NFPA® 276

Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components

2023 Edition

NFPA, 1 Batterymarch Park, Quincy, MA 02169-7471
An International Codes and Standards Organization

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ISBN: 978-145592962-7

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NFPA® 276

Standard Method of

Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components

2023 Edition

This edition of NFPA 276, *Standard Method of Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components*, was prepared by the Technical Committee on Fire Tests. It was issued by the Standards Council on April 28, 2022, with an effective date of May 18, 2022, and supersedes all previous editions.

This edition of NFPA 276 was approved as an American National Standard on May 18, 2022.

Origin and Development of NFPA 276

Fires involving roof deck assemblies have resulted in significant losses and damage to buildings and structures that otherwise had fire protection systems, construction features, or both in place to minimize the spread of fire. Perhaps the most famous of those fires is the 1953 fire at the General Motors Corporation facility in Livonia, MI. Analysis of that fire indicated that, while the exterior roof surface might have been able to minimize the propagation of fire, the interior portions of the roof decking that included combustible materials installed on the deck allowed the fire to spread along the interior underside of the roof deck assembly.

Although insurance company interests developed some test protocols to address the spread of fire along the underside of steel roof decks, no national test or evaluation standard had been devised to address this potential concern until 2006, when NFPA 276 was proposed. The fire performance of the roof assembly is evaluated by measuring the heat release rate below the roof deck where the assembly incorporates combustible construction components, a common construction technique.

The protocol includes a fire exposure test and an evaluation test with an auxiliary fuel package. To properly characterize the performance of the roof assembly, NFPA 276 specifies the requisite provisions for the furnace construction and configuration; instrumentation needs; size, attributes, and conditioning of the test sample; calibration of the furnace; procedure for running the tests; and the reporting requirements to describe the test results.

NFPA 276 can be referenced in model building codes, state or local regulations, and private sector loss prevention policies to allow for a full and complete evaluation of these common roofing assemblies.

There were no substantive changes in the 2015, 2019, or 2023 editions.

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Standard Method of

Fire Test for Determining the Heat Release Rate of Roofing Assemblies with Combustible Above-Deck Roofing Components

2023 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced and extracted publications can be found in Chapter 2 and Annex B.

Chapter 1 Administration

1.1* Scope.

1.1.1* This standard describes a method for determining the heat release rate from below the deck of roofing assemblies that have combustible above-deck roofing components when the assemblies are exposed to a fire from below the roof deck.

1.1.2 The performance of the above-deck roofing assembly is evaluated by determining the heat release rate below the deck of the roof test specimen.

1.1.3* This test method is based on the substitution method for measuring the heat release rate by using an auxiliary fuel (propane) to provide the surrogate heat release rate.

1.2 Purpose.

1.2.1* Test Method.

1.2.1.1 Two fire tests are conducted to determine the heat release rate of the test specimen as follows:

(1) Fire exposure test
(2) Evaluation test with auxiliary fuel

1.2.1.2 Each fire test is 30 minutes in duration.

1.2.2 Fire Exposure Test.

1.2.2.1 The fire exposure test consists of developing a flue time–temperature curve based on the combined burning of the test specimen and the fire exposure.

1.2.2.2 The fire exposure is produced by heptane-fired burners (main burners), which subject the underside of the roof deck assembly to a predetermined exposure condition.

1.2.3 Evaluation Test.

1.2.3.1* The evaluation test determines the contribution of the test specimen by introducing an auxiliary fuel (propane) through evaluating burners in addition to the heptane-fired main burners.

1.2.3.2 The same time–temperature curve as in the fire exposure test is recreated with a noncombustible (blank) specimen in place.

1.3 Application.

1.3.1 This method of fire test determines the heat release rate of the test specimen during the 30-minute fire test.

1.3.2 This method of fire test determines the heat release rate of the test specimen when subjected to a specified fire exposure condition.

1.3.3 This standard does not address all safety problems or considerations associated with its use.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. (Reserved)

2.3 Other Publications.

2.3.1 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM C62, *Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale)*, 2017.

ASTM C208, *Standard Specification for Cellulosic Fiber Insulating Board*, 2012 (2017) e2.

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, 2019a.

2.3.2 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections. (Reserved)

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary,* 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1 Shall. Indicates a mandatory requirement.

3.2.2 Should. Indicates a recommendation or that which is advised but not required.

3.2.3 Standard. An NFPA standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrases "standards development process" or "standards development activities," the term "standards" includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

3.3.1* Blank Test Specimen. A noncombustible test specimen placed on the furnace opening when the evaluation test is conducted.

3.3.2 Calibration Specimen. A test specimen constructed of known materials that will produce specific heat release rates.

Chapter 4 Test Furnace

4.1 Furnace Construction.

4.1.1* The fire test apparatus shall consist of a furnace, an opening for mounting the test specimen, a method for providing supply air, fire exposure burners, auxiliary propane burners, and data acquisition equipment.

4.1.2* The fire test furnace shall be a rectangular, horizontal chamber with a removable lid, having inside dimensions of 60 in. ± ⅛ in. (1524 mm ± 3 mm) wide, 210 in. ± ½ in. (5300 mm ± 3 mm) long, and 45 in. ± ⅛ in. (1143 mm ± 3 mm) deep.

4.1.3 The interior sides shall be lined with refractory firebrick or equivalent, having dimensions of 4½ in. ± ⅛ in. (114 mm ± 3 mm) wide, 9 in. ± ⅛ in. (229 mm ± 3 mm) long, and 2½ in. ± ⅛ in. (64 mm ± 3 mm) deep and the following properties:

(1) Maximum recommended temperature: 2800°F (1538°C)
(2) Bulk density: 55 lb/ft^3 ± 3 lb/ft^3 (880 kg/m^3 ± 48 kg/m^3)
(3) Thermal conductivity in accordance with Table 4.1.3

4.1.4 The exterior sides and top edges of the furnace shall be constructed using clay brick, Grade NW or greater, per ASTM C62, *Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale).*

4.1.5 A gap of 1¼ in. (32 mm) shall be maintained between the refractory firebrick and the standard brick on the four walls of the furnace.

4.1.6 The floor of the furnace shall consist of a minimum 3 in. (76 mm) thick layer of sand.

4.1.7 A baffle having dimensions of 16 in. ± ⅛ in. (406 mm ± 6 mm) high, 48 in. ± ⅛ in. (1219 mm ± 6 mm) wide, and 2½ in. ± ⅛ in. (64 mm ± 6 mm) thick shall be located on the floor of the test furnace 12 in. ± ⅛ in. (305 mm ± 3 mm) from the exposure (front) end of the test furnace and shall be constructed of wire-reinforced castable refractory material with physical properties as follows:

(1) Maximum recommended temperature: 1200°F (650°C)
(2) Bulk density: 120 lb/ft^3 ± 6 lb/ft^3 (1920 kg/m^3 ± 96 kg/m^3)
(3) Thermal conductivity at 300°F to 700°F (149°C to 371°C) of 0.50 Btu·in./hr·ft^2·°F to 0.71 Btu·in./hr·ft^2·°F (0.072 W/m·°C to 0.102 W/m·°C)

4.1.8 The top of the furnace shall be constructed of a minimum 3½ in. (90 mm) thick castable refractory material having physical properties as specified in 4.1.7.

4.1.8.1 A 48 in. ± ⅛ in. × 48 in. ± ⅛ in. (1219 mm ± 3 mm × 1219 mm ± 3 mm) opening shall be provided in the top of the furnace.

4.1.8.2 The front edge of the opening shall be located 48 in. ± ⅛ in. (1219 mm ± 3 mm) from the interior surface of the wall containing the main burners.

4.1.9 The opening into the test furnace shall be framed to keep the installed test specimen stationary.

4.1.9.1 The inside dimensions of the framed area shall be 63½ in. ± ⅛ in. (1613 mm ± 3 mm) long and 57½ in. ± ⅛ in. (1461 mm ± 3 mm) wide.

4.1.9.2 A minimum 1½ in. (38 mm) lip shall be provided to support the test specimen.

4.1.10 A removable cover shall be constructed of the same castable refractory material as the top of the furnace and shall have the same thickness as the top of the furnace.

4.1.11* The main burners shall be spray nozzles with a 60-degree spray cone and shall be capable of providing a fuel flow rate of 4½ gal/hr ± ¼ gal/hr (17 L/hr ± 1 L/hr).

Table 4.1.3 Insulating Brick Thermal Conductivity

Mean Temperature		Thermal Conductivity	
°F	°C	Btu·in./ hr·ft^2·°F	W/m·°C
500	260	2.3	0.33
1000	538	2.4	0.34
1500	815	2.6	0.37
2000	1093	2.7	0.39

4.1.12 The auxiliary burners shall be venturi, high pressure nozzle, air-aspirating burners with the following properties:

(1) Operating range: Gauge pressure ≤ 15 psi (103 kPa)
(2) Rating: 360,000 Btu/hr (105 kW) at 5 psi (35 kPa) and 800,000 Btu/hr (234 kW) at 25 psi (172 kPa)
(3) Nozzle orifice outside diameter: 4⅛ in. (105 mm) nominal

4.1.13 A 16 in. ± ⅛ in. (405 mm ± 3 mm) diameter flue shall be located on the side of the test furnace opposite the main burners.

4.1.14* The flue shall be covered with insulation that provides an R-value of 30 $ft^2 \cdot °F \cdot h/Btu$ (5.3 $K \cdot m^2/W$).

4.1.15 Airflow twisting baffles shall be located in the flue, positioned within the plane of the wall.

4.2 Burner Fuels and Supply Air.

4.2.1 The main burners shall burn liquid n-heptane.

4.2.2 The heptane fuel shall be supplied to the main burners using a delivery system consisting of the following:

(1) Supply tank
(2) Shutoff valve
(3) Filter
(4) Pump
(5) Pressure gauge
(6) Bleeder valve
(7) Flow controller and control valve
(8) Solenoid valve
(9) Control valves for each of the three main burners

4.2.3 The auxiliary burners shall burn propane with a known heat of combustion.

4.2.4 Propane fuel shall be supplied to the auxiliary burners through a delivery system consisting of the following:

(1) Supply tank
(2) Pressure regulator
(3) Gas temperature thermocouple
(4) Flow controller and control valve
(5) Gas solenoid valves

4.2.5 Supply air shall be supplied to the main burners through a blower.

4.2.6 The supply air shall be preheated to 100°F ± 5°F (38°C ± 3°C) prior to injection into the burners.

4.2.7 The flow rates of the air and the heptane shall be controlled such that the fire exposure rate to the specimen is 1650 $Btu/ft^2/min$ ± 60 $Btu/ft^2/min$ (312 kW/m^2 ± 11 kW/m^2).

Chapter 5 Instrumentation

5.1 Thermocouples. Insulated, ungrounded, Inconel-sheathed, type K (Chromel–Alumel) thermocouples, with wires 0.012 in. ± 0.002 in. (0.3 mm ± 0.05 mm) in diameter, shall be used at each required location.

5.1.1 Twelve thermocouples shall be located inside the flue to measure the exhaust gas temperatures and arranged as shown in Figure 5.1.1.

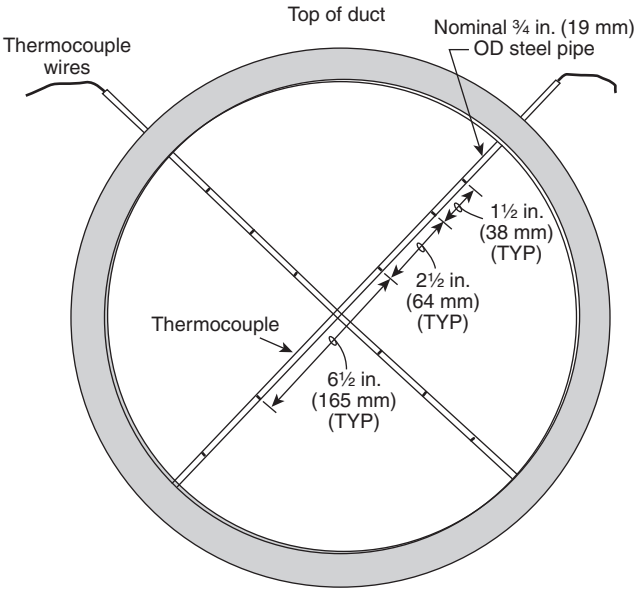


FIGURE 5.1.1 Flue Thermocouple Layout.

5.1.2 The thermocouple array shall be positioned such that the array is placed in the flue at a distance of 64 in. ± 1 in. (1626 mm ± 25 mm) from the fire-exposed face of the firebrick.

5.1.3 The thermocouples in the array shall face toward the airflow.

5.1.4 Two 18 AWG (1.02 mm) thermocouples embedded ⅛ in. (3.1 mm) into the furnace apparatus wall surface shall be mounted in refractory cement, which has been dried to avoid cracking.

5.1.5 The thermocouples required by 5.1.4 shall be placed in the two side walls of the furnace apparatus such that they are centered side to side and top to bottom.

5.2 Pressure Measurement.

5.2.1 The pressure inside the test furnace shall be monitored using one of two pressure probes.

5.2.2 The pressure probe shall be located 3 in. ± ¼ in. (76 mm ± 6 mm) below the exposed surface of the test specimen.

Chapter 6 Test Specimens and Conditioning

6.1 Blank Test Specimen.

6.1.1 A blank test specimen shall be constructed using noncombustible refractory concrete.

6.1.2 The blank test specimen shall be 61 in. ± ⅛ in. (1549 mm ± 3 mm) long, 55½ in. ± ⅛ in. (1410 mm ± 3 mm) wide, and 3½ in. ± ⅛ in. (90 mm ± 3 mm) thick.

6.2 Calibration Specimen.

6.2.1 The calibration specimen shall consist of wood fiber insulation placed on a steel deck and covered with a steel cover.

6.2.2 The specimen shall be 61 in. ± ⅛ in. (1549 mm ± 3 mm) long and 55½ in. ± ⅛ in. (1410 mm ± 3 mm) wide.

6.2.3 The steel deck shall be constructed of a primed steel deck measuring 59 ½ in. ± ½ in. (1511 mm ± 13 mm) long, 30 in. ± ½ in. (762 mm ± 13 mm) wide, and 18 gauge, 0.05 in. (1.3 mm) thick.

6.2.4 The steel deck shall be constructed using two pieces of 18 gauge, 0.05 in. (1.3 mm) narrow rib, fluted steel deck, with the steel flutes parallel to the long dimension of the specimen.

6.2.4.1 One piece of steel deck shall contain four flutes.

6.2.4.2 The second piece of steel deck shall contain five flutes and be placed over the first piece of steel deck such that one flute overlaps.

6.2.5 The wood fiber insulation shall meet ASTM C208, *Standard Specification for Cellulosic Fiber Insulating Board*, Type II, Grade 1 or 2, and shall be 1 in. ± ⅛ in. (25 mm ± 3 mm) thick.

6.2.5.1 The wood fiber shall be conditioned in accordance with Section 6.4 prior to construction of the calibration specimen.

6.2.5.2 The wood fiber shall consist of a board 48 in. ± ¼ in. (1219 mm ± 6 mm) long and 48 in. ± ¼ in. (1219 mm ± 6 mm) wide cut into equal halves.

6.2.5.3 The wood fiberboard shall be weighed prior to cutting and the weight recorded.

6.2.5.4 The two boards shall be butted tight at the cutline, positioned in the center of the steel deck, and fastened to the steel deck with two fasteners per board. The fasteners shall be self-tapping screws with 3 in. (76 mm) diameter steel washers placed along the centerline of each board and separated by a minimum of 6 in. (152 mm).

6.2.5.5 The area between the wood fiberboard and the specimen edge shall not be filled and shall remain open.

6.2.6 The steel cover shall be fabricated from nominal 2 in. (51 mm) × 2 in. (51 mm) angles, sized to fit around the calibration specimen and a single piece of sheet steel that is 61 in. ± ⅛ in. (1549 mm ± 3 mm) long, 55½ in. ± ⅛ in. (1410 mm ± 3 mm) wide, and 25 gauge, 0.02 in. (0.5 mm) thick.

6.2.6.1 The nominal 2 in. (51 mm) × 2 in. (51 mm) angles shall be welded to form a frame that is 61 in. ± ⅛ in. (1549 mm ± 3 mm) long and 55½ in. ± ⅛ in. (1410 mm ± 3 mm) wide, with the angles turned in.

6.2.6.2 The sheet steel cover shall be placed inside the angle iron frame and spot welded to the frame.

6.2.6.3 The angle iron frame and sheet steel shall be inverted and placed over the sheet steel deck and wood fiber.

6.2.6.4 The completed steel cover shall be placed over the steel deck and wood fiber to form the completed calibration test specimen.

6.3 Test Specimen.

6.3.1 Components, workmanship, and construction of the test specimen shall be representative of the materials or assembly that the test is intended to examine.

6.3.2 Care shall be taken to ensure that each layer of the specimen (steel deck, insulation, cover boards, each ply, and top sheets) is installed such that the joints between adjacent layers are staggered or oriented perpendicular to the layer below during construction of a test specimen.

6.3.3 The test specimen shall have dimensions of 54½ in. ± ½ in. (1385 mm ± 13 mm) wide and 60 in. ± ½ in. (1525 mm ± 13 mm) long and shall be oriented such that the long dimension of the specimen is parallel with the long dimension of the test furnace.

6.3.4 The steel deck shall be installed in two pieces with the flutes oriented parallel to the long dimension of the opening.

6.3.4.1 One piece of steel deck shall contain four flutes.

6.3.4.2 The second piece of steel deck shall contain five flutes and be placed over the first piece of steel deck such that one flute overlaps.

6.3.5 The first layer of insulation board shall be installed in four pieces where the insulation boards are 36 in. (914 mm) × 48 in. (1219 mm) pieces or larger.

6.3.5.1 The first piece of insulation board shall be 36 in. ± ⅛ in. (914 mm ± 3 mm) × 48 in. ± ⅛ in. (1219 mm ± 3 mm) and shall be located in the left front side of the assembly when the specimen is viewed from above, with the nominal 36 in. (914 mm) dimension perpendicular to the 54½ in. (1385 mm) dimension of the opening.

6.3.5.2 The second piece of insulation board shall be 24 in. ± ⅛ in. (610 mm ± 3 mm) × 48 in. ± ⅛ in. (1219 mm ± 3 mm) and shall be located in the right front side of the assembly when the specimen is viewed from above, with the 24 in. (610 mm) dimension perpendicular to the 54½ in. (1385 mm) dimension of the opening.

6.3.5.3 The third piece of insulation board shall be 6 in. ± ⅛ in. (152 mm ± 3 mm) × 48 in. ± ⅛ in. (1219 mm ± 3 mm) and shall be located in the right rear of the assembly when the specimen is viewed from above, with the 48 in. (1219 mm) dimension parallel to the 60 in. (1525 mm) dimension of the opening.

6.3.5.4 The fourth piece of insulation board shall be 6 in. ± ⅛ in. (152 mm ± 3 mm) × 12 in. ± ⅛ in. (305 mm ± 3 mm) and shall be located in the left rear of the assembly when the specimen is viewed from above, with the 12 in. (305 mm) dimension parallel to the 60 in. (1525 mm) dimension of the opening.

6.3.5.5 The edges of the insulation board pieces shall be permitted to be trimmed such that at all joints formed by the insulation the edges of the insulation pieces are in contact with each other.

6.4 Conditioning. All test specimens shall be conditioned in a room having a temperature of 73°F ± 5°F (23°C ± 3°C) and a relative humidity of 50 percent ± 5 percent.

6.4.1 The test specimen shall be placed in the conditioning room for curing for the manufacturer's specified time period, but no less than 24 hours and no more than 28 days.

6.4.2 The test specimens shall be tested within 30 minutes of removal from the conditioning room.

Chapter 7 Furnace Verification and Calibration

7.1 Verification of Operation Using Blank Test Specimen. The operation of the furnace shall be verified using the blank test specimen within a maximum of 5 days prior to testing being conducted.

7.2 Calibration Using Calibration Specimen. The furnace shall be calibrated at a minimum of every 90 days using the calibration test specimen.

7.3 Preheating. The test furnace shall be preheated with the blank test specimen in place, and the main burner fuel flow shall be adjusted to the required flow.

7.3.1 The supply air shall be initiated, and the temperature of the supply air shall be 100°F ± 5°F (38°C ± 3°C).

7.3.2 The flow rate of heptane shall be constant to the main burners until the temperature inside the furnace is 300°F (149°C) as measured by the thermocouples embedded in the refractory brick as described in 5.1.4.

7.3.3 The fuel flow to the main burners shall be shut off when the preheat temperature is reached.

7.3.4 The supply air shall continue to operate.

7.3.5 The blank test specimen shall then be removed.

7.3.6 The next specimen shall not be placed into position for testing until the thermocouples embedded in the refractory brick as described in 5.1.4 indicate 170°F ± 5°F (77°C ± 3°C).

7.4 Blank Specimen Test Procedure. The verification of the operation of the test furnace shall be conducted for 40 minutes with the blank test specimen placed in the specimen opening.

7.4.1 The test furnace shall be preheated as described in Section 7.3.

7.4.2 The blank test specimen shall be placed in the sample opening of the test furnace.

7.4.3 The average temperatures measured by the 12 thermocouples located in the exhaust flue shall be recorded throughout the 40-minute test duration.

7.4.4 The temperatures shall be measured at intervals not exceeding 10 seconds during the test period.

7.4.5 Only the main burners shall be operated for the first 30 minutes of the test.

7.4.6 The supply air shall be provided at a temperature of 100°F ± 5°F (38°C ± 3°C).

7.4.7 Airflow into the main burners shall be 763 ft^3/min ± 76 ft^3/min (21.6 m^3/min ± 2.2 m^3/min).

7.4.8 The main burners shall be fired with the heptane supplied at a constant flow rate of 0.228 gal/min ± 0.002 gal/min (0.86 L/min ± 0.01 L/min) for the duration of the 40-minute test.

7.4.9 The airflow and the heptane pressure shall be permitted to be adjusted to achieve the required heptane flow rate.

7.4.10 The internal furnace pressure shall be maintained at 0.04 psi ± 0.01 psi (276 Pa ± 66 Pa) for the duration of the 40-minute test.

7.4.11 The average temperature within the test furnace after the 30-minute exposure using the main burners shall be 950°F ± 50°F (510°C ± 28°C) as measured by the 12 thermocouples described in 5.1.1.

7.4.12 The auxiliary propane burners shall be ignited after 30 minutes of testing.

7.4.13 The main burners and the auxiliary burners shall operate simultaneously during the last 10 minutes of the test.

7.4.14 The auxiliary burners shall be operated for a series of ten 1-minute periods, for a total auxiliary burner run time of 10 minutes.

7.4.15 The propane flow rate shall be adjusted for each time interval to achieve the target heat input shown in Table 7.4.15.

7.4.16 The average temperature within the test furnace after the 10-minute exposure using the main burners and the auxiliary burners shall be 1150°F ± 60°F (621°C ± 15°C) as measured by the 12 thermocouples described in 5.1.1.

7.4.17 The auxiliary propane burners shall be extinguished upon completion of the 40-minute test period, and then the heptane burners shall be extinguished.

7.4.18 Following the completion of the test with the blank test specimen and before additional tests are conducted, the blank test specimen shall be removed from the test furnace and the furnace allowed to cool to an internal temperature of 170°F ± 5°F (77°C ± 3°C), as indicated by the thermocouples embedded in the furnace walls.

7.4.19 The average temperature measured by the 12 thermocouples located in the exhaust flue shall be plotted as a function of time, resulting in the time–temperature curve produced during the duration of the test period.

7.4.20 The data derived from the blank test specimen shall be compared to previous blank test specimen data to verify proper operation of the test equipment.

7.4.21 Proper operation shall be verified if the integrated area under the time–temperature curve developed in accordance with 7.4.19 is within ±10 percent of the previous blank specimen test.

7.5 Calibration Test Procedure. Calibration tests using the calibration test specimen shall be conducted at a period not to exceed 90 days, and the test shall be conducted in accordance with Section 7.5.

Table 7.4.15 Auxiliary Propane Burner Flow Rates

Time Interval (min)	Target Heat Input	
	Btu/min	kW
1	1763 ± 200	31 ± 3.5
2	2388 ± 200	42 ± 3.5
3	3014 ± 200	53 ± 3.5
4	3583 ± 200	63 ± 3.5
5	4208 ± 200	74 ± 3.5
6	4834 ± 200	85 ± 3.5
7	5459 ± 200	96 ± 3.5
8	6028 ± 200	106 ± 3.5
9	6654 ± 200	117 ± 3.5
10	7279 ± 200	128 ± 3.5

7.5.1 Verification Using Blank Specimen. A successful verification of operation shall have been conducted within the previous 5 days using the blank specimen in accordance with Section 7.4.

7.5.2 Fire Exposure Test Procedure. The calibration test specimen shall be exposed to the fire exposure test procedure.

7.5.2.1 The test furnace shall be preheated as described in Section 7.3.

7.5.2.2 The calibration test specimen described in Section 6.2 and conditioned in accordance with Section 6.4 shall be placed on the test furnace, over the furnace opening.

7.5.2.3 The test specimen–furnace interface shall be sealed with an insulating cement material to prevent heat loss from the test furnace chamber, with physical properties as follows:

(1) Density: ≥22 lb/ft^3 (352 kg/m^3)
(2) Recommended use temperature: ≤2000°F (1093°C)
(3) Noncombustible in accordance with ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*

7.5.2.4 The average temperatures measured by the 12 thermocouples located in the exhaust flue shall be recorded throughout the 30-minute test duration.

7.5.2.5 The temperatures shall be measured at intervals not exceeding 10 seconds during the test period.

7.5.2.6 The temperature of the supply air shall be 100°F ± 3°F (38°C ± 5°C).

7.5.2.7 The main burners shall be fired with the heptane supplied at a constant flow rate of 0.228 gal/min ± 0.002 gal/min (0.86 L/min ± 0.01 L/min) and shall provide a heat input to the furnace of 26,420 Btu/min ± 925 Btu/min (27,875 kJ/min ± 975 kJ/min).

7.5.2.8 The main burner heat input shall be held constant for the 30-minute test duration.

7.5.2.9 The heptane fuel flow to the main burners shall be secured 30 minutes after the initiation of the burners.

7.5.2.10 The supply air shall continue to run.

7.5.2.11 The calibration test specimen shall be removed.

7.5.2.12 The average temperature measured by the 12 thermocouples located in the exhaust flue shall be plotted as a function of time, resulting in the time–temperature curve produced during the test.

7.5.2.13 The furnace shall be allowed to cool until the thermocouples embedded in the furnace walls indicate 170°F ± 5°F (77°C ± 3°C), before additional tests are conducted.

7.5.3 Evaluation Test Procedure. The evaluation test shall be conducted using the blank test specimen.

7.5.3.1 The blank specimen shall be placed over the furnace opening, and all interfaces shall be sealed with a cementitious fireproofing material to prevent heat loss from the test furnace chamber.

7.5.3.2 The average temperatures measured by the 12 thermocouples located in the exhaust flue shall be recorded throughout the 30-minute test duration.

7.5.3.3 The temperatures shall be measured at intervals not exceeding 10 seconds during the test period.

7.5.3.4 The fuel flow rate of the auxiliary propane burners in gal/min (L/min) shall be recorded during the 30-minute test.

7.5.3.5 The fuel flow readings shall be recorded by the data acquisition system at intervals not exceeding 5 seconds.

7.5.3.6 The temperature of the supply air shall be 100°F ± 3°F (38°C ± 5°C).

7.5.3.7 The main burners shall be initiated as specified in 7.5.3.6, followed immediately by initiation of the auxiliary propane burners.

7.5.3.8 The flow rate of the auxiliary propane burners shall be adjusted to reproduce the time–temperature curve generated in 7.5.3.11.

7.5.3.9 The test shall continue for 30 minutes.

7.5.3.10 The main and auxiliary burners shall be extinguished at the end of 30 minutes, and the blank specimen shall be removed.

7.5.3.11 The heat release rate of propane in Btu/min (kW) shall be calculated as a function of time, based on the fuel flow rate recorded in 7.5.3.4.

7.5.3.12 The maximum average heat release rate, in Btu/ft^2·min (kW/m^2), shall be calculated for any 3-minute, 5-minute, and 10-minute interval during the test period and for the total 30-minute test duration using the integrated area under the heat release rate rate–time curve developed in 7.5.3.11 for the calibration test specimen.

7.5.3.13 The calculated heat release rate values shall not exceed the values specified in Table 7.5.3.13.

7.5.3.14 If the calculated maximum heat release rate values exceed the values in Table 7.5.3.13, the following procedure shall be performed:

(1) The test equipment shall be checked for leaks, malfunctions, or other problems.
(2) Where a problem is found, the problem shall be corrected, and a new calibration test in accordance with 7.5.1 through 7.5.3.13 shall be performed.

Table 7.5.3.13 Maximum Average Rate of Heat Release Rate for Various Time Intervals (Furnace Verification and Calibration)

	Maximum Heat Release Rate	
Time Interval (min)	Btu/ft^2·min	kW/m^2
3	410	77.6
5	390	73.8
10	360	68.1
Test average	285	54.0

Chapter 8 Conduct of Tests

8.1 Calibration Using Calibration Test Specimen. Prior to testing specimens, the test furnace shall have been successfully calibrated within the last 90 days using the calibration test specimen in accordance with Section 7.5.

8.2 Verification Using Blank Specimen. A successful verification of operation shall have been conducted within the previous 5 days using the blank specimen in accordance with Section 7.4.

8.3 Testing. The testing procedure shall be performed as described in 8.3.1 through 8.3.5.

8.3.1 The test specimen constructed in accordance with Section 6.3 and conditioned in accordance with Section 6.4 shall be installed on the test furnace.

8.3.2 The test procedure for the test specimen shall be in accordance with the procedures described in Section 7.5 except that the test specimen shall replace the calibration test specimen.

8.3.3* The application of an insulating cement material meeting 7.5.2.3 to the top of the test specimen shall be permitted to prevent flaming or visible smoke generation during the fire exposure test of the test specimen.

8.3.4 The maximum average heat release rate shall be calculated for any 3-minute, 5-minute, and 10-minute interval during the test period and for the total 30-minute test duration using the integrated area under the heat release rate rate–time curve developed in 7.5.3.13 for the test specimen.

8.3.5 The values shall be reported as Btu/ft^2·min (kW/m^2).

8.4 Acceptance Criteria.

8.4.1 The calculated maximum average rate of heat release for the test specimen for each time interval as calculated in 8.3.4 shall not exceed the values for the same time interval in Table 8.4.1.

8.4.2 During the fire test, there shall be no dropping of flaming particles into the furnace or uncontrolled flaming on the exterior surface of the test specimen.

Table 8.4.1 Maximum Average Rate of Heat Release Rate for Various Time Intervals

	Maximum Heat Release Rate	
Time Interval (min)	Btu/ft^2·min	kW/m^2
3	410	77.6
5	390	73.8
10	360	68.1
30	285	54.0

Chapter 9 Report

9.1 Data and Information. The report shall include the data and information described in Sections 9.2 through 9.10.

9.2 Calibration Information. A description of the test results from the calibration test specimen shall be reported and shall include the following:

(1) Weight of the wood fiberboard
(2) Conditioning of the test specimen prior to testing
(3) Date that the calibration was conducted
(4) Auxiliary burner fuel flow rate, plotted as heat release rate as a function of time
(5) Maximum heat release rate calculated at 3-minute, 5-minute, 10-minute, and 30-minute intervals

9.3 Test Specimen Materials. The name, thickness, density, size of all components (steel deck, insulation, cover boards, base, ply, top sheets, etc.) used to construct the test specimen, and a description of the construction details, including a diagram, shall be reported.

9.4 Main Burner Fuel Flow. The heptane fuel flow rate to the main burners for the duration of both the 30-minute fire exposure test and the evaluation test, plotted as heat release rate versus time, shall be reported.

9.5 Flue Gas Temperatures. The average flue gas temperatures, representing the time–temperature curve for the test specimen, measured by the 12 thermocouples located in the flue exhaust, for the duration of both the fire exposure test and the evaluation test shall be reported.

9.6 Auxiliary Burner Fuel Flow. The propane fuel flow rate to the auxiliary burner for the duration of the 30-minute evaluation test, plotted as heat release rate versus time, shall be reported.

9.7 Heat Release Rate. Calculated heat release rates of the test specimen, as determined by the auxiliary burner fuel flow rate at 3 minutes, 5 minutes, 10 minutes, and 30 minutes shall be reported.

9.8 Visual Observations. Observable damage to the exposed and unexposed sides of the test specimen after the test shall be documented using text, pictures, and drawings.

9.9 Internal Component Description. Post-test examination of the internal components of the test specimen shall be described.

9.10 Discussion of Performance. A complete discussion of specimen performance shall be provided, including a determination of the test specimen's performance based on the acceptance criteria in Section 8.4.

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.1.1 In August 1953, the 35-acre General Motors Hydro-Matic factory in Livonia, MI, was destroyed by fire. Unprotected steel construction and the thin steel deck, which permitted the asphalt built-up roof covering to melt, drip through joints, and thereby contribute to fire spread within the building, were

factors cited as responsible for the extent of the loss. The fire resulted in the largest industrial fire loss in the United States to that date.

A 20 ft × 100 ft (6.1 m × 30.5 m) test structure was constructed to facilitate the analysis of the potential for contribution of roof-covering materials to fire spread within a building. Subsequent analysis consisted of a series of five large-scale fire tests utilizing different roof deck constructions, one of which represented the roof deck construction used in the General Motors factory. Based on those large-scale fire tests, a roof deck construction evaluated for the purpose of establishing limits for underdeck fire spread consisted of a built-up steel roof deck system.

Based on this full-scale testing, Factory Mutual (FM) developed the fire test procedure described in Appendix B of FM 4450, *Class 1 Insulated Steel Deck Roofs*, and incorporated only the wood fiberboard sample (on a steel deck with a steel cover) and not the roof-covering materials. The roof-covering materials were not included because research at FM determined that they did not contribute significantly to the heat release. In a 1959 NFPA article, "The FM Construction Materials Calorimeter," Thompson and Cousins reported on the development of the roof calorimeter test apparatus. The heat release contribution from this roof deck assembly was used to establish the 3-minute, 5-minute, 10-minute, and 30-minute average heat release limits. The wood fiberboard material used in the original test series is no longer available, but a substitute material has been identified. The wood fiberboard currently used in the test specimen provides the same heat release rate limits that are prescribed in Section 8.4.

A.1.1.1 This test was originally developed as a part of FM 4450, *Class 1 Insulated Steel Deck Roofs*.

A.1.1.3 Additional information on substitution method calorimetry is provided in Chapter 27 of the *SFPE Handbook of Fire Protection Engineering*.

A.1.2.1 This test method is based on the Fire Hazard Test Procedure in Appendix B of FM 4450, *Class 1 Insulated Steel Deck Roofs*.

A.1.2.3.1 The auxiliary fuel is intended to evaluate the heat release of the specimen compared with assemblies that performed acceptably based on full-scale testing following the fire at the GM factory in Livonia, MI (see A.1.1). The auxiliary fuel added equals the heat release produced by the test specimen because all other test conditions are maintained constant.

A.3.3.1 Blank Test Specimen. The blank test specimen is a reinforced refractory concrete panel that can also be used as a furnace cover.

A.4.1.1 Complete sets of construction details are available from FM Approvals, P.O. Box 9102, Norwood, MA 02062.

A.4.1.2 Figure A.4.1.2(a) is a photograph of the test furnace, and Figure A.4.1.2(b) is a sketch of the test furnace.

A.4.1.11 The following information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by NFPA or any of its technical committees: Bete P54 nozzles (manufactured by Bete Fog Nozzle, Inc., Greenfield, MA) or equivalent spray nozzles are considered to be satisfactory.

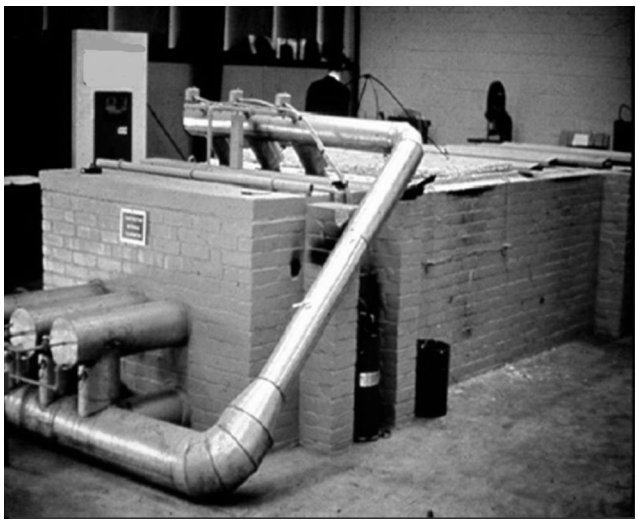
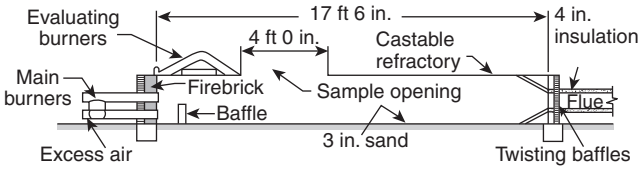


FIGURE A.4.1.2(a) Photograph of the Test Furnace.



Note: For SI units, 1 in. = 25.4 mm; 1 ft = 0.3048 m.

FIGURE A.4.1.2(b) Sketch of the Test Furnace.

A.4.1.14 The following information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by NFPA or any of its technical committees: B&W K-20 or equivalent insulation is considered to be satisfactory.

A.8.3.3 The following information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by NFPA or any of its technical committees: Insulating cement, available from ANH Refractories Company, Moon Township, PA, or its equivalent is considered to be satisfactory.

Annex B Informational References

B.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this code and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

B.1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

Thompson, N. J., and E. W. Cousins, "The FM Construction Materials Calorimeter," *Quarterly of the National Fire Protection Association International*, Vol 52, No. 3, January 1959.