



Standard Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Insulated Marine Bulkheads and Decks, Constructed of Steel¹

This standard is issued under the fixed designation F2133; 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 These test methods described in this fire-test response standard are used for determining the fire-test response of insulated marine steel bulkheads and decks. The insulation is either homogeneous or composite construction.

1.2 It is the intent that tests conducted in accordance with these test methods will indicate whether bulkheads and decks will continue to perform their intended function during the period of fire exposure. These test methods shall not be construed as implying suitability for use after fire exposure.

1.3 These test methods prescribe a standard fire exposure for comparing the relative performance of different bulkhead and deck assemblies under controlled laboratory conditions. The application of these test results to predict the performance of actual assemblies when exposed to large pool fires requires a careful engineering evaluation.

1.4 *Limitations*—These test methods do not provide the following:

1.4.1 Full information on the performance of assemblies constructed with components or of dimensions other than those tested.

1.4.2 An evaluation of the degree to which the assembly contributes to the fire hazard through the generation of smoke, toxic gases, or other products of combustion.

1.4.3 Measurement of flame spread over the surface of the test assembly.

1.4.4 The erosive effect that the velocities or turbulence, or both, generated in large pool fires has on some fire protection materials.

1.4.5 Full information on the performance of assemblies at times less than 5 min because the rise time called out in Section 6 is longer than that of a real fire.

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

1.6 This standard measures and describes 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 This test method is based on the fire exposure as defined in Test Methods E1529 (issued by the Committee on Fire Standards, E05).

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

E119 Test Methods for Fire Tests of Building Construction and Materials

E176 Terminology of Fire Standards

E511 Test Method for Measuring Heat Flux Using a Copper-Constantan Circular Foil, Heat-Flux Transducer

E1529 Test Methods for Determining Effects of Large Hydrocarbon Pool Fires on Structural Members and Assemblies

3. Terminology

3.1 *Definitions of Terms Specific to These Test Methods*—Refer to Terminology E176 for definitions of terms associated with fire issues used in these test methods.

4. Summary of Test Methods

4.1 The fire environment within the furnace shall develop a total heat flux of $204 \pm 16 \text{ kW/m}^2$ ($65\,000 \pm 5000 \text{ Btu/ft}^2\text{-h}$)

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

and an average temperature of $1093 \pm 111^{\circ}\text{C}$ ($2000 \pm 200^{\circ}\text{F}$) within 5 min from the start of the test. The fire environment shall be controlled by reproducing the furnace temperatures recorded during the furnace calibration method specified in Section 7. This temperature shall be maintained throughout the remainder of the fire test as shown in Fig. 1.

4.2 Performance is defined as the time period during which bulkheads and decks will continue to perform their intended function when subjected to fire exposure. The results are reported in terms of time increments such as 15, 30, 60, 90, and 120 min.

5. Significance and Use

5.1 These test methods are intended to provide a basis for evaluating the time period during which bulkheads and decks will continue to perform its intended function when subjected to a controlled, standardized fire exposure.

5.1.1 In particular, the selected standard exposure condition simulates the condition of total continuous engulfment of a member or assembly in the luminous flame (fire plume) area of a large free-burning fluid hydrocarbon pool fire. The standard fire exposure is basically defined in terms of the total flux incident on the test specimen together with appropriate temperature conditions.

5.1.2 It is recognized that the thermodynamic properties of free-burning, hydrocarbon fluid pool fires have not been completely characterized and are variable depending on the conditions, the physical relationship of the structural member to the exposing fire, and other factors. As a result, the exposure specified in these test methods is not necessarily representative of all the conditions that exist in large hydrocarbon pool fires. The specified standard exposure is based upon the best available information and testing technology. It provides a basis for comparing the relative performance of different assemblies under controlled conditions.

5.1.3 It is feasible that substantial changes in the fire performance characteristics of the assembly will result from any variation from the construction or conditions (that is, size, method of assembly, and materials) that are tested.

5.2 The structural assemblies that will be evaluated in accordance with these test methods will be located on a ship.

6. Furnace Control

6.1 The fire environment within the furnace shall develop a total heat flux of $204 \pm 16 \text{ kW/m}^2$ ($65\,000 \pm 5\,000 \text{ Btu/ft}^2\text{-h}$) and an average temperature of $1093 \pm 111^{\circ}\text{C}$ ($2000 \pm 200^{\circ}\text{F}$) within 5 min from the start of the test. The fire environment shall be controlled by reproducing the furnace temperatures recorded during the furnace calibration method specified in Section 7. This temperature shall be maintained throughout the remainder of the fire test as shown in Fig. 1.

6.2 The furnace shall be controlled to maintain the area under the time-temperature curve to within 10 % of the corresponding area under the standard time-temperature curve shown in Fig. 1 for fire tests of 60-min or less duration; to within 7.5 % for test longer than 60 min but not longer than 120 min; and to within 5 % for tests exceeding 120 min in duration. The area under the time-temperature curve shall be obtained by averaging the results of thermocouple readings.

6.3 A correction will be applied for variation of the furnace exposure from the prescribed, where such variation will affect the test results, by multiplying the indicated time period by two thirds of the value obtained by dividing the difference in area between the curve of average furnace temperature and the standard curve for the first three fourths of the period by the area between the standard curve above a baseline of 20°C (68°F) for the same part of the indicated period during the first part of the test. For fire exposure times longer than standard, it is feasible that the indicated rating period will be increased by the amount of the correction, and for fire exposure times less than standard, the indicated rating period may be similarly decreased. The correction will be expressed by the following formula:

$$C = \frac{2I(A - A_s)}{3(A_s)} \quad (1)$$

where:

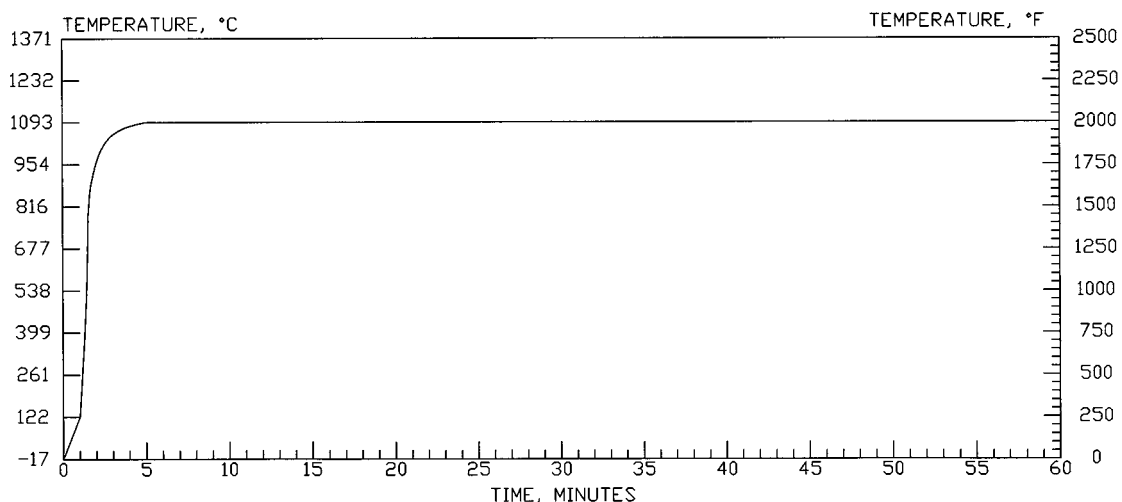


FIG. 1 Time-Temperature Curve

C = correction in the same units as I ,
 I = indicated fire-resistance period,
 A = area under the curve of indicated average furnace temperature for the first three fourths of the indicated period, and
 A_s = area under the standard furnace curve for the same part of the indicated period.

6.4 The temperature fixed by the furnace calibration (see Section 7) shall be the average temperature obtained from the readings of five thermocouples symmetrically disposed and distributed within the test furnace to show the temperature near all parts of the assembly.

6.5 The thermocouples shall be fabricated by fusion-welding the twisted ends of (0.064-in.) diameter (No. 14 B & S gage) chromel-alumel wires having a time constant of 2 min or less, and mounting the wires in porcelain insulators. The thermocouple assembly shall be inserted through a standard weight, nominal 13-mm (1/2-in.) iron, steel, or inconel pipe, and the end of the pipe from which the welded junction protrudes is to be open. The thermocouple junction shall protrude 13 mm (1/2 in.) from the open end of the pipe.

6.6 The junction of the thermocouples shall be placed 102 mm (4 in.) away from the exposed face of the test specimen and located at the 1/3 and 2/3 heights of the test specimen.

6.7 Each thermocouple within the furnace shall be recorded at intervals not exceeding 1 min.

7. Calibration of Furnace

7.1 A furnace calibration record shall be maintained and the furnace shall be recalibrated after completion of any repair that could alter the heat generation, retention, or flow characteristics of the furnace.

7.2 The temperature of the furnace shall be measured by five thermocouples. They shall be located as shown in Fig. 2.

7.3 The measured values of all thermocouples and calorimeters shall be recorded at intervals not exceeding 1 min.

7.4 The thermocouples used to measure the temperatures on the face of the calibration wall shall be No. 28 gage, Type K inconel sheathed thermocouples having a time constant of 0.5 s or less. The thermocouple junction shall be located 6.3 mm (1/4 in.) from the face of the calibration wall.

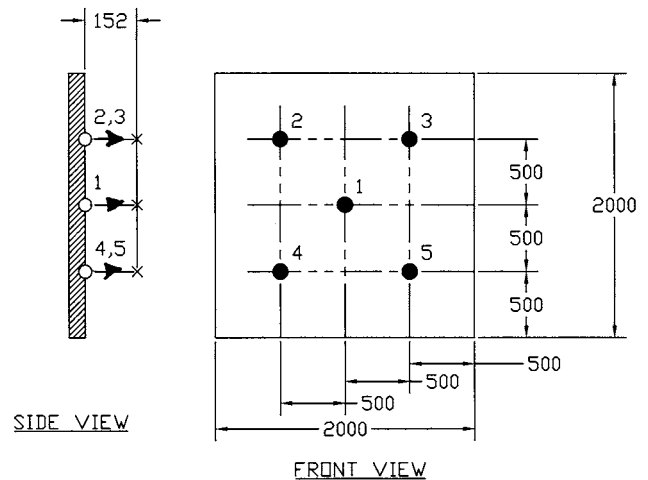
7.5 The thermocouples used to measure the temperatures within the furnace shall be constructed as described in 6.5.

7.6 The calorimeters shall have a minimum range from 315 kW/m² (100 000 Btu/ft²-h) and a 180° view angle. They shall be located as shown in Fig. 2.

7.7 The fire environment during the calibration test shall comply with the requirements of 6.1. The length of the calibration test shall be 60 min.

7.8 Individual total heat flux measurements shall lie within the limits shown in Fig. 3.

7.9 The average furnace temperature shall be determined by averaging the temperatures recorded by the five thermocouples placed 102 mm (4 in.) from the specimen. The average shall be



NOTE 1—• denotes site of heat flux measurement, X a gas temperature sensor.

NOTE 2—Arrow denotes viewing direction of heat flux sensor.

NOTE 3—All dimensions are in mm.

NOTE 4—Calibration assembly is to be fabricated from noncombustible materials.

FIG. 2 Calibration Assembly for Fire-Containment Walls

1093 ± 111°C (2000 ± 200°F) and individual temperatures are to be 1093 ± 219°C (2000 ± 400°F) 5 min after the start of the test and until the end of the test.

7.10 The average furnace temperature curve shall be reproduced to maintain the furnace control described in Furnace Control, Section 6.

7.11 A record of the temperatures measured near the face of the wall and the oxygen content shall be retained by the testing laboratory on file for a period of ten years.

8. Furnace Pressure

8.1 A linear pressure gradient exists over the height of furnace, and although the gradient will vary slightly as a function of the furnace temperature, a mean value of 8 Pa/m height shall be assumed in assessing the furnace pressure conditions. The value of the furnace pressure shall be the nominal mean value, disregarding rapid fluctuation of pressure outside the furnace at the same height. It shall be monitored and controlled continuously and by 5 min from the commencement of the test shall be achieved within ±3 Pa, see Fig. 4 for design of the T-shaped sensor.

8.2 For vertically orientated specimens, the furnace should be operated such that a pressure of zero is established at a height of 500 mm above the notional floor level to the test specimen. However, for specimens with a height greater than 3 m, the pressure at the top of the test specimen shall not be greater than 20 Pa, and the height of the neutral pressure axis shall be adjusted accordingly.

8.3 For horizontally orientated specimens, the furnace shall be operated such that a pressure of 20 Pa is established at a position 100 mm below the underside of the specimen.

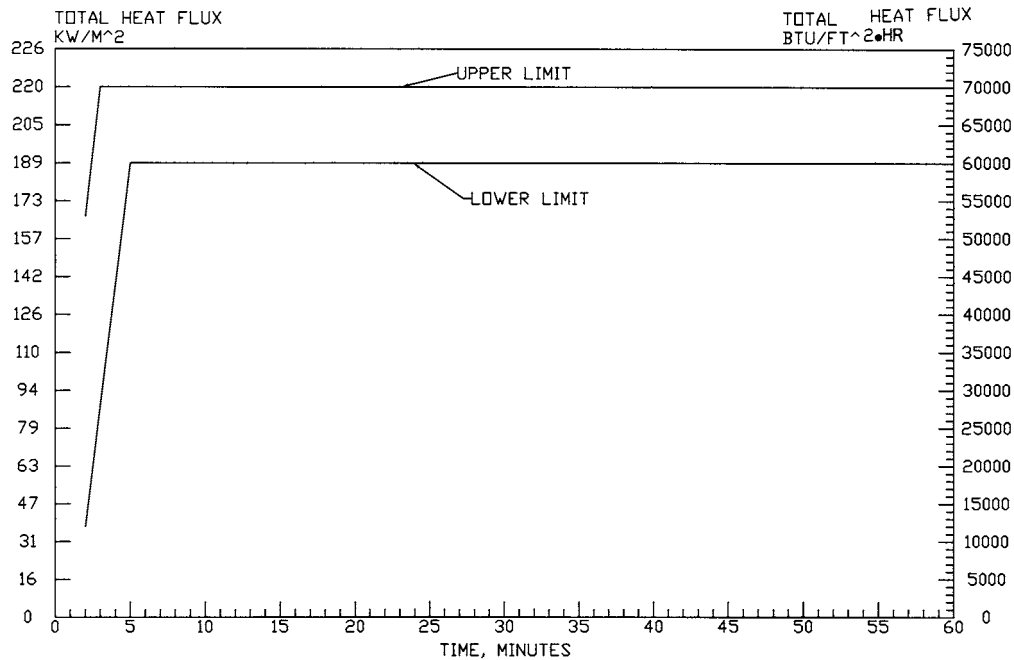


FIG. 3 Time-Total Heat Flux Curve

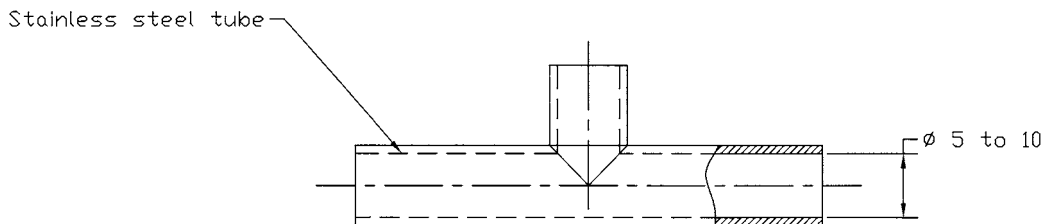


FIG. 4 T-Shaped Sensor

9. Test Specimen

9.1 Bulkheads:

9.1.1 Dimensions:

9.1.1.1 The minimum overall dimensions for the test specimen including the perimeter details at the top, bottom, and vertical edges, are 2440-mm width and 2500-mm height.

9.1.1.2 The overall dimensions of the structural core shall be 20 mm less in both the width and the height than the overall dimensions of the specimen, and the other dimensions of the structural core shall be as follows:

Thickness of plating: steel	4.5 ± 0.5 mm
Stiffeners spaced: steel at 600 mm	65 ± 5 × 65 ± 5 × 6 ± 1 mm

9.1.1.3 The width of the structural core shall be greater than the specified dimensions providing that the additional width is in increments of 600 mm to maintain the stiffener centers and the relationship between the stiffeners and the perimeter detail.

9.1.1.4 Any joints in the plating shall be full-welded, at least from one side.

9.1.1.5 The construction of a structural steel core having the recommended dimensions is shown in Fig. 5; the thickness of the plating and dimensions of the stiffeners shown are nominal dimensions. Irrespective of the dimensions of the structural core and the material of manufacture, the details around the perimeter shall be as illustrated in Fig. 6.

9.2 Decks:

9.2.1 Dimensions:

9.2.1.1 The minimum overall dimensions for the test specimen including the perimeter details at all edges are 2440 mm in width and 3040 mm in length.

9.2.1.2 The overall dimensions of the structural core shall be 20 mm less in both the width and length than the overall dimensions of the specimen, and the other dimensions of the structural core shall be as follows:

Thickness of plating: steel	4.5 ± 0.5 mm
Stiffeners spaced: steel at 600 mm	100 ± 5 × 70 ± 5 × 8 ± 1 mm

9.2.1.3 The width of the structural core shall be greater than the specified dimensions providing that the additional width is in increments of 600 mm to maintain the stiffener center and the relationship between the stiffeners and the perimeter detail.

9.2.1.4 Any joints in the plating shall be full welded, at least from one side.

9.2.1.5 The construction of a structural steel core having the recommended dimensions is shown in Fig. 2; the thickness of the plating and dimensions of the stiffeners shown are nominal dimensions. Irrespective of the dimensions of the structural core and the material of manufacture, the details around the perimeter shall be as illustrated in Fig. 7.



10.1 Restraint and Support Frames :

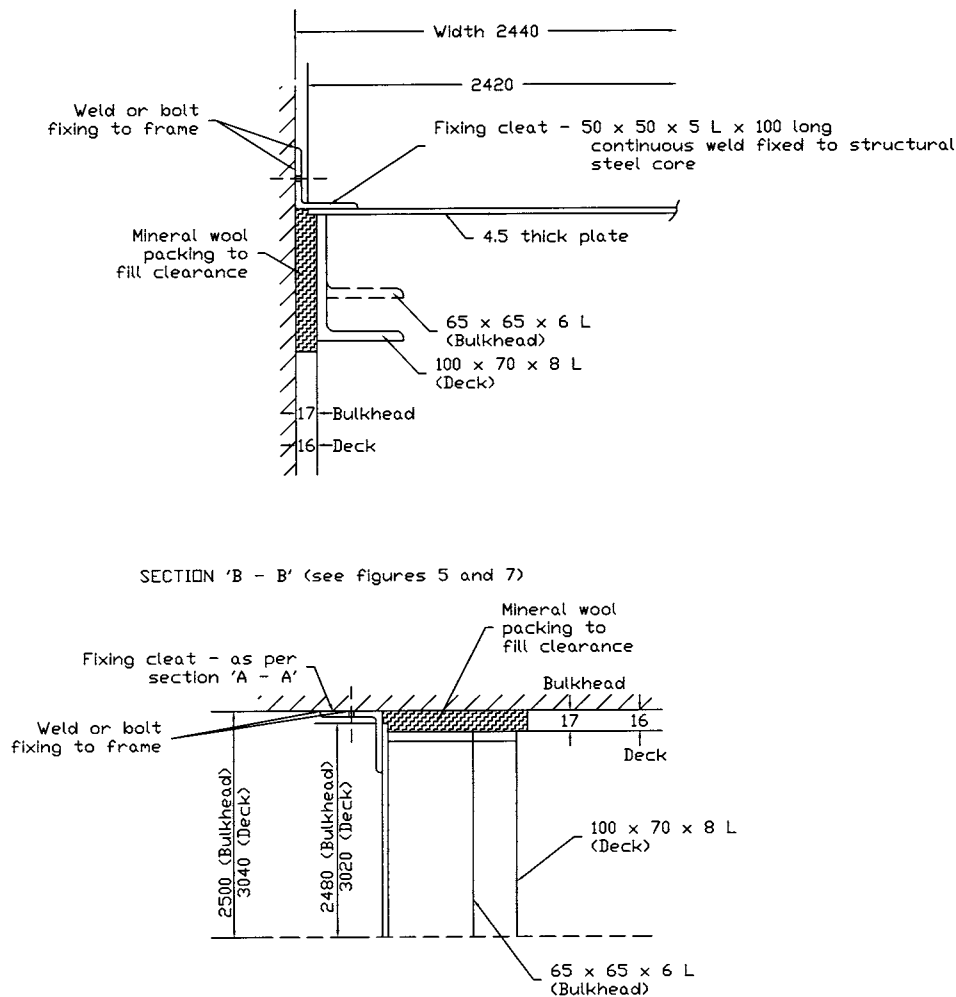
10.1.2 The rigidity of the restraint frames shall be evaluated by applying an expansion force of 100 kN within the frame at mid-width between two opposite members of the frame, and measuring the increase in the internal dimensions at these position. This evaluation shall be conducted in the direction of the bulkhead or deck stiffeners, and the increase of the internal dimension shall not exceed 2 mm.

10.2.1 The structural core to bulkheads and decks shall be fixed into the restraint frame and sealed around its perimeter as shown in Fig. 6. It is feasible that steel spacers, with an

10.2.2 When the structural core of a bulkhead or a deck is to be exposed to the heating conditions of the test, that is, when the fixing cleats are on the exposed side of the structural core, then a 100-mm-wide perimeter margin adjacent to the restraint frame shall be insulated such that the fixing cleats and the edges of the structural core are protected from direct exposure to the heating condition. In no other situations, irrespective of the type of test specimen, shall the perimeter edges be protected from direct exposure to the heating conditions.

11.2 For unrestricted use, bulkhead insulation shall be installed on the unexposed side.

11.3 If the insulation is installed on the unstiffened or stiffened exposed side, the use shall be restricted.



NOTE 1—Section 'A—A' (see Fig. 5 and Fig. 7).

NOTE 2—Section 'B—B' (see Fig. 5 and Fig. 7).

FIG. 6 Section Details

11.4 If the insulation is installed on both sides in identical details then the use shall be unrestricted. The unexposed face shall be the stiffened side of the test specimen.

11.5 If different insulation details are installed on both sides of the bulkhead, then the bulkhead shall be tested from both sides for unrestricted use.

12. Conditioning

12.1 General:

12.1.1 The test specimen shall not be tested until it has reached an air-dry condition. This condition is defined as an equilibrium (constant weight) with an ambient atmosphere of 50 % relative humidity at 23°C (73°F).

12.1.2 Accelerated conditioning is permissible provided the test method does not alter the properties of component materials. In general, high-temperature conditioning shall be below temperatures critical for the materials.

12.2 Verification—The condition of the test specimen shall be monitored and verified by use of special samples for the determination that shall be so constructed as to materials, as appropriate. These samples shall be so constructed as to

represent the loss of water vapor from the specimen by having similar thicknesses and exposed faces. They shall have minimum linear dimensions of 300 by 300 mm (12 by 12 in.) and a minimum mass of 100 g. Constant weight shall be considered to be reached when two successive weighing operations, carried out at an interval of 24 h, do not differ by more than 0.3 % of the mass of the reference specimen or 0.3 g, whichever is the greater.

12.3 Encapsulated Materials—When the test specimen incorporates encapsulated materials, it is important to ensure that these materials have reached an equilibrium moisture content prior to assembly, and special arrangements shall be made with the applicant for the test to ensure that this is so.

13. Unexposed Face Temperature Thermocouples

13.1 Design—The temperature of the unexposed surface shall be measured by means of disk thermocouples of the type shown in Fig. 8. Thermocouple wires, 0.5-mm-thick noncombustible insulating pad. The pad material shall have a density of $900 \pm 100 \text{ kg/m}^3$.