

# NFPA® 271

## Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

### 2009 Edition



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An International Codes and Standards Organization

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## NFPA® 271

### Standard Method of Test for

## Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter

### 2009 Edition

This edition of NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, was prepared by the Technical Committee on Fire Tests. It was issued by the Standards Council on December 9, 2008, with an effective date of December 29, 2008, and supersedes all previous editions.

This edition of NFPA 271 was approved as an American National Standard on December 29, 2008.

### Origin and Development of NFPA 271

NFPA 271 was originally numbered NFPA 264 and was first published in 1992. NFPA 264 was closely related to and derived from NFPA 264A, *Standard Method of Test for Heat Release Rates for Upholstered Furniture Components or Composites and Mattresses Using an Oxygen Consumption Calorimeter*. NFPA 264 was based on the methods of measuring rates of heat release using an oxygen consumption calorimeter developed at the National Institute of Standards and Technology by Dr. Vytenis Babrauskas, et al. The document provided a general methodology for measuring the heat release rates of a variety of materials in a variety of end uses. It was intended that this approach be adopted and customized for the testing of specific products and materials. Such a bench-scale approach provides a mechanism for deriving information that can be used for product and material evaluation, mathematical modeling, and design purposes, as well as for research and development purposes.

The 1995 edition of NFPA 264 reflected changes that were both editorial and technical in nature. The technical revisions included standardization of the horizontal position as the orientation for testing of specimens. The horizontal orientation provides greater repeatable and reproducible results. The vertical orientation details, located in Annex D, were intended to be used more for research purposes. The definition of sustained flaming was revised from existence of flame for 10 seconds to existence of flame for 4 seconds, in order to coordinate with other documents.

The 1998 edition of NFPA 264 was renumbered as NFPA 271. The designation was changed for coordination purposes and placed the document in rotation with other documents that use the oxygen consumption calorimeter. The changes to the 1998 edition were minor in nature. They included updating the document to the latest terminology used in the industry and the current laboratory processes and some editorial clarification. A new section pertaining to the radiation shield was added.

The 2001 edition was a complete revision that incorporated the layout and provisions of the *Manual of Style for NFPA Technical Committee Documents*, 2000 edition. Minor revisions included updating ignition circuit applications in Chapter 2 and Annex D, identifying the type of radiation shield not permitted, and correcting the heat release calibration in Chapter 5.

The 2004 edition included editorial changes to be in further compliance with the *Manual of Style for NFPA Technical Committee Documents*. Technical changes included revising the term *sustained flaming* and new requirements concerning the test environment and the conditioning of test specimens. Advisory information was added to the annex regarding testing of nonplanar surfaces and the testing of assemblies and materials not specified in the body of the standard. References to test methods similar to that of NFPA 271 were also provided.

The 2009 edition is largely a reconfirmation of the 2004 edition with minor editorial revisions.

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## NFPA 271

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Materials and Products Using an Oxygen  
Consumption Calorimeter

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

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

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

## Chapter 1 Administration

## 1.1 Scope.

**1.1.1\*** This test method measures the response of materials exposed to controlled levels of radiant heating, with or without an external igniter.

**1.1.2** This test method determines the ignitability, heat release rate, mass loss rates, effective heat of combustion, and visible smoke development of materials and products.

**1.1.3\*** This test method tests the specimen in the horizontal orientation.

## 1.2 Purpose.

**1.2.1\*** This test method provides measurements of the behavior of material and product specimens under a specified radiant heat exposure in terms of the rate of heat release, effective heat of combustion, mass loss rate, time to ignition, and smoke production.

**1.2.2** The data obtained for a specific test describe the rate of heat and smoke release of the specimen when exposed to the specific conditions and procedures used in performance of that test.

**1.2.3** Release rate measurements provide a quantitative measure of specific changes in performance caused by product modification.

## 1.3 Application.

## 1.3.1 Significance.

**1.3.1.1** This test method is useful for the following:

- (1) Evaluations of materials or products
- (2) Mathematical modeling
- (3) Design of new materials or products
- (4) Research and development

**1.3.1.2** Types of materials suitable for testing with this method include specimens from an end-use product and the various components used in the end-use product.

**1.3.1.3** Release rates for a given material depend on how the material is used, its thickness, and the method of mounting.

**1.3.1.4** Other factors, some of which cannot be controlled, that can affect the heat release rate for a given material include the orientation of the material (vertical, horizontal, or otherwise), the types of joints or other methods used for installation, the way the material reacts to fire (melts and drips, recedes, chars, pyrolyzes, intumesces, or flames), and the use of fire retardants.

**1.3.1.5** This standard does not purport to address all safety problems associated with its use. The user of this standard shall be responsible for establishing appropriate safety and health practices and for determining the applicability of regulatory limitations prior to use.

## 1.3.2\* Test Limitations.

**1.3.2.1\*** This test method shall not apply to end-use products that do not have planar external surfaces.

**1.3.2.2** The test data shall be invalid if any of the following occurs:

- (1) The specimen undergoes explosive spalling.
- (2) The specimen swells to the point where it touches the spark plug prior to ignition.
- (3) The specimen swells to the point where it touches the heater base plate during combustion.

**1.3.2.3** If delamination of the specimen occurs, the test results shall be considered suspect, and this shall be described in the test report.

**1.3.2.4\*** This test method shall be performed in a controlled environment under controlled laboratory conditions in order to obtain material properties data for use in evaluating the fire hazard of materials.

**1.3.2.4.1** These data alone do not describe the fire hazard of a material's specific end use or predict its response to real fires.

**1.3.2.4.2** The data obtained by this test method have not yet been correlated with the real-world fire performance for most materials.

**1.3.2.4.3** Thus, caution shall be used in the utilization of such data to evaluate the full-scale fire performance of the end use of materials tested in accordance with this method.

## 1.3.3 Summary of Test Method.

**1.3.3.1** This test method is based on the observation that the net heat of combustion is directly related to the amount of oxygen necessary for combustion: Approximately  $13.1 \times 10^3$  kJ of heat are released per 1 kg of oxygen consumed.

**1.3.3.2** Specimens in the test shall be combusted in ambient air conditions while being subjected to a predetermined external radiant heat flux, which ranges from 0 kW/m<sup>2</sup> to 100 kW/m<sup>2</sup>. Combustion shall be initiated with or without a spark igniter.

**1.3.3.3** The primary measurements, as a function of time, shall be oxygen concentration and exhaust gas flow rate (for assessing heat release rate).

**1.3.3.3.1** Additional measurements shall include specimen mass, for assessing mass loss rate and smoke obscuration, both of them as a function of time, and time to sustained flaming, which is a measure of ignitibility.

**1.3.3.3.2** The test method is also suitable for other measurements.

**1.3.3.4\*** This test method shall be intended to determine the heat released by a product or material when exposed to an external radiant heat source.

**1.3.3.4.1** This test method also determines the effective heat of combustion, mass loss rate, time to sustained flaming, and smoke production.

**1.3.3.4.2** These properties shall be determined on small-size specimens that are representative of the intended end-use materials.

**1.3.3.5** The rate of heat release shall be determined by measurement of the oxygen consumption, which is determined by the oxygen concentration and the flow rate in the exhaust product stream.

**1.3.3.5.1** The effective heat of combustion shall be determined from a concomitant measurement of specimen mass loss rate in combination with the heat release rate.

**1.3.3.5.2** Smoke development shall be determined from the obscuration of light by the combustion product stream.

**1.3.3.6** This test method shall be applicable to various categories of products and shall not be limited to a single fire scenario.

**1.3.3.7\*** Specimens shall be exposed to heating fluxes in the range of 0 kW/m<sup>2</sup> to 100 kW/m<sup>2</sup> in a horizontal orientation.

**1.3.3.7.1** External ignition, where used, shall be by electric spark.

**1.3.3.7.2** The value of the heating flux and the use of external ignition shall be specified by the relevant material or performance standard or by the test sponsor for research and development purposes.

**1.3.3.8** Ignitibility shall be determined as a measurement of time from initial exposure to time of sustained flaming.

#### 1.4 Units.

**1.4.1** The values stated in SI units shall be regarded as the standard.

**1.4.2** Unless otherwise stated, all dimensions included in the test and figures shall be mandatory and shall be followed within nominal tolerances of 1 mm. Dimensions in figures that are not followed by an asterisk (\*) shall be considered nonmandatory.

**1.5 Symbols.** The following symbols are used in this standard:

|                  |                                                                                                               |
|------------------|---------------------------------------------------------------------------------------------------------------|
| $A_s$            | = nominal specimen exposed surface area (0.01 m <sup>2</sup> )                                                |
| $C$              | = calibration constant for oxygen consumption analysis (m <sup>1/2</sup> kg <sup>1/2</sup> K <sup>1/2</sup> ) |
| $-dm/dt$         | = required mass loss rate                                                                                     |
| $\Delta H_c/r_0$ | = net heat of combustion (kJ/kg)                                                                              |

|                    |                                                                                                   |
|--------------------|---------------------------------------------------------------------------------------------------|
| $\Delta H_{c,eff}$ | = effective heat of combustion (kJ/kg)                                                            |
| $I$                | = actual beam intensity                                                                           |
| $I_0$              | = beam intensity with no smoke                                                                    |
| $k$                | = smoke extinction coefficient (m <sup>-1</sup> )                                                 |
| $L$                | = extinction beam path length (m)                                                                 |
| $m$                | = specimen mass (kg)                                                                              |
| $m_f$              | = final specimen mass (kg)                                                                        |
| $m_i$              | = initial specimen mass (kg)                                                                      |
| $\dot{m}$          | = specimen mass loss rate (kg/sec)                                                                |
| $\Delta P$         | = orifice meter pressure differential (Pa)                                                        |
| $q''$              | = total heat release (kJ/m <sup>2</sup> )                                                         |
| $\dot{q}$          | = heat release rate (kW)                                                                          |
| $\dot{q}''$        | = heat release rate per unit area (kW/m <sup>2</sup> )                                            |
| $t_0$              | = stoichiometric oxygen/fuel mass ratio                                                           |
| $t$                | = time (sec)                                                                                      |
| $t_d$              | = oxygen analyzer delay time (sec)                                                                |
| $\Delta t$         | = sampling time interval (sec)                                                                    |
| $T_e$              | = absolute temperature of gas at the orifice meter (K)                                            |
| $\dot{v}$          | = volume exhaust flow rate measured at the location of the laser photometer (m <sup>3</sup> /sec) |
| $X_{O_2}$          | = oxygen analyzer reading, mole fraction of O <sub>2</sub>                                        |
| $X_{O_2}^0$        | = initial value of oxygen analyzer reading                                                        |
| $X_{O_2}^1$        | = oxygen analyzer reading before delay time correction                                            |
| $s_f$              | = specific extinction area for smoke (m <sup>2</sup> /kg)                                         |

## 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.**

*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.** A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for

mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

### 3.3 General Definitions.

#### 3.3.1 Heat of Combustion.

**3.3.1.1 Effective Heat of Combustion.** The measured heat release divided by the mass loss for a specified time period.

**3.3.1.2\* Net Heat of Combustion.** The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water.

**3.3.2 Heat Release Rate.** The heat evolved from the specimen, per unit of time.

**3.3.3 Heating Flux.** The incident radiant heat flux imposed externally from the heater on the specimen at the initiation of the test.

**3.3.4 Ignitibility.** The propensity for ignition, as measured by the time to sustained flaming, in seconds, at a specified heating flux.

**3.3.5 Orientation.** The plane in which the exposed face of the specimen is located during testing (i.e., horizontally facing the heater).

**3.3.6 Oxygen Consumption Principle.** The expression of the relationship between the mass of oxygen consumed during combustion and the heat released.

**3.3.7 Smoke Obscuration.** The reduction of light transmission by smoke, as measured by light attenuation.

**3.3.8 Sustained Flaming.** The existence of flame on or over the surface of the specimen for a period of at least 4 seconds.

**3.3.9 Visible Smoke.** The obscuration of transmitted light caused by combustion products released during the test.

## Chapter 4 Test Apparatus

**4.1 General.** The test apparatus shall consist of the following components:

- (1) A conical-shaped radiant electric heater
- (2) Specimen holders
- (3) An exhaust gas system with oxygen-monitoring and flow-measuring instrumentation
- (4) An electric ignition spark plug
- (5) A data collection and analysis system
- (6) A load cell for measuring specimen mass loss

**4.1.1** A general view of the apparatus shall be as shown in Figure 4.1.1.

**4.1.2** A cross-sectional view of the heater shall be as shown in Figure 4.1.2.

**4.1.3** An exploded view of the horizontal orientation shall be as shown in Figure 4.1.3.

### 4.2 Conical Heater.

**4.2.1** The active element of the heater shall consist of an electrical heater rod, rated at 5000 W at 240 V and tightly wound into the shape of a truncated cone, as shown in Figure 4.1.2.

**4.2.2** The heater shall be encased on the outside with a double-wall stainless steel cone packed with a refractory fiber material of approximately 100 kg/m<sup>3</sup> density.

**4.2.3\*** The heater shall be mounted in a horizontal orientation.

**4.2.4** The heater shall be capable of producing irradiances on the surface of the specimen of up to 100 kW/m<sup>2</sup>.

**4.2.5** The irradiance shall be uniform within the central 50 mm × 50 mm area of the specimen to within 10 percent.

**4.2.6** The irradiance from the heater shall be capable of being held at a preset level by means of a temperature controller and three Type K stainless steel-sheathed thermocouples, symmetrically dispersed and in contact with, but not welded to, the heater element, as shown in Figure 4.1.2.

**4.2.7** The thermocouples shall be of equal length and wired in parallel to the temperature controller.

**4.2.8** The standard thermocouples shall be sheathed, 1.5 mm to 1.6 mm O.D., with an unexposed hot junction. Alternatively, either 3 mm O.D. sheathed thermocouples with an exposed hot junction or 1 mm O.D. sheathed thermocouples with unexposed hot junction shall be suitable for use.

### 4.2.9 Radiation Shield.

**4.2.9.1** The cone heater shall be provided with a removable radiation shield to protect the specimen from the heat flux prior to the start of the test.

**4.2.9.2** The shield shall be made of noncombustible material, with a total thickness not to exceed 12 mm.

**4.2.9.3** The shield shall be one of the following:

- (1) Water-cooled and coated with a durable matte black finish of surface emissivity,  $\epsilon = 0.95 \pm 0.05$
- (2) Not water-cooled, with a metallic reflective top surface
- (3) Not water-cooled, with a ceramic, nonmetallic surface that minimizes radiation transfer to the specimen surface

**4.2.9.4** The shield shall be equipped with a handle or other suitable means for insertion and removal in accordance with 7.2.2 and 7.2.3.

**4.2.9.5** The cone heater base plate shall be equipped with the means for holding the shield in position and allowing its insertion and removal in accordance with 7.2.2 and 7.2.3.

### 4.3 Temperature Controller.

**4.3.1** The temperature controller for the heater shall be capable of holding the element temperature steady to within 2°C.

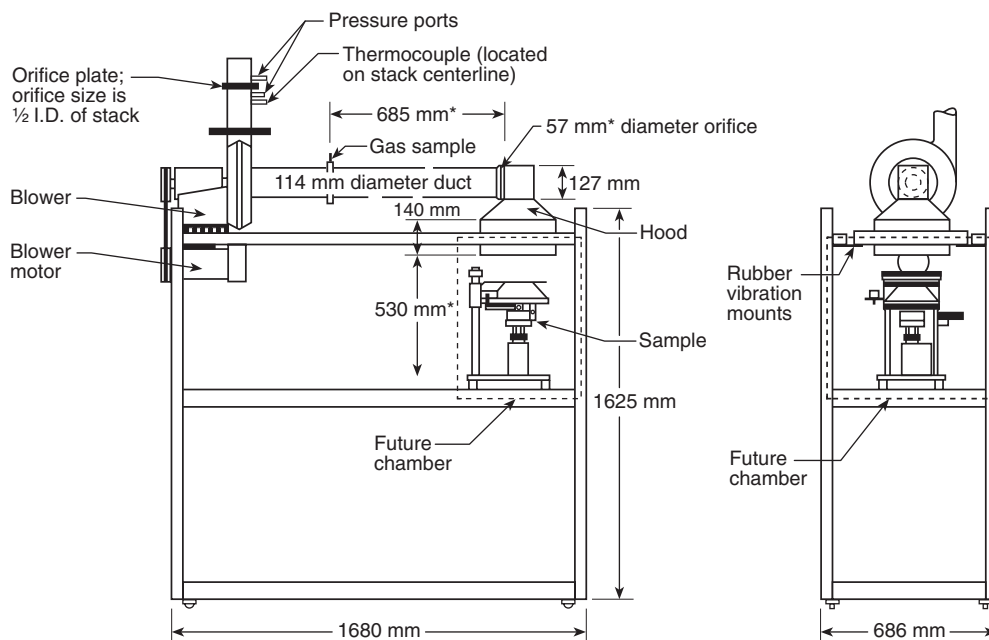
**4.3.2** An acceptable system shall be a three-term controller (proportional, integral, and derivative) and a thyristor unit capable of switching currents up to 25 A at 250 V.

**4.3.3** The controller shall have a temperature input range of 0°C to 1000°C, a set scale capable of being read to 2°C or better, and automatic cold junction compensation.

**4.3.4** The controller shall be equipped with a safety feature that, in the event of an open circuit in the thermocouple line, causes the temperature to fall to near the bottom of its range.

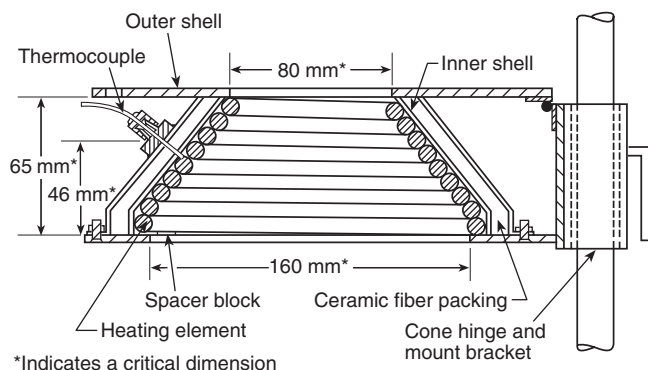
**4.3.5** The thyristor unit shall be of the zero crossing type and not of the phase angle type.





\*Indicates a critical dimension

**FIGURE 4.1.1 Overall View of Apparatus.**



\*Indicates a critical dimension

**FIGURE 4.1.2 Cross-Sectional View of Heater.**

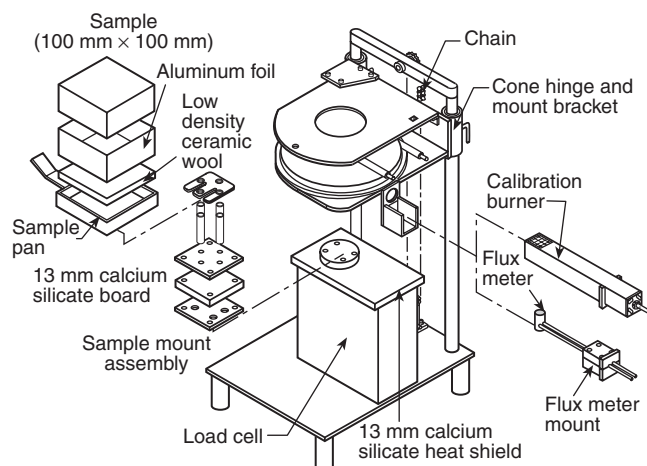


**FIGURE 4.1.3 Exploded View, Horizontal Orientation, of Apparatus.**

**4.3.6** The heater temperature shall be monitored by a meter capable of being read to 2°C or better.

#### 4.4 Exhaust System.

**4.4.1** The exhaust gas system shall consist of a high-temperature centrifugal exhaust fan, a hood, intake and exhaust ducts for the fan, and an orifice plate flowmeter as shown in Figure 4.4.1.

**4.4.2** The exhaust system shall be capable of developing flows from 0.012 m<sup>3</sup>/sec to 0.035 m<sup>3</sup>/sec.

**4.4.3** A restrictive orifice (57 mm I.D.) shall be located between the hood and the duct to promote mixing.

**4.4.4** A ring sampler for gas sampling shall be located in the fan intake duct 685 mm from the hood, as shown in Figure 4.4.1.

**4.4.5** The ring sampler shall contain 12 holes to average the stream composition, with the holes facing away from the flow to avoid soot clogging.

**4.4.6** The temperature of the gas stream shall be measured using a 1.0 mm to 1.6 mm O.D. sheathed-junction thermocouple or a 3 mm O.D. exposed-junction thermocouple positioned in the exhaust stack on the centerline and 100 mm upstream from the measuring orifice plate.

**4.4.7** The flow rate shall be determined by measuring the differential pressure across a sharp-edged orifice (57 mm I.D.) in the exhaust stack at a location at least 350 mm downstream from the fan.