smoothed by filtering the transducer output signal through an RC circuit with a time constant of 5 s. Alternatively, digital filtering of the pressure transducer output signal to simulate the effect of this RC circuit shall be permitted.

A1.2.1.1 One pair of thermocouples shall be placed 3350 mm downstream of the entrance to the horizontal duct. The pair of thermocouples shall straddle the center of the duct and be separated 50 mm from each other.

NOTE A1.1—The bi-directional probe was chosen for measuring velocity in the exhaust duct, rather than the Pitot-static tube in order to avoid

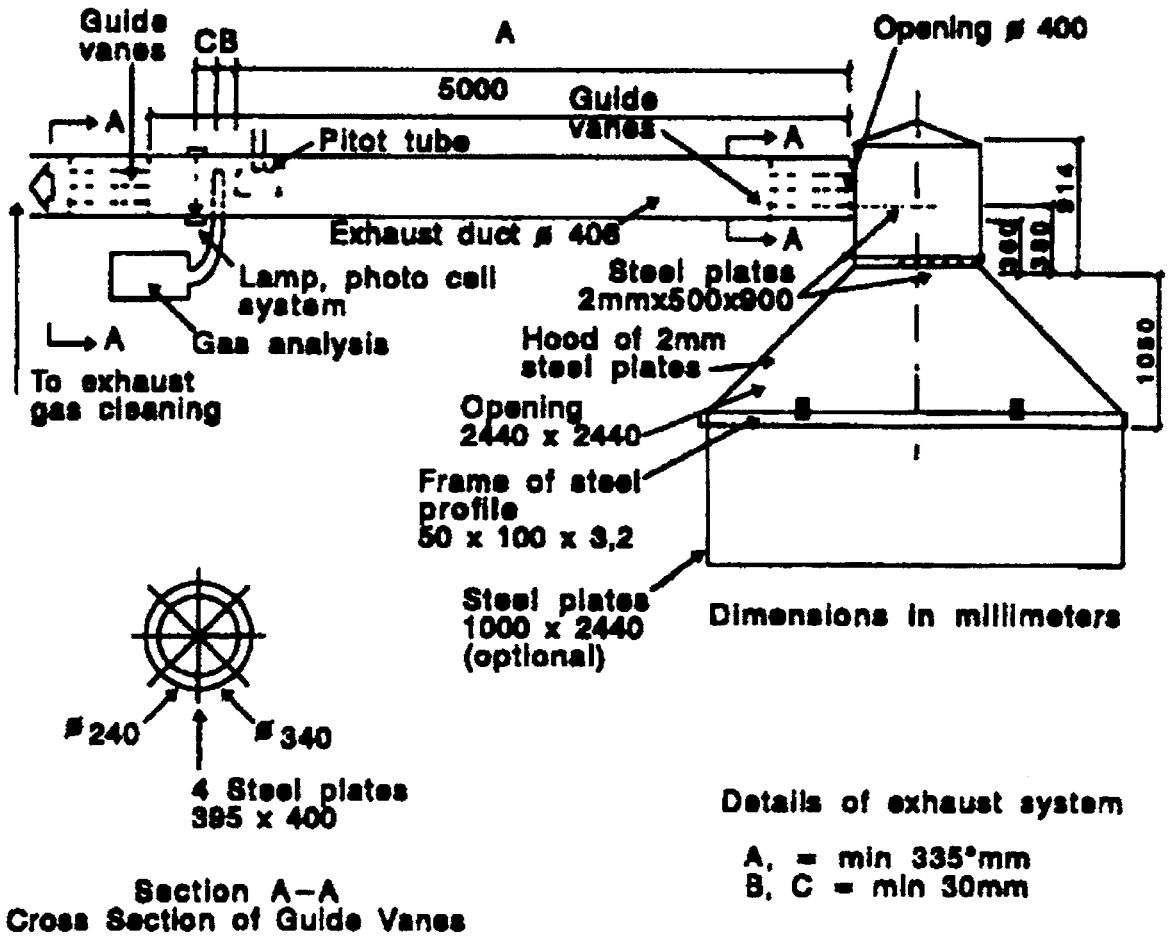



**FIG. A1.1 Hood Geometry and Placement of Duct Instrumentation**

problems of clogging with soot.

NOTE A1.2—Capacitance pressure transducers have been found to be most suitable for this application.

NOTE A1.3—*Thermocouple Specification*—Bare Type K Chromel-Alumel thermocouples 0.5 mm in diameter shall be used at each required location. The thermocouple wire, within 13 mm of the bead, shall be run along expected isotherms (horizontally) to minimize conduction errors. The insulation between the Chromel and Alumel wires shall be stable to at least 1100°C or the wires shall be separated. 1.6 mm OD Inconel sheathed thermocouples with an ungrounded junction and high purity (99.4 %) magnesium oxide insulation will work satisfactorily. The commonly used silicone-impregnated glass insulation breaks down above 800°C.

A1.2.2 *Duct Oxygen Concentration Specification*—A stainless steel gas sampling tube shall be located 3660 mm downstream from the entrance to the duct, to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time. A suitable filter and cold trap or permeable membrane drier shall be placed in the line ahead of the analyzer, to remove particulates and water. The oxygen analyzer shall be of the paramagnetic type and shall be capable of measuring the oxygen concentration in the range from 21 % down to 15 % with an accuracy of ±0.01 % in this concentration range. The signal from the oxygen analyzer shall be within 5 % of its final value in 60 s after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

A1.2.3 *Duct Carbon Dioxide Concentration Specification*—The gas sampling tube described in A1.2.2, or an alternative tube in the same location, shall provide a continuous sample for the measurement of the carbon dioxide concentration using an analyzer with a range of 0 to 5 %, with a maximum error of 0.1 % of full scale. The signal from the analyzer shall be within 5 % of its final value in 60 s after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

A1.2.4 *Duct Carbon Monoxide Concentration Specification*—The gas sampling tube defined in A1.2.2, or an alternative tube in the same location, shall provide a continuous sample for the measurement of the carbon monoxide concentration using an analyzer with a range from 0 to 1 % with a maximum error of ±0.02 %. The signal from the analyzer shall be within 5 % of its final value in 60 s after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

A1.2.5 *Data Acquisition*—The data collection system used shall have facilities for the recording of the output from the bi-directional probe, the gas analyzers, the heat flux meter, the

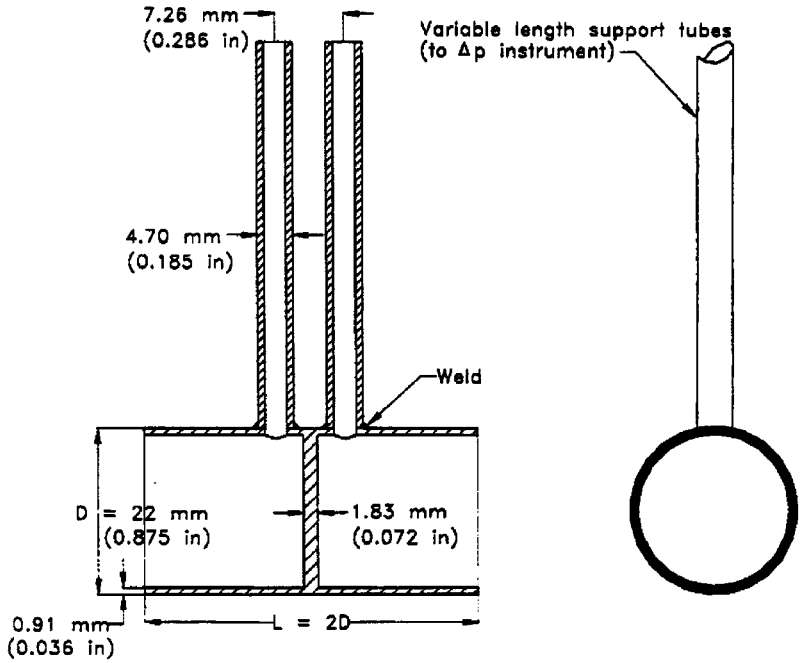



FIG. A1.2 Bi-directional Probe

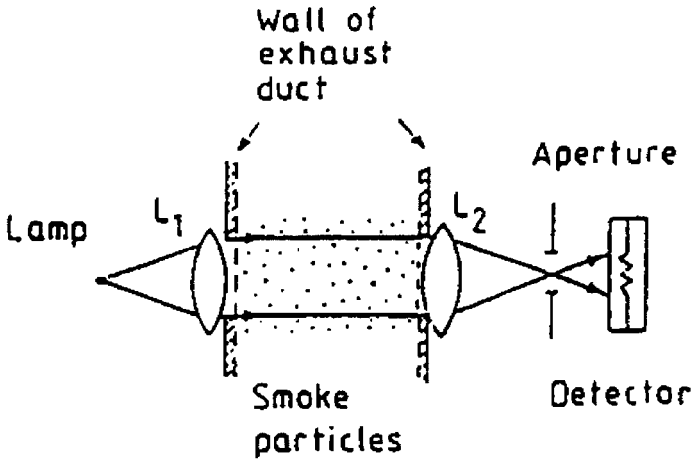



FIG. A1.3 White-Light Smoke Photometer

thermocouples, and the smoke measuring system. The data acquisition system shall have an accuracy corresponding to at least 50 ppm oxygen for the oxygen channel, 0.5°C for the temperature measuring channels, and 0.01 % of full-scale instrument output for all other instrument channels. The system shall be capable of recording data for at least 22 min, at intervals not exceeding 6 s.

NOTE A1.4—The system should be calibrated at least once per year.

### A1.3 Heat Release Rate Calibration

A1.3.1 A heat release rate calibration test shall be performed prior to and within 30 days of any test measurements according to the calibration procedure described in Test Method E 2257.

### A1.4 Procedure

A1.4.1 Zero the pressure transducer signal after connecting the two ports of the transducer.

A1.4.2 Establish an initial volumetric flow of 1 $m^3/s$ through the duct. During the test, increase the volume flow through the duct to 2.5 $m^3/s$ as necessary to collect all combustion products emerging from the room.

A1.4.3 Calibrate the smoke meter by blocking the light beam (zero) and using a neutral density filter (span). Calibrate the gas analyzers with zero (nitrogen) and span gases (dry air for oxygen and certified mixtures for carbon monoxide and carbon dioxide).

A1.4.4 Turn on all exhaust gas sampling and recording devices, and establish steady-state baseline readings from the radiant panel for at least 2 min.

NOTE A1.5—This will allow the baseline heat release from the operation of the radiant panel to be established.

A1.4.5 Continue collecting data after introducing the test specimen in front of the radiant panel.

### A1.5 Heat Release Rate Report

A1.5.1 The heat release rate report shall include the following:

A1.5.1.1 *Radiant Panel Gas Flow*—The fuel gas flow to the radiant panel and its measured of heat output (see A1.4.4).

A1.5.1.2 *Mass Flow in the Duct Gas*—The mass flow of the gas in the duct shall be calculated from A1.7 and reported as a function of time starting 1 min prior to the test.

A1.5.1.3 *Oxygen Concentration*—The oxygen concentration measured by the analyzer as a function of time.

A1.5.1.4 *Carbon Dioxide Concentration*—The carbon dioxide concentration measured by the analyzer as a function of

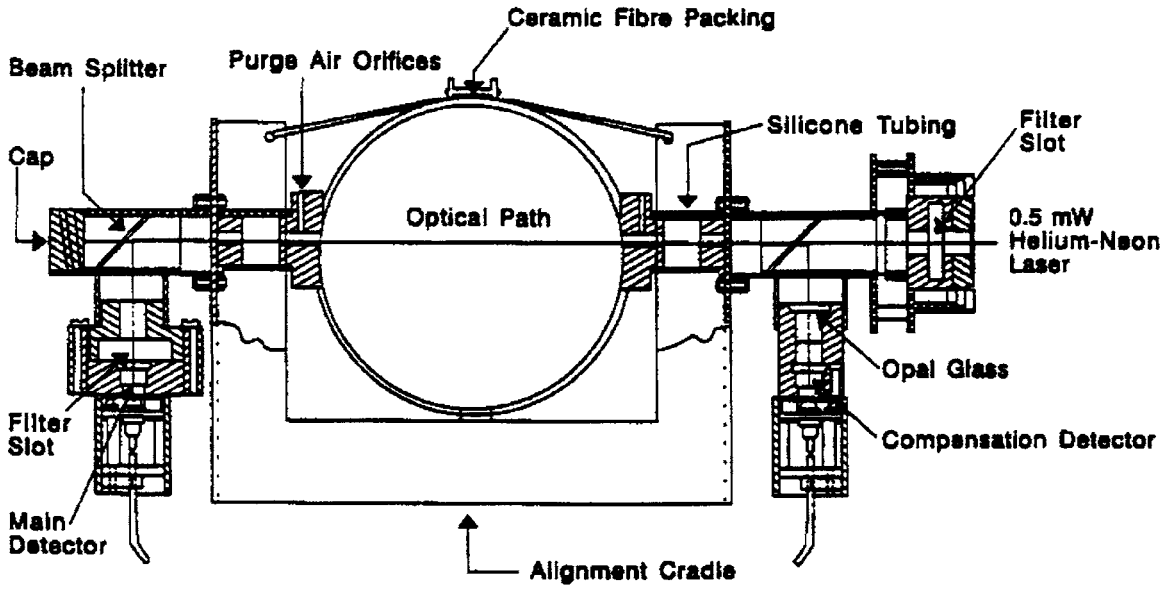



FIG. A1.4 Laser Smoke Photometer

time starting 1 min prior to the test. (Separate reporting of the mass flow, temperature, oxygen and carbon dioxide concentrations provide diagnostic information on the performance of the exhaust gas collection system and also provide a check on the heat production calculations).

A1.5.1.5 *Time History of the Total Rate of Heat Production*—The total rate of heat production shall be calculated from the measured oxygen and carbon dioxide concentrations and the temperature and mass flow of the gas in the duct. The calculation is based on A1.7.

## A1.6 Precision and Bias

A1.6.1 See Test Method E 2257.

## A1.7 Calculation of the Rate of Heat Production

A1.7.1 Prior to performing any calculations, all measurements in the exhaust duct shall be shifted over the appropriate time interval to account for the travel time of the products of combustion between the fire and the instrumentation in the duct. New values for the delay times shall be determined during each calibration test (see Test Method E 2257).

A1.7.2 *Mass Flow through the Duct*:

A1.7.2.1 The mass flow through the duct is obtained from the velocity measured with a bi-directional probe (see A1.2.1) along the center line. The equation to calculate mass flow is (symbols are defined in A1.8):

$$\dot{m}_e = C\sqrt{\frac{\Delta p}{T_e}} \tag{A1.1}$$

A1.7.2.2 The theoretical value of $C$ is approximately constant for the range of operating conditions specified in this test method, and is estimated as follows. The center-line velocity measured with the bi-directional probe is given by:

$$V_c = \frac{\sqrt{2\,\Delta p\,\rho_e}}{f(Re)} \tag{A1.2}$$

where the Reynolds number correction, $f\,(Re)$, for $40 < Re < 3800$ is calculated from:

$$f(Re) = 1.533 - 1.366\,10^{-3}\,Re + 1.688\,10^{-6}\,Re^2 - 9.706\,10^{-10}\,Re^3 + 2.555\,10^{-13}\,Re^4 - 2.484\,10^{-17}\,Re^5 \tag{A1.3}$$

A1.7.2.3 If $Re > 3800$, $f\,(Re)$ is equal to an asymptotic value of 1.08. The average velocity over the cross-section of the duct, $V_e$, is slightly smaller than $V_c$. Defining the ratio of $V_e$ to $V_c$ as $k_c$, and assuming that the gases flowing through the exhaust duct are at atmospheric pressure and have the same properties as air, the mass flow can be estimated from:

$$\dot{m} = \rho_e V_e A \approx \frac{353}{T_e} k_c V_c A \tag{A1.4}$$

A1.7.2.4 Combination of Eq A1.1, Eq A1.2, and Eq A1.4 then results in:

$$C_{th} \approx 26.54\frac{k_c A}{f(Re)} \tag{A1.5}$$

A1.7.2.5 Using a typical value of 0.9 for $k_c$, and the asymptotic value of 1.08 for $f\,(Re)$, leads to the following simple estimate:

$$C_{th} \approx 22A \tag{A1.6}$$

A1.7.3 *Rate of Heat Release*:

A1.7.3.1 Calculate the mass flow according to Eq A1.1, and the oxygen depletion factor according to Eq A1.7:

$$\phi = \frac{X_{O2}^{A^\circ}(1 - X_{CO2}^{A} - X_{CO}^{A}) - X_{O2}^{A}(1 - X_{CO2}^{A^\circ})}{X_{O2}^{A^\circ}(1 - X_{O2}^{A} - X_{CO2}^{A} - X_{CO}^{A})} \tag{A1.7}$$

A1.7.3.2 Then calculate the rate of heat release according to Eq A1.8:

$$\dot{q} = \left(E\phi - (E_{CO} - E)\frac{1 - \phi}{2}\frac{X_{CO}^{A}}{X_{O2}^{A}}\right)\frac{M_{O2}}{Ma}\frac{\dot{m}_e}{1 + \phi(\alpha - 1)}X_{O2}^{A^\circ} \tag{A1.8}$$

### A1.8 Symbols

$A$ = cross-sectional area of the duct at the location of the probe (in $m^2$)
$C$ = orifice plate coefficient ($kg^{1/2} \times m^{1/2} \times K^{1/2}$)
$D$ = duct diameter (m)
$E$ = net heat released per unit mass of $O_2$ consumed (13.1 MJ/kg)
$E_{CO}$ = net heat released per unit mass of $O_2$ consumed, for CO (17.6 MJ/kg)
$f(Re)$ = Reynolds number correction
$k_c$ = velocity profile shape factor (non dimensional)
$m_e$ = mass flow in exhaust duct (kg/s)
$\dot{m}_{CO}$ = release rate of carbon monoxide (kg/s)
$M_a$ = molecular mass of incoming air (29 kg/kmol)
$M_{CO}$ = molecular mass of carbon monoxide (28 kg/kmol)
$M_{O2}$ = molecular mass of oxygen (32 kg/kmol)
$\Delta p$ = differential pressure measured across the bi-directional probe (Pa)
$\dot{q}$ = rate of heat release (kW)
$T_e$ = gas temperature at the bidirectional probe (K)
$T_s$ = gas temperature at the smoke meter (K)
$V_s$ = volumetric flow at the smoke meter ($m^3/s$)
$X_{CO}^{A}$ = measured mole fraction of CO in exhaust flow
$X_{CO2}{}_{A}$ = measured mole fraction of $CO_2$ in exhaust flow
$X_{CO2}{}_{A^\circ}$ = measured mole fraction of $CO_2$ in incoming air
$X_{O2}^{A}$ = measured mole fraction of $O_2$ in exhaust flow
$X_{O2}{}_{A^\circ}$ = measured mole fraction of $O_2$ in incoming air
$\alpha$ = combustion expansion factor (normally a value of 1.084)

## APPENDIXES

**(Nonmandatory Information)**

## X1. SPECIMEN CONSTRUCTION

### X1.1 Effect of Thermal Characteristics on the Performance of Assemblies

X1.1.1 With thin materials or composites, particularly those with a high thermal conductivity, the presence of an air gap and the nature of any underlying construction may significantly affect the ignition and spread of flame performance of the exposed surface. Increasing the thermal capacity of the underlying construction increases the “heat sink” effect and may delay ignition of the exposed surface and slow flame spread. Any backing provided to the test specimen and in intimate contact with it, such as the non-combustible spacers (see 8.4.7), may alter this ’heat sink’ effect and may be fundamental to the test result itself. The influence of the underlying layers on the performance of the assembly should be understood and care should be taken to ensure that the result obtained on any assembly is relevant to its use in practice.

### X1.2 Preparation of Test Specimens

X1.2.1 The following advice is offered on the construction and preparation of test specimens:

X1.2.1.1 Where the thermal properties of the product are such that no significant heat loss to the underlying layers can occur, for example, a material/composite greater than approximately 6 mm thick of high thermal capacity or low thermal conductivity, or both, then the product should be tested backed only by the backing board.

X1.2.1.2 Where the product is normally used as a free-standing sheet and the characteristics noted in a) do not apply, then an air space should be provided at the back of the product by spacers of non-combustible insulation board.

X1.2.1.3 Where the product is to be used in practice over a low density non-combustible substrate and the characteristics noted in X1.2.1.1 do not apply, then the product should be tested in conjunction with that substrate.

X1.2.1.4 Where the product is to be used in practice over a combustible substrate and the characteristics noted in X1.2.1.1 do not apply, then the product should be tested in conjunction with that substrate. The advice on selection of substrates given in ISO TR 14697 should also be followed.

### X1.3 Significance and Use

X1.3.1 Ducts, panels and pipes can be tested in their end-use conditions according to this test method. The user is, however, cautioned against comparing flame spread and distance measurements of such specimens with those from planar materials.

X1.3.2 Upward flame spread is not limited to surfaces which are vertical. It is recognized that an enhanced form of upward, wind-aided flame spread can occur on surfaces at an angle greater than 20° from the horizontal without any external ventilation. This type of flame spread can occur in both planar sloping surfaces and stepped surfaces such as stairs. Flame spread in these situations can become very rapid and can cause serious problems in escape ways such as staircases. Therefore, when assessing stepped or sloping surface materials, it may be more appropriate to use a vertical flame spread test rather than a test in which the specimen is horizontal.

## X2. GUIDELINES FOR INTERPRETATION OF RESULTS OF FIRE PROCEDURE

X2.1 The objective of this appendix is to provide guidance on the uniform interpretation of results of the fire test procedure.

| | Unusual Behavior | Guidance for Reporting |
|---|---|---|
| 1 | Flashing or transitory flaming, no steady flame | Report furthest progress of flame and time |
| 2 | Explosive spalling, no flashing or flame | Report severity of spalling |
| 3 | Rapid flash or transitory flame over surface, later steady flame progress | Report result for both flame fronts |
| 4 | Specimen or surface-coating melts and drips off, no flame | Report behavior and extend of damage on specimen |
| 5 | Explosive spalling, and flame on exposed part of specimen | Report explosions and flame progress |
| 6 | Specimen or surface-coating melts, burns and drips off | Report flame front and extent of damage. Also report whether flaming drips were observed |
| 7 | Pilot flame extinguished | Report occurrence and repeat test |
| 8 | Very short ignition delay which could be caused by protrusion of specimen above holder surface, reducing space to pilot flame | Report behavior (see 12.3) |
| 9 | Specimen breaks up, and falls out of holder | Report behavior |
| 10 | Sudden release of combustible pyrolysis gases from specimen, adhesive or bonding agents | Report behavior |
| 11 | Small flame remaining along the edge of specimen | Report behavior and terminate the test after 30 min (see 10.9.4) |
| 12 | Flaming of specimen in discrete areas | Report extent and position of flaming |
| 13 | Specimens with air-gaps (see Fig. 15) form flaming debris or drips, which fall behind specimen inside air-gap into spacer. | Report behavior and observe if debris continues to burn inside the air-gap |

## X3. VARIABILITY IN THE IGNITABILITY AND FLAME SPREAD MEASURED

X3.1 The precision of ISO 5658-4 was examined in an inter-laboratory trial conducted by ISO/TC92/SC1/WG3 during 1997. Eleven laboratories from 8 countries participated in this exercise, which involved the testing of 16 products. Each product was tested with 6 replicate specimens. The flame spread results were recorded using special software, which allowed the recording of flame spread into 100 mm by 100 mm zones drawn as a grid over the whole of the exposed specimen (see 8.6). The test results were analyzed according to ISO 5725-2:1994 Precision of Test Methods—Determination of Repeatability and Reproducibility for a Standard Test Method by Inter-laboratory Tests. The essential repeatability and reproducibility values for qualifying a test procedure are the Coefficients of Variation, expressed in percentages as the relative repeatability ($S_r$/m) and the relative reproducibility ($S_R$/m). The values for coefficient of variation are shown in Table X3.2 for the means (m) of time to ignition and area of flame spread. The ranges of variations for both parameters may be summarized in Table X3.1.

**TABLE X3.1 Summary of Variability of Parameters**

| Parameter | Coefficient of Variation | Range (%) | Average % |
|---|---|---|---|
| Time to Ignition | $S_r$/m | 12–46 | 26 |
| | $S_R$/m | 28–133 | 59 |
| Area of Flame Spread | $S_r$/m | 0–36 | 17 |
| | $S_R$/m | 0–61 | 31 |

X3.1.1 The repeatability (r) and the reproducibility (R) are defined as follows:

X3.1.1.1 r = the value below which the absolute difference between two single test results obtained under repeatability conditions (inter-laboratory) may be expected to lie with a probability of approximately 95 %.

X3.1.1.2 R = the value below which the absolute difference between two single test results obtained under reproducibility conditions (inter-laboratory) may be expected to lie with a probability of approximately 95 %.

X3.1.2 The repeatability r is calculated as $2{,}8 \times s_r$ where $s_r$ is the repeatability standard deviation and the reproducibility R is calculated as $2{,}8 \times s_R$, where $s_R$ is the reproducibility standard deviation.

X3.1.3 This inter-laboratory trial has shown that the ignitability of some materials was more variable than others.

X3.1.4 The variability increased particularly for fire-retarded materials (for example, 2,15) and for faced-materials (see clause 3). For materials such as these, it may be desirable to utilize an impinging pilot flame to replace the standard non-impinging burner-flame.

X3.1.5 The variability in the ignitability and flame spread demonstrated by this inter-laboratory trial compares favorably with values found in previous ISO/TC92/SC1 inter-laboratory trials on other reaction to fire parameters.

**TABLE X3.2 Variations of Test Results for the ISO 5658-4 Test**

| Product Ref: | Product Description | Time to Ignition (s) | | | Area of Flame Spread ($m^2 \times 10^{-2}$) | | |
|---|---|---|---|---|---|---|---|
| | | m | $s_r$/m(%) | $S_R$/m(%) | M | $s_r$/m(%) | $s_R$/m(%) |
| 1 | Paper-faced gypsum board | 267 | 27 | 37 | 6,3 | 24 | 61 |
| 2 | FR-EPS | 141 | 31 | 101 | 91,2 | 17 | 31 |
| 3 | Al-foil faced PUR foam panel | 243 | 42 | 133 | 5,3 | 25 | 35 |
| 4 | PUR foam panel | 3 | 46 | 82 | 150,0 | 0 | 0 |
| 5 | Varnished wood (pine) | 26 | 29 | 42 | 86,3 | 14 | 22 |
| 6 | 3-layer PC panel | 89 | 27 | 51 | 18,7 | 36 | 48 |
| 7 | Paper wall covering on gypsum board | 41 | 16 | 43 | 35,1 | 12 | 23 |
| 8 | PVC wall covering on gypsum board | 19 | 15 | 30 | 44,3 | 13 | 53 |
| 9 | Textile wall covering on gypsum board | 47 | 31 | 68 | 62,9 | 26 | 41 |
| 10 | Unvarnished wood (pine) | 37 | 19 | 49 | 83,9 | 15 | 25 |
| 11 | MF-faced MDF | 76 | 12 | 28 | 79,1 | 10 | 16 |
| 12 | NFR-Chipboard | 72 | 23 | 39 | 100,9 | 12 | 22 |
| 13 | Paper wall-covering on chipboard | 54 | 16 | 32 | 91,2 | 8 | 27 |
| 14 | LD-Fibreboard | 11 | 29 | 44 | 144,3 | 3 | 5 |
| 15 | FR-Plywood | 395 | 34 | 112 | 7,8 | 33 | 46 |
| 16 | NFR-Plywood | 29 | 21 | 51 | 65,2 | 24 | 34 |