NFPA® 289

Standard Method of Fire Test for Individual Fuel Packages

2009 Edition

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NFPA® 289

Standard

Method of Fire Test for Individual Fuel Packages

2009 Edition

This edition of NFPA 289, *Standard Method of Fire Test for Individual Fuel Packages,* was prepared by the Technical Committee on Fire Tests. It was issued by the Standards Council on May 30, 2008, with an effective date of July 18, 2008.

This edition of NFPA 289 was approved as an American National Standard on July 18, 2008.

Origin and Development of NFPA 289

The 2009 edition of NFPA 289 is the first for this standard. It establishes a fire test method for determining the contribution of individual fuel packages to heat and smoke release when exposed to various ignition sources. Testing protocols are provided for three types of individual fuel packages: single decorative objects such as signs, wall hangings, and mannequins; exhibit booths; and stage sets including backdrops and scenery. NFPA 289 is a standard test method for determining the extent to which these fuel packages contribute to fire growth and the potential for the spread of fire in a controlled environment.

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Standard

Method of Fire Test for Individual Fuel Packages

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A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex C. 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 publications can be found in Chapter 2 and Annex C.

Chapter 1 Administration

1.1 Scope.

1.1.1 This standard describes a fire test method for determining the fire test response characteristics of individual fuel packages when exposed to various ignition sources.

1.1.2 This fire test method is applicable to individual fuel packages.

1.1.3 This fire test method is not intended to evaluate fire resistance.

1.1.4 This standard contains detailed descriptions of three types of individual fuel packages to be investigated, as follows:

(1)*Single decorative object
(2) Exhibit booth
(3) Stage setting

1.1.5* This test method shall not apply to seating furniture, mattresses, stacking chairs, interior finish, textile wall coverings, or mattress sets.

1.2 Purpose.

1.2.1 This method of test measures certain fire test response characteristics of individual fuel packages under specified fire exposure conditions.

1.2.2 The method of test provides the following data:

(1) Extent of fire growth
(2) Rate of heat release by the individual fuel package
(3) Total heat released by the individual fuel package
(4) Smoke obscuration, as determined in the exhaust duct
(5) Production of carbon monoxide, as determined in the exhaust duct
(6) Emissions of other combustion gases, as determined in the exhaust duct
(7) Gas temperatures at suitable locations
(8) Mass loss of single decorative objects

1.2.3* The performance observed in the test is based on the test conditions.

1.2.4 The method of test does not provide the following:

(1) Full information concerning toxicity of combustion gases
(2) Fire resistance of systems

1.3 Symbols. The following symbols are used in this standard:

C	= calibration factor for orifice plate or bidirectional probe ($kg^2\ m^2\ K^2$)
C_{est}	= an approximate value of the calibration factor
C_{cor}	= corrected calibration factor
dt	= time (sec)
F_{mb}	= mass of fuel burned (kg)
E	= net heat released per unit mass of oxygen consumed (13.1 MJ/kg)
E_{CO}	= net heat released per unit mass of oxygen consumed, for CO (17.6 MJ/kg)
Ht_{comb}	= heat of combustion of the fuel used (46.5 MJ/kg for propane and 50.0 MJ/kg for methane)
I_0	= light intensity for a beam of parallel light rays, measured in a smoke-free environment, with a detector having the same spectral sensitivity as the human eye and reaching the photodetector
I	= light intensity for a parallel light beam having traversed a certain length of smoky environment and reaching photodetector
k	= smoke extinction coefficient (l/m)
L_p	= light path length of beam through smoky environment, which is equal to the duct diameter (m)
$\dot{m}_e$	= mass flow rate in exhaust duct (kg/sec)
$\dot{m}_{CO}$	= release rate of CO (kg/sec)
$\dot{m}_x$	= release rate of combustion product x (kg/sec)
M_a	= molecular weight of incoming and exhaust air (29 kg/kmol)
M_{CO}	= molecular weight of CO (28 kg/kmol)
M_{O_2}	= molecular weight of oxygen (32 kg/kmol)
MW	= fuel mass loss
OD	= optical density per unit light path length (l/m)
ΔP	= pressure drop across the orifice plate or bidirectional probe (Pa)
$\dot{q}$	= rate of heat release (kW)
RSR	= rate of smoke release (m^2/sec)
Δt	= scan period (sec)
T_e	= gas temperature at the orifice plate or bidirectional probe (K)
test period	= duration of test (sec)
THR	= total heat released (MJ)
TSR	= total smoke released (m^2)
$\dot{V}_s$	= volumetric flow rate at location of smoke meter (value adjusted for smoke measurement calculations) (m^3/sec)

X_{CO} = measured mole fraction of CO in exhaust flow (nondimensional)

X_{CO_2} = measured mole fraction of CO_2 in exhaust flow (nondimensional)

$X^0_{CO_2}$ = measured mole fraction of CO_2 in incoming air (nondimensional)

X_{O_2} = measured mole fraction of O_2 in exhaust flow (nondimensional)

$X^0_{O_2}$ = measured mole fraction of O_2 in incoming air (nondimensional)

X_x = measured mole fraction of combustion gas x in exhaust flow (nondimensional)

α = combustion expansion factor (nondimensional; use a value of 1.105, unless the value for the test specimen, and not the ignition gas, is known)

ϕ = oxygen depletion factor (nondimensional)

ρ_0 = density of air at 273.15 K : 1.293 (kg/m^3)

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.

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter,* 2004 edition.

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* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.4 Shall. Indicates a mandatory requirement.

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

3.2.6 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 Individual Fuel Package. An item or a group of items for which the fire test response characteristics are to be measured.

3.3.2 Heat of Combustion.

3.3.2.1 ***Effective Heat of Combustion.*** The measured heat release divided by the mass loss for a specified time period. [**271,** 2004]

3.3.2.2 ***Net Heat of Combustion.*** The oxygen bomb calorimeter value for the heat of combustion, corrected for the gaseous state of product water. [**271,** 2004]

3.3.3 Heat Release Rate. The heat evolved from the specimen, per unit of time. [**271**, 2004]

3.3.4 Heating Flux. The incident radiant heat flux imposed externally from the heater on the specimen at the initiation of the test. [**271,** 2004]

3.3.5 Oxygen Consumption Principle. The expression of the relationship between the mass of oxygen consumed during combustion and the heat released. [**271,** 2004]

3.3.6 Smoke Obscuration. The reduction of light transmission by smoke, as measured by light attenuation. [**271,** 2004]

Chapter 4 Summary of Method

4.1 General.

4.1.1* The individual fuel package shall be tested by using one of the ignition sources as described in 4.1.7.

4.1.2* Decorative objects shall be tested as described in Section 5.1.

4.1.3 Exhibit booths shall be tested as described in Section 5.2.

4.1.4 Theater, motion picture, and television stage settings shall be tested as described in Section 5.3.

4.1.5 Individual fuel packages and decorative objects, other than those described in 4.1.2 through 4.1.4, shall be tested as described in Section 5.4.

4.1.6 The test methods described herein shall use a gas burner to produce a diffusion flame to expose the individual fuel package.

4.1.6.1 The burner shall produce a prescribed rate of heat output as described in 4.1.7.

4.1.6.2 The fire test response characteristics of the individual fuel package shall be measured by constant monitoring of heat release, smoke release, and the temperature of the gases in the exhaust duct connected to the hood.

4.1.6.3 The combustion products shall be collected in a hood that feeds into a plenum connected to an exhaust duct in which measurements of the gas velocity, temperature, smoke obscuration, and concentrations of selected gases are made.

4.1.7 The ignition source shall be a gas burner as described in Section 7.1.

4.1.7.1* The ignition source shall be set at one of six power levels, namely, 20, 40, 70, 100, 160, or 300 kW, and shall be applied for an exposure period of 15 minutes.

4.1.7.2* The choice of power levels shall be based both on the type of individual fuel package to be tested and on its potential application.

Chapter 5 Individual Fuel Packages

5.1 Decorative Objects.

5.1.1 Individual decorative objects of irregular shape such as, but not limited to, mannequins and other such objects used for display purposes shall be tested in the size and shape intended for use.

5.1.2 Materials intended for use in the manufacture of decorative objects comprising individual fuel packages that are planar such as, but not limited to, murals, wall hangings, and signs shall be permitted to be tested as a material in the thickness and size intended for use.

5.1.2.1 Objects intended to exceed width and height dimensions of 2.4 m (8 ft) shall be tested at maximum width and height dimensions not exceeding 2.4 m (8 ft).

5.1.2.2 The decorative object shall be mechanically supported in such a manner that the support system does not interfere with the fire test response characteristics of the decorative object.

5.1.3 The individual fuel package shall be placed on a protective barrier large enough to prevent melting or material from falling off the protective barrier as described in 5.1.4 and 7.5.2.1.

5.1.4 The protective barrier shall serve to catch falling material and to protect the load cell as described in Section 7.5.

5.1.5 For individual fuel packages of irregular shape, the ignition source shall be placed on the protective barrier *(see 5.1.3)* and in contact with the fuel package or located to optimize ignition and fire growth of the individual fuel package.

5.1.6 For murals, signs, wall hangings, and other objects that are planar, the vertical centerline of the ignition source shall be aligned with the vertical centerline of the decorative object ± 25 mm (± 1 in.) and located within 25 mm ± 2.5 mm (1 in. ± 0.1 in.) of the vertical face of the decorative object.

5.2 Exhibit Booths.

5.2.1* Panels intended for exhibit booth construction shall be constructed into a 2.4 m ± 0.1 m × 2.4 m ± 0.1 m (8 ft ± 0.32 ft × 8 ft ± 0.32 ft) rear wall section and two 1.8 m ± 0.1 m long × 2.4 m ± 0.1 m high (6 ft ± 0.32 ft long × 8 ft ± 0.32 ft high) sidewall sections.

5.2.1.1 The booth shall be an open-top, open-front assembly.

5.2.1.2 The panels shall be mechanically fastened to angle iron framework not exceeding 51 mm (2 in.) in nominal size.

5.2.2 The ignition source shall be placed on the protective barrier *(see 5.1.3)* in one of the rear corners of the exhibit booth within 25 mm ± 2.5 mm (1 in. ± 0.1 in.) of the rear wall and the side wall.

5.3 Theater, Motion Picture, and Television Stage Settings.

5.3.1 Material intended for use in the construction of theater, motion picture, and television stage settings such as, but not limited to, simulated backdrops, boulders, mountains, and caves, shall be permitted to be formed into 50.8 mm (2 in.) thick panels and assembled into an open-front structure with two side walls, a back wall, and a ceiling, meeting at 90 degree (± 5 degrees) angles in the corners.

5.3.2 The interior dimensions of the structure shall be 1.5 m × 1.5 m × 1.5 m (5 ft × 5 ft × 5 ft) [± 0.1 m (± 0.32 ft)].

5.3.3 For open-front structures, the ignition source shall be placed on the protective barrier in one of the rear corners of the structure within 25 mm ± 2.5 mm (1 in. ± 0.1 in.) of the rear wall and the side wall.

5.3.4 For other than open-front structures, the ignition source shall be placed on the protective barrier *(see 5.1.3)* and in contact with the individual fuel package or located to optimize ignition and fire growth of the individual fuel package.

5.4 Other Individual Fuel Packages.

5.4.1 For individual fuel packages other than those described in 4.1.2 through 4.1.4, the individual fuel package shall be centrally positioned on a weighing platform as described in Section 7.5.

5.4.2 The weighing platform shall be located centrally under the collection hood.

5.4.3 The ignition source shall be placed on the protective barrier *(see 5.1.3)* and in contact with the individual fuel package or located to optimize ignition and fire growth of the individual fuel package.

Chapter 6 Environmental Conditions

6.1* Conditioning. Prior to testing, the individual fuel package shall be conditioned to equilibrium in an atmosphere at a temperature of 21°C ± 3°C (70°F ± 5°F) and a relative humidity of 50 percent ± 5 percent.

6.1.1 Equilibrium shall be considered to be reached when the individual fuel package has achieved constant mass.

6.1.2 Constant mass shall be considered to be reached when two successive weighing operations, carried out at an interval of 24 hours, do not differ by more than 0.1 percent of the mass of the individual fuel package or by more than 0.1 g (0.0035 oz), whichever is greater.

6.1.3 The individual fuel package shall be tested within 30 minutes of removal from the conditioning room.

6.1.4 The time between removal from the conditioning room and start of testing shall be reported.

6.2 Fire Test Area Environment.

6.2.1 The test building in which the fire test area is located shall have vents for the discharge of combustion products and shall have provisions for fresh air intake so that no oxygen-deficient air is introduced into the fire area during the test.

6.2.1.1 Prior to the start of the test, the ambient air at the mid-height entrance to the fire test area shall have a velocity of less than 0.5 m/sec (100 ft/min) in any direction, as measured at a horizontal distance of 1 m ± 0.1 m (3.3 ft ± 0.3 ft) from the center of the hood.

6.2.1.2 The building shall be of adequate size so that smoke shall not accumulate in the building below the level of the top of the fire test area.

6.2.2 The fire test area shall be the area under the hood.

6.2.3 The ambient temperature in the test building at locations around the fire test area shall be in the range of 20°C ± 10°C (68°F ± 18°F), and the relative humidity shall be less than 75 percent for the duration of the test.

6.2.4* The surface of the protective barrier shall not be covered with materials that are able to alter the burning characteristics of material falling off the burning individual fuel package.

Chapter 7 Test Equipment and Instrumentation

7.1 Ignition Source.

7.1.1 The ignition source for the test shall be a gas burner with a nominal 305 mm × 305 mm (nominal 12 in. × 12 in.) porous top surface of a refractory material.

7.1.1.1 The refractory material through which the gas is supplied shall be a nominal 25 mm (nominal 1 in.) thick porous ceramic fiberboard over a 152 mm ± 5 mm (6 in. ± 0.2 in.) plenum.

7.1.1.2 Alternatively, a minimum 102 mm (4 in.) layer of white Ottawa silica sand shall be permitted to be used to provide the horizontal surface through which the gas is supplied, as shown in Figure 7.1.1.2.

7.1.1.3 The burner with a layer of white Ottawa silica sand as shown in Figure 7.1.1.2 shall be used for individual fuel packages with a potential for dripping.

7.1.2 The top surface of the burner through which the gas is applied shall be located horizontally 305 mm ± 50 mm (12 in. ± 2 in.) above the protective barrier *(see 5.1.3 and 7.5.2.1)*.

7.1.3 The gas supply to the burner shall be propane of C.P. grade (99 percent purity) or having a net heat of combustion of 46.5 MJ/kg ± 0.5 MJ/kg.

7.1.3.1 Flow rates of gas shall be calculated using a net heat of combustion of propane of 85 MJ/m^3 (2280 Btu/ft^3) at standard conditions of 101 kPa (14.7 psi) pressure and 20°C (68°F) temperature.

7.1.3.2 The gas flow rate shall be metered throughout the test, with an accuracy of at least ±5 percent.

7.1.3.3 The heat output to the burner shall be controlled within ±5 percent of the prescribed value.

7.1.4 The gas supply to the burner shall produce a net heat output of any of the following for a total of 15 minutes:

(1) 20 kW
(2) 40 kW
(3) 70 kW
(4) 100 kW
(5) 160 kW
(6) 300 kW

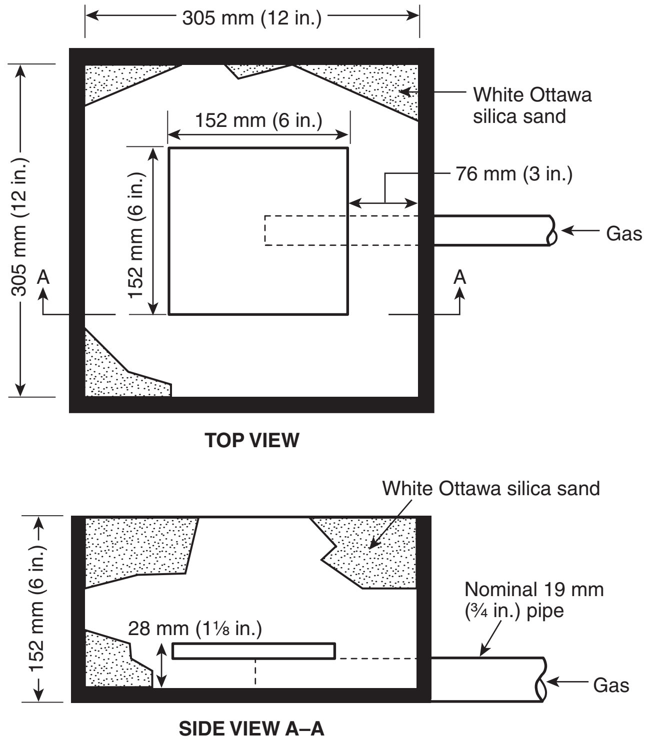

FIGURE 7.1.1.2 Gas Burner Using White Ottawa Silica Sand as Refractory Surface.

7.1.5 Burner controls shall be provided for automatic shutoff of the gas supply if flameout occurs.

7.1.6 The burner shall be ignited by a pilot burner or a remotely controlled spark igniter.

7.2* Fire Test Documentation.

7.2.1 The equipment described in 7.2.2 shall be used for recording visual information regarding this test.

7.2.2* Photographic Equipment. Video and photographic equipment shall be used to record the spread of fire and generation of smoke in the fire test area during the fire test.

7.2.2.1 A nominal 300-watt flood-type, quartz halogen lamp shall be positioned near the floor level and aimed at a level above the burner.

7.2.2.2 Video Recording. A video camera with a manually adjustable iris, adjusted to prevent automatic closing of the iris opening due to brightness of the fire (at least 50 percent open), shall be used.

7.2.2.2.1 A video monitor shall be used to determine when adjustments and compensation for the brightness of the ignition flames are needed.

7.2.2.2.2 The camera angle and magnification shall be adjusted until the entire test area is in full view.

7.2.2.2.3 A timer depicting "elapsed time" shall be included in all videos. The timer shall be clearly viewed throughout the test period. The timer shall be permitted to be integral to the video camera.

7.2.2.2.4 Prior to ignition of the burner, the date and laboratory test report identification number shall be recorded on the video. The video shall be started at least 30 seconds prior to ignition of the burner, and the video recording shall be continuous for the duration of the test period.

7.2.2.3 Photographic Documentation. A photographic record (still pictures) of the test shall be made.

7.2.2.3.1 A timer depicting "elapsed time" shall be included in all photographs. The timer shall be clearly viewed throughout the test period. The timer shall be permitted to be integral to the camera.

7.2.2.3.2 Prior to ignition of the burner, the date and laboratory test report identification number shall be photographed. Color slides, photographs, or digital images shall be taken at intervals not exceeding 15 seconds for the first 3 minutes of the test and at intervals not exceeding 30 seconds thereafter for the duration of the test.

7.3 Canopy Hood and Exhaust Duct.

7.3.1 A hood shall be positioned directly above the test area.

7.3.1.1 The bottom of the hood shall not be lower than the top of any individual fuel package.

7.3.1.2 The face dimensions of the hood shall be at least 2.44 m × 2.44 m (8 ft × 8 ft), and the depth shall be 1.1 m ± 0.1 m (3.5 ft ± 4 in.).

7.3.1.3 The hood shall feed into a plenum that has a 0.92 m ± 0.1 m × 0.92 m ± 0.1 m (3 ft ± 4 in. × 3 ft ± 4 in.) cross-section.

7.3.1.4 The plenum shall have a minimum height of 0.92 m (3 ft).

7.3.1.5 The height of the plenum shall be permitted to be increased to a maximum of 1.8 m (5 ft 11 in.) to satisfy building constraints.

7.3.1.6 The exhaust duct connected to the plenum shall be horizontal and at least 406 mm (16 in.) in diameter, and it shall be permitted to have a circular aperture of at least 305 mm (12 in.) at its entrance or at mixing vanes in the duct.

7.3.2* The hood shall have the capability to collect all the combustion products leaving the fire test area.

7.3.3 An alternative exhaust system design shall be permitted to be used if it has been shown to produce equivalent results.

7.3.4 The alternative draft system shall have shown equivalency by meeting the calibration requirements outlined in Chapter 8.

7.4 Instrumentation in Exhaust Duct.

7.4.1 Exhaust Collection System. The exhaust collection system shall be constructed with at least the following components:

(1) Blower
(2) Steel hood
(3) Duct
(4) Bidirectional probe
(5) Thermocouple(s)
(6) Oxygen measurement system
(7) Smoke obscuration measurement system (white light photocell lamp/detector or laser)
(8) Combustion gas sampling and analysis system

7.4.2* Bidirectional Probe.

7.4.2.1 General.

7.4.2.1.1 A bidirectional probe or an equivalent measuring system shall be used to measure gas velocity in the duct.

7.4.2.1.2 A typical probe shall consist of a stainless steel cylinder that is 44 mm ± 1 mm (1.75 in. ± 0.040 in.) long and 22 mm ± 1 mm (0.875 in. ± 0.040 in.) inside diameter with a solid diaphragm in the center.

7.4.2.1.3 The pressure taps on either side of the diaphragm shall support the probe.

7.4.2.1.4 The axis of the probe shall run along the centerline of the duct 3.35 m ± 0.1 m (11 ft ± 4 in.) (or at least 8 duct diameters for larger-diameter ducts) downstream from the entrance.

7.4.2.2* Pressure Transducer.

7.4.2.2.1 The taps shall be connected to a pressure transducer that is able to resolve pressure differences of 0.25 Pa (0.001 psi H_2O).

7.4.2.2.2 The response time to a stepwise change of the duct flow rate shall not exceed 5 seconds to reach 90 percent of the final value.

7.4.2.3 Thermocouples.

7.4.2.3.1 One pair of thermocouples shall be placed 3.40 m ± 0.1 m (11 ft 2 in. ± 4 in.) (or at least 8 duct diameters for larger-diameter ducts) downstream from the entrance to the horizontal duct and 50 mm ± 5 mm (2.0 in. ± 0.2 in.) downstream from the axis of the probe.

7.4.2.3.2 The pair of thermocouples shall straddle the center of the duct and be separated from each other by 50 mm ± 5 mm (2 in. ± 0.2 in.) .

7.4.3* Sampling Line.

7.4.3.1 General.

7.4.3.1.1 The sampling line tubes shall be constructed of a material not influencing the concentration of the combustion gas species to be analyzed.

7.4.3.1.2 The following sequence of the gas train shall be used:

(1) Sampling probe
(2) Soot filter
(3) Cold trap
(4) Gas path pump
(5) Vent valve
(6) Plastic drying column and carbon dioxide removal columns (if used)
(7) Flow controller
(8) Oxygen analyzer

7.4.3.1.3 The gas train shall also include appropriate spanning and zeroing facilities.

7.4.3.2* The cold trap, or cooling column, in the gas train shall be used to remove water from the combustion gases.

7.4.3.3* For each gas analyzer used, the system delay time (or time shift) for the analyzer to reach a 90 percent response to a step change in the gas concentration shall be determined before testing.

7.4.4 Oxygen Concentration. See Annex B.

7.4.4.1 A gas sampling tube shall be located 3.5 m ± 0.1 m (11.5 ft ± 4 in.) (or at least 8 duct diameters for larger-diameter ducts) downstream from the entrance of the duct at the geometric center of the duct [to within 10 mm (0.4 in.) of the center] and 150 mm ± 5 mm (6 in. ± 0.2 in.) downstream from the axis of the probe.

7.4.4.1.1 This gas sampling tube shall be used to obtain a continuously flowing sample for determining the oxygen concentration of the exhaust gas as a function of time.

7.4.4.1.2 A suitable filter and cold trap shall be placed in the line ahead of the analyzer to remove particulates and water.

7.4.4.2 The oxygen analyzer shall be of the paramagnetic or polarographic type and shall be capable of measuring oxygen concentration in a range of 21 percent to 15 percent, with a relative accuracy of 100 ppm in this concentration range.

7.4.4.2.1 The signal from the oxygen analyzer shall be within 5 percent of its final value and occur within 30 seconds of introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

7.4.4.2.2 The oxygen analyzer shall include an absolute pressure transducer for gas pressure variations.

7.4.4.2.3 A rotameter shall be on the outlet of the oxygen analyzer.

7.4.5 Carbon Dioxide Concentration.

7.4.5.1 The gas sampling tube described in 7.4.4.1 or an alternative tube at the same location shall be used to provide a continuous sample for measuring the carbon dioxide concentration, using an analyzer with a range of 0 to 10 percent and a maximum relative error of 2 percent of full scale.

7.4.5.2 The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds to reach a value within 5 percent of the final value, after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

7.4.6 Carbon Monoxide Concentration.

7.4.6.1 The gas sampling tube described in 7.4.4.1 or an alternative tube at the same location shall be used to provide a continuous sample for measuring the carbon monoxide concentration, using an analyzer with a range of 0 to 1 percent and a maximum relative error of 2 percent of full scale.

7.4.6.2 The total system response time between the sampling inlet and the meter shall be no longer than 30 seconds to reach a value within 5 percent of the final value, after introducing a step change in composition of the gas stream flowing past the inlet to the sampling tube.

7.4.7 Smoke Obscuration.

7.4.7.1* An optical system shall be installed for determining smoke obscuration by measuring light obscuration across the centerline of the exhaust duct.

7.4.7.2 The optical density of the smoke shall be determined by measuring the light transmitted with a photometer system consisting of a laser system or a white light source with a photocell/detector.

7.4.7.3 The light beam used to measure light transmission shall be horizontal.

7.4.7.4* A white light system shall consist of a lamp, lenses, an aperture, and a photocell.

7.4.7.5 The white light system shall be constructed so that soot deposits on the optics during a test do not reduce the light transmission by more than 5 percent.

7.4.7.6* The laser system shall consist of a helium-neon laser, silicon photodiodes as main beam and reference detectors, and electronics to derive an extinction and to set a zero reading.

7.4.7.6.1 The system shall be designed for split yoke mounting in two pieces that are rigidly coupled together but resiliently attached to the exhaust duct by means of refractory gasketing.

7.4.7.6.2 A 0.5 mW to 2.0 mW helium-neon laser beam shall be projected horizontally across the exhaust duct.

7.5 Load Cell.

7.5.1 The mass loss rate of the burning individual fuel package shall be measured during the test by means of a load cell.

7.5.2 The individual fuel package shall be placed on a load cell covered by a protective barrier.

7.5.2.1 The protective barrier shall consist of reinforced inorganic board having dimensions not less than 1.2 m ± 0.1 m × 2.4 m ± 0.1 m (3.9 ft ± 0.32 ft × 7.87 ft ± 0.32 ft) and shall be located on top of the load cell.

7.5.2.2 The protective barrier perimeter shall have a rim with a height of 100 mm ± 10 mm (4 in. ± 0.4 in.).

7.5.3 The load cell shall be capable of measuring mass with an accuracy of not less than 0.1 percent.

7.5.3.1 The load cell and protective barrier shall be installed in such a way that the heat from the burning individual fuel package and any eccentricity of the load do not affect the accuracy of the load cell.

7.5.3.2 All parts of the load cell shall be located below the top level of the protective barrier.

7.5.4 The protective barrier shall support the base of the individual fuel package at a height of 127 mm ± 76 mm (5 in. ± 3 in.) above the floor.

7.5.5 The protective barrier shall be located beneath the hood at its geometric center.

Chapter 8 Calibration

8.1 Calibration and Documentation of Ignition Source and Test Equipment.

8.1.1 Instruments.

8.1.1.1 All instruments shall be calibrated with standard sources after initial installation.

8.1.1.2 The instruments to be calibrated shall be smoke meters, flow or velocity transducers, and gas analyzers.

8.1.2 A calibration test shall have been performed prior to and within 30 days of any fire test.

8.1.2.1 Such calibration tests shall be performed no more than 30 days prior to any fire test.

8.1.2.2* If modifications are made to the system since the last calibration, a recalibration test shall be performed before any fire test.

8.1.2.3 The calibration test shall use the standard ignition source intended for the test, centered under the exhaust hood.

8.1.3* The data resulting from a calibration test shall provide the following:

(1) The output as a function of time, after the burner is activated, of all instruments normally used for the standard fire test
(2) The maximum extension of the burner flame, as recorded by still photographs taken at 30-second intervals or by continuous video recording
(3) The temperature and velocity profiles across the duct cross-section at the location of the bidirectional probe
(4) The differential pressure across the bidirectional probe

8.1.4 The results in 8.1.3(1) through 8.1.3(4) shall be used to determine the calibration factor, *C*, in Section 8.2.

8.2* Calibration Procedure. The calibration procedure for heat release measurements shall be conducted in accordance with this section.

8.2.1 An approximate value, C_{est}, of the calibration factor, *C*, shall be estimated as the product of the cross-section of the duct (in m^2) multiplied by 22.1.

8.2.2* Propane shall be burned, as described in 7.1.3, for 15 minutes at an incident heat release rate of 50 kW, 100 kW, and 150 kW. Measurements shall be taken at least once every 6 seconds.

8.2.2.1 The response of the system to a stepwise change of the heat output from the burner shall be a maximum of 12 seconds to 90 percent of final value.

8.2.2.2 The following values shall be used for the combustion expansion factor, α; for energy, *E*; and for heat of combustion, Ht_{comb}: $\alpha = 1.084$, $E = 12.8$ MJ/kg, and effective $Ht_{comb} = 44.2$ MJ/kg. *(The symbols are described in Section 1.3.)*

8.2.3 The total heat released and the corrected calibration factor, C_{cor}, shall be calculated so that the total heat released, as determined by the oxygen consumption calculation, agrees with the theoretical value, obtained from measurement of the volumetric flow rate and weight loss of the fuel, to within 5 percent, by using the following equation:

$$C_{cor} = \frac{\left(Ht_{comb} \times F_{mb}\right)}{\int \dot{q}\left(MW\right)dt} C_{est}$$

8.2.4 The total heat release, as determined by the oxygen consumption calculation, shall agree with the theoretical value, obtained from measurement of the volumetric flow rate and weight loss of the fuel, to within 5 percent.

8.2.5 The corrected value of calibration factor shall be used for all tests.

8.2.6 If the calibration factor does not agree within ±5 percent with the value determined during the previous calibration, the system shall be checked for leaks or other problems before proceeding with the test.

8.2.7 The problem shall be corrected, and a new calibration shall be performed in accordance with this chapter.

8.3 Smoke Measurement Calibration. The smoke measuring system shall be calibrated initially by using two neutral density filters of significantly different values and one at 100 percent transmission.

8.3.1 Once this calibration is set, at least the zero value of extinction coefficient (100 percent transmission) shall be verified each day prior to testing.

8.3.2 If departure from the zero line is found at the end of a calibration test, the problem shall be corrected and a new calibration shall be performed in accordance with this chapter.

8.4* Gas Analyzer Calibration. Gas analyzers shall be calibrated daily, prior to testing, using the manufacturer's instructions.

Chapter 9 Test Procedure

9.1 Procedure.

9.1.1 An initial volumetric flow rate of at least 0.71 m^3/sec (1000 ft^3/min) shall be established through the duct, and the volume flow rate shall be increased as required to keep the oxygen content above 14 percent and to capture all effluents from the fire test.

9.1.2 All sampling and recording devices shall be turned on, and steady-state baseline readings shall be established for at least 2 minutes prior to burner ignition.

9.1.3 The gas burner shall be ignited.

9.1.3.1 The clock shall be started once burner ignition has been observed, and the gas flow rate shall be increased to provide a burner rate of heat release equal to the heat output as selected from one of the six power levels specified in 4.1.7.1.

9.1.3.2 The burner output shall be one of the following for 15 minutes with a heat output controlled to within ±5 percent of the prescribed value:

(1) 20 kW
(2) 40 kW
(3) 70 kW
(4) 100 kW
(5) 160 kW
(6) 300 kW

9.1.3.3 The exposure shall be continued at that same level for the duration of the test.

9.1.4 Color photographs and video recordings shall be taken as indicated in Section 7.2.

9.1.5 A spoken or written record of the fire shall be provided that gives the times of all significant events, such as, but not limited to, times of ignition.

9.1.6 The ignition burner shall be shut off 15 minutes after start of the test in order to terminate the test at that time, unless safety considerations dictate an earlier termination.

9.1.7 Data acquisition shall continue for a minimum of 2 minutes after the burner has been shut off.

9.1.8 Damage shall be documented after the test, using words, photographs, and drawings.

Chapter 10 Calculation Methods for Total Rate of Heat Release

10.1* Mass Flow Rate.

10.1.1 The mass flow rate through the exhaust duct shall be obtained from the velocity measured with a bidirectional probe at one point in the duct. The mass flow rate shall be calculated using the results found in Section 7.1 and Equation 10.1.2.

10.1.2 The mass flow rate shall be obtained through the duct from the velocity measured with a bidirectional probe at one point in the duct. The mass flow rate shall be calculated using the following equation:

$$\dot{m}_e = C\sqrt{\frac{\Delta P}{T_e}} \qquad \textbf{(10.1.2)}$$

10.1.3 The mass flow rate shall be monitored by using Equation 10.1.2. *(See symbol description in Section 1.3.)*

10.1.4* Concentration measurements of O_2, CO_2, and CO shall be used.

10.1.5 The mass flow rate shall be calculated according to Equation 10.1.2, and the oxygen depletion factor shall be calculated as follows:

$$\phi = \frac{X^0_{O_2}\left(1 - X_{CO_2} - X_{CO}\right) - X_{O_2}\left(1 - X^0_{CO_2}\right)}{X^0_{O_2}\left(1 - X_{O_2} - X_{CO_2} - X_{CO}\right)}$$

10.1.6 The rate of heat release shall be calculated as follows:

$$\dot{q} = \left[E\phi - \left(E_{CO} - E\right)\left(\frac{1-\phi}{2}\right)\left(\frac{X_{CO}}{X_{O_2}}\right)\right]\left(\frac{M_{O_2}}{M_e}\right)\left(\frac{\dot{m}_e}{1+\phi(\alpha-1)}\right)X^0_{O_2}$$

10.1.7 The total heat release shall be calculated as follows:

$$THR = \int \dot{q}\,dt$$

10.2 Smoke Measurement Equations.

10.2.1 The extinction coefficient, *k*, shall be calculated as follows:

$$k = \frac{1}{L_p}\ln\left(\frac{I_0}{I}\right)$$

10.2.2 The optical density per unit light path length shall be calculated as follows:

$$OD = \frac{1}{D}\log\left(\frac{I_0}{I}\right)$$

10.2.3 The volumetric flow rate at the smoke meter shall be calculated as the product of the mass flow rate and the temperature at the measurement point (bidirectional probe), corrected by the density of air, at the standard temperature 273.15 K, and by the temperature, in K, as in the following equation:

$$\dot{V}_s = \dot{m}_e\left(\frac{T_e}{\rho_0 273.15}\right) = \frac{\dot{m}_e T_e}{353}$$

10.2.4 Rate of smoke release shall be defined as follows:

$$RSR = \left(\dot{V}_s k\right)$$

10.2.5 The total smoke released shall be defined as follows:

$$TSR = \int RSR\ dt$$

10.3 Release Rate of Combustion Gases.

10.3.1 The release rate of carbon monoxide shall be calculated as follows:

$$\dot{m}_{CO} = \frac{X_{CO}\left(1 - X^0_{O_2} - X^0_{CO_2}\right)}{\left(1 - X_{O_2} - X_{CO_2} - X_{CO}\right)}\frac{M_{CO}}{M_a}\frac{\dot{m}_e}{1+\phi(\alpha-1)}$$

10.3.2 For other combustion gases, the release rate shall be a function of the summation of the concentrations of that gas at each scan in the exhaust (i.e., the products of the mole fraction of the combustion gas, the overall mass flow rate for that scan, and the scan period), its molecular weight, and the total test period, as follows:

$$\dot{m}_x = \frac{\Sigma\left(X_{xi}\dot{m}_{ei}\Delta t_i\right)\left(\frac{M_x}{M_a}\right)}{\text{test period}}$$

Chapter 11 Report

11.1 Report.

11.1.1 Description of Individual Fuel Packages. The report shall include the following:

(1) Overall description of individual fuel package, along with identifying characteristics or labels
(2) Name, thickness, density, and size of the materials used to make up the final package, along with other identifying characteristics or labels
(3) Mounting and conditioning of materials, including detailed description of mounting procedure and justification for any variations from end-use installation
(4) Layout of individual fuel package and attachments, including appropriate drawings, in fire test area
(5) Relative humidity and temperature of the fire test area and the test building prior to and during the test
(6) Time between removal from the conditioning room and start of testing

11.1.2 Ignition Source. The report shall describe the ignition source used, its location with respect to the individual fuel package, its heat release rate, and the duration of the exposure.

11.1.3 Time History of the Rate of Heat Release of the Fire.

11.1.3.1 The rate of heat release shall be calculated from the measured oxygen, carbon monoxide, and carbon dioxide concentrations and the temperature and volumetric flow rate of the gas in the duct.

11.1.3.2 The time history of the rate of heat release as well as the maximum and average values shall be reported.

11.1.3.3 Similarly, the time history of total heat released as well as the final value and the values every 5 minutes shall be reported.

11.1.3.4 The measurement method used shall also be reported.

11.1.4 Time History of the Fire Growth.

11.1.4.1 The time history of the fire growth shall be a transcription of the visual, photographic, audio, and written records of the fire test.

11.1.4.2 The records shall indicate the time of ignition of the individual fuel package and the approximate location of the flame front most distant from the ignition source at intervals not exceeding 15 seconds during the fire test.

11.1.4.3 Still photographs and continuous video recording as required by Section 7.2 shall be supplied.

11.1.4.4 Drawings and photographs or video recording showing the extent of the damage of the individual fuel package after the test also shall be supplied.

11.1.5 Time History of Smoke Obscuration.

11.1.5.1 The smoke obscuration shall be described by means of the optical density, rate of smoke release, and total smoke released measured with the instrumentation in the exhaust duct.

11.1.5.2 The following shall be reported:

(1) Time histories of smoke release rate, optical density, and volumetric duct flow rate as well as the maximum and average values
(2) The total smoke release time history as well as the final value and the values every 5 minutes
(3) Details of the smoke obscuration measurement equipment used, including the orientation of the light beam

11.1.6 Time History of Mass Lost by the Individual Fuel Package. The time history of the mass loss rate as well as the maximum and average values and the total mass lost (in kg and percentage) shall be reported.

11.2 Discussion of Performance. A description of individual fuel package performances shall be provided and shall include the following:

(1) Flame spread on or within the individual fuel package during exposure
(2) Presence of falling debris or burning droplets on the protective barrier that persist in burning for 30 seconds or more
(3) Visibility information in the fire test area
(4) Other pertinent details with respect to fire growth
(5) Falling debris, melting or dripping of materials

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.1.1.4(1) This includes natural and artificial combustible vegetation.

A.1.1.5 The heat release of these products can be tested using existing standard tests:

(1) Seating furniture can be tested using ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture,* or California Technical Bulletin TB 133.
(2) Mattresses can be tested using ASTM E 1590, *Standard Test Method for Fire Testing of Mattresses.*
(3) Stacked chairs can be tested using ASTM E 1822, *Standard Test Method for Fire Testing of Stacked Chairs.*
(4) Interior finish can be tested using NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth.*
(5) Textile wall coverings can be tested using NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls.*
(6) Mattress sets (bed sets) can be tested using 16 CFR 1633.

A.1.2.3 If an individual fuel package is exposed to a different environment, as in an actual fire, it is possible that the performance of the individual fuel package will be different.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.4.1.1 UL 1975, *Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes*, includes procedures for sample preparation of the following types of products, when they contain foamed plastics used for decorative purposes:

(1) Individual manufactured decorative objects such as, but not limited to, mannequins, murals, and signs
(2) Open-ceiling portable exhibit booth constructions incorporating manufactured panels containing foam plastics
(3) Theater, motion picture, and television stage settings with or without horizontal projections

In UL 1975, such products are tested to assess their ability to resist rapid heat release when subjected to a flaming ignition source: a 340 g wood crib. Codes often include requirements for peak heat release rates of such products based on the use of UL 1975.

A.4.1.2 Decorative objects can include irregular-shaped objects such as combustible vegetation (natural or artificial).

A.4.1.7.1 The six basic ignition sources chosen correspond to the following concepts:

(1) A 20 kW ignition source is similar to the peak heat release rate of the wood crib ignition source used in UL 1975, *Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes*.
(2) A 40 kW ignition source can be used as a more severe approach to testing the same products otherwise tested using the 20 kW ignition source if additional fire safety is required. Moreover, a 40 kW ignition source also corresponds to the heat output from a small wastebasket fire. Finally, a 40 kW ignition source is also the minimum ignition source used for testing of interior finish materials with NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*.
(3) A 70 kW ignition source offers an intermediate range between the 40 kW and 100 kW ignition sources.
(4) A 100 kW source is the lower ignition source used for testing of interior finish materials with either ASTM E 2257, *Standard Test Method for Room Fire Test of Wall and Ceiling Materials or Assemblies*, or ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products*. It is used to initially differentiate interior finish materials on their likelihood of leading to flashover.
(5) A 160 kW ignition source is the higher ignition source used for testing of interior finish materials with NFPA 286. It is used to assess whether such interior finish materials are likely to lead to flashover.
(6) A 300 kW ignition source is the higher ignition source used for testing of interior finish materials with either ASTM E 2257 or ISO 9705. It is used to differentiate interior finish materials with very low levels of heat release and very low likelihood of leading to flashover.

A series of ad hoc tests was also conducted with the gas burner located at 1.2 m from the floor and 1.2 m below the bottom of the hood (with the top of the hood at 3.0 m from the floor), which showed the approximate flow rates and flame heights associated with each ignition source. The results are shown in Table A.4.1.7.1.

A.4.1.7.2 Each individual fuel package should be tested using at least one of the ignition sources specified in 4.1.7.

Table A.4.1.7.1 Approximate Flow Rates and Flame Heights for Various Heat Release Rates (HRR)

HRR (kW)	Flow Rate (L/sec)	Flame Height (mm)
20	16.5	380
40	30.7	610
60	47.2	815
70	54.8	920
100	77.9	1120
160	122.7	1525
300	226.5	2085

Theater, motion picture, and television stage settings; portable exhibit booths; and other single decorative objects constructed of foamed plastics should be tested with an ignition source of 20 kW.

A.5.2.1 This should create a 4.5 m^2 (48 ft^2) floor area.

A.6.1 For products in which vaporization of solvents occurs, such as those using adhesives or products containing wood, a conditioning time of 4 weeks is common.

A.6.2.4 It has been shown that if the floor is covered with sand, this rapidly extinguishes burning sections of material. If the material is extinguished, the measured heat release is lower than it would have been if the material had continued burning, thus altering the expected results.

A.7.2 NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*; ASTM E 2067, *Standard Practice for Full-Scale Oxygen Consumption Calorimetry Tests;* and ASTM E 603, *Guide for Room Fire Experiments*, contain the rationale for the instrumentation used and its location.

A.7.2.2 Any floodlights used for photography should not raise the ambient temperature in the area surrounding the fire test area above what is specified, namely 30°C (86°F).

A.7.3.2 Experience suggests that a draft capable of moving up to 2.5 m^3/sec (5150 standard ft^3/min), which is equivalent to 5.7 m^3/sec (11,800 ft^3/min) at 400°C (752°F), during the test is sufficient for fires up to flashover.

A.7.4.2 A bidirectional probe is preferable to a pitot-static tube for measuring velocity in the exhaust duct in order to avoid problems of clogging with soot.

A.7.4.2.2 Capacitance transducers have been found to be most stable for this application.

A.7.4.3 Stainless steel sampling lines have been shown to be satisfactory.

A.7.4.3.2 The recommended approach to designing a cooling (and drying) column (to remove water from the combustion gases) is to use a refrigerated column and separation chamber fitted with a drain plug from which the collected water is removed from time to time. Alternative approaches or devices that are shown to give equivalent results are also acceptable. It is very important to remove water from the combustion stream before it reaches the oxygen, carbon monoxide, and carbon dioxide analyzers.

A.7.4.3.3 Combustion gas concentration measurements require the use of appropriate time shifts in order to account for the time required for gas analyzer response and for combustion gas transit time within the sampling system.

A.7.4.7.1 White light and laser systems have been shown to give similar results. See the following publications for more information:

(1) "Comparison of Smoke Release from Building Products," by B. Ostman
(2) "Rate of Heat Release Testing for Vinyl Wire and Cable Materials with Reduced Flammability and Smoke: Small Scale and Full Scale Tests," by A. W. Coaker, M. M. Hirschler, and C. L. Shoemaker

Some research has shown differences between white light and laser measurements in one application. See "Optical Measurement of Smoke," by W. K. Chow and K. F. Lai.

A.7.4.7.4 The following information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by the NFPA or any of its technical committees. The following describes an example of a white light measuring system that has been found to be satisfactory:

(1) Lenses. Plano convex: diameter 40 mm, focal length 50 mm
(2) Lamp. Osram Halo Stars: 64410C6 V, 10 W or equivalent
(3) Photocell. United Detector Technology: PIN 10 AP or equivalent
(4) Power supply. Gresham Lion Ltd: Model G x012 or equivalent

A.7.4.7.6 The following information is being provided for informational purposes only and has not been independently verified, certified, or endorsed by the NFPA or any of its technical committees. The following describes an example of a laser measuring system that has been found to be satisfactory:

(1) Helium-neon laser. Aerotech OEM-05P or equivalent
(2) Laser power supply. Aerotech LSS-05 or equivalent
(3) Photocells. Hammamatsu S1336-44BK or equivalent

A.8.1.2.2 A recalibration test need not necessarily be performed following minor modifications that are unlikely to affect test results.

A.8.1.3 Measurement of the temperature and velocity profiles across the duct cross-section at the location of the bidirectional probe and of the differential pressure across the bidirectional probe is not needed when the calibration factor, *C*, is used as described in Section 8.2.

A.8.2 The estimated calibration factor is likely to be within 20 percent of the correct value.

A.8.2.2 Effective heat of combustion from propane is 44.2 MJ/kg, which is calculated at a combustion efficiency of 95 percent for propane, which is 46.5 MJ/kg.

A.8.4 ASTM E 800, *Standard Guide for Measurement of Gases Present or Generated During Fires*, gives guidance on the calibration of gas analyzers.

A.10.1 Further information can also be found in "Measuring Rate of Heat Release by Oxygen Consumption," by M. L. Janssens and in "Oxygen Consumption Calorimetry," by M. L. Janssens and W. J. Parker.

The mass flow rate is usually placed along the centerline of the duct. The velocity profile is obtained by measuring velocity at a sufficient number of representative points over the diameter or cross-section of the duct prior to any fire tests. Detailed procedures for obtaining this profile are described in *The Measurement of Air Flow*, by E. Ower and R. Pankhurst. Usually, conditions in full-scale fire tests are such that the flow in the duct is turbulent, resulting in a shape factor *kc* (ratio of the average velocity to the velocity along the centerline) that is close to 1.

Due to considerable soot production in many fires, pitot-static tubes are generally not useful because of the potential for the holes to become clogged. In response to this problem, B. J. McCaffrey and G. Heskestad ("A Robust Bidirectional Low-Velocity Probe for Flame and Fire Application") designed the bidirectional probe described in 7.4.2. This system involves measuring the differential pressure across the probe and the centerline velocity.

A.10.1.4 Water vapor has to be removed before the sample air is introduced into the oxygen analyzer. A water trap and desiccant can be used to remove water.

Annex B Method of Determining Suitability of Oxygen Analyzers for Making Heat Release Measurements

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 General. The paramagnetic type of oxygen analyzer is best suited for fire gas analysis. Electrochemical analyzers or analyzers using zirconia sensors have generally been found not to have adequate sensitivity or suitability for this type of work. The normal range of the instrument to be used is 0 to 25 percent volume oxygen. The linearity of paramagnetic analyzers is usually better than can be checked by a user laboratory, thus verifying that their linearity is not necessary. It is important, however, to confirm the noise and short-term drift of the instrument used.

B.2 Procedure. The analyzer suitability is checked by the following steps:

(1) Connect two different gas bottles that are approximately 2 percentage points apart (for example, 15 percent volume and 17 percent volume) to a selector valve at the inlet of the analyzer.
(2) Connect the electrical power and let the analyzer warm up for 24 hours, with one of the test gases from the bottles described in B.2(1) flowing through it.
(3) Connect a data acquisition system to the output of the analyzer. Quickly switch from the first gas bottle to the second bottle and immediately start collecting data, taking one data point per second. Collect data for 20 minutes.
(4) Determine the drift by using a least-squares analysis fitting procedure to pass a straight line through the last 19 minutes of data. Extrapolate the line back through the first minute of data. The difference between the readings at 0 minutes and at 20 minutes on the fitted straight line represents the short-term drift. Record the drift in units of parts per million of oxygen.
(5) The noise is represented by the root-mean-square deviation around the fitted straight line. Calculate that root-mean-square value and record it in units of parts per million of oxygen.

The analyzer is suitable for use in heat release measurements if the sum of the drift plus the noise terms is 250 ppm oxygen. (Note that both terms have to be expressed as positive numbers.)

B.3 Additional Precautions. A paramagnetic oxygen analyzer is directly sensitive to barometric pressure changes at its outlet port and to flow rate fluctuations in the sample supply stream. It is essential that the flow rate be regulated. Use either a flow rate regulator of the mechanical diaphragm type or an electronic mass flow rate controller. To protect against errors due to changes in barometric pressure, one of the following procedures should be used:

(1) Control the back pressure to the analyzer with a back pressure regulator of the absolute pressure type
(2) Electrically measure the actual pressure at the detector element and provide a signal correction for the analyzer output

See NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter.*

Annex C Informational References

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

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

NFPA 265, *Standard Methods of Fire Tests for Evaluating Room Fire Growth Contribution of Textile Coverings on Full Height Panels and Walls*, 2007 edition.

NFPA 271, *Standard Method of Test for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter*, 2004 edition.

NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*, 2006 edition.

C.1.2 Other Publications.

C.1.2.1 ASTM Publications. ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959.

ASTM E 603, *Guide for Room Fire Experiments* (Annual Book of ASTM Standards, Vol. 4.07), 1998a.

ASTM E 800, *Standard Guide for Measurement of Gases Present or Generated During Fires* (Annual Book of ASTM Standards, Vol. 4.07), 1999.

ASTM E 1537, *Standard Test Method for Fire Testing of Real Scale Upholstered Furniture,* 2002.

ASTM E 1590, *Standard Test Method for Fire Testing of Mattresses,* 2002.

ASTM E 1822, *Standard Test Method for Fire Testing of Stacked Chairs*, 2002a.

ASTM E 2067, *Standard Practice for Full-Scale Oxygen Consumption Calorimetry Tests* (Annual Book of ASTM Standards, Vol. 4.07), 2000.

ASTM E 2257, *Standard Test Method for Room Fire Test of Wall and Ceiling Materials or Assemblies,* 2003.

C.1.2.2 ISO Publications. International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland.

ISO 9705, *Fire Tests — Full Scale Room Fire Tests for Surface Products,* 1993.

C.1.2.3 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 1975, *Standard for Fire Tests for Foamed Plastics Used for Decorative Purposes,* 1996.

C.1.2.4 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 16, Code of Federal Regulations, Part 1633.

C.1.2.5 Other References.

California Technical Bulletin TB 133.

Chow, W. K., and K. F. Lai, "Optical Measurement of Smoke," *Fire and Materials*, vol. 16, 135–139, 1992.

Coaker, A. W., M. M. Hirschler, and C. L. Shoemaker, "Rate of Heat Release Testing for Vinyl Wire and Cable Materials with Reduced Flammability and Smoke: Small Scale and Full Scale Tests," in Proc. 15th. Int. Conference. on Fire Safety, Product Safety Corporation, San Francisco, Ed. C. J. Hilado, January 8–12, pp. 220–256, 1990.

Janssens, M. L., "Measuring Rate of Heat Release by Oxygen Consumption," *Fire Technology*, pp. 234–249, August 1991.

Janssens, M. L., and W. J. Parker, "Oxygen Consumption Calorimetry," in *Heat Release in Fires*, Ed. V. Babrauskas and S. J. Grayson, Elsevier, London, Chapter 3, pp. 31–59, 1992.

McCaffrey, B. J., and G. Heskestad, "A Robust Bidirectional Low-Velocity Probe for Flame and Fire Application," *Combustion and Flame*, vol. 26, no. 1, pp. 125–127, February 1976.

Ostman, B., "Comparison of Smoke Release from Building Products," Int. Conf. FIRE. Control the Heat...Reduce the Hazard, London, Oct. 24–25, 1988, Fire Research Station, UK, paper 8.

Ower, E., and R. Pankhurst, *The Measurement of Air Flow*, Pergamon Press, 5th Edition, pp. 112–147, 1977.

C.2 Informational References. (Reserved)

C.3 References for Extracts in Informational Sections. (Reserved)

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