FIRE TESTS

Table of Contents

List of Figures

List of Tables

1.0 SCOPE

This data sheet is intended to describe certain small-scale, intermediate-scale, and large-scale tests, and explain the differences in their conclusions when performed on the same materials. This data sheet focuses on fire tests performed on various construction materials, and does not address fire tests on storage arrangements protected by fire protection systems. This data sheet does not cover design, installation, or protection for construction materials.

The tests are discussed primarily as indicators of the fire hazard of various construction materials, including those with an ASTM E-84 flame spread index of 25 or less, and those containing fire-retardant additives.

The tests discussed are reaction-to-fire tests evaluating the ignitibility and fire spread potential of building materials. Tests to evaluate fire resistance of building materials are covered in Data Sheet 1-21, *Fire Resistance*. Building materials tested to ASTM E-119 still require reaction-to-fire testing for FM Approval or fire spread evaluation.

1.1 Changes

April 2019. The scope of this document was clarified, and new information was added on NFPA 285 and BS 8414 exterior wall system fire tests.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Construction and Location

2.1.1 Do not use small-scale test results on plastic construction materials as the sole determination of noncombustibility or limited combustibility (Class 1).

2.1.2 For intermediate-scale and large-scale testing, verify that proper materials/assemblies have been tested, conclusions reached, and field-installed materials/assembly are as tested. If doubts remain, obtain and review the full laboratory testing report.

2.1.3 Do not use third-party consultant assessments (desktop assessments) in lieu of large-scale fire testing for exterior wall systems as a means of determining the true fire behavior of an assembly.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Good fire protection decisions result from a combination of fire experience and fire testing. As new product formulations are created for which there is little fire experience, fire testing becomes of great importance. Obviously, it is not feasible to conduct full-scale tests on every new product. But reliance should be placed only on small-scale tests that have a satisfactory history of confirming large-scale tests. And these tests should be used only as a basis for comparison among similar products. Tests that have a lower heat flux exposure than realistic post-flashover and exterior fires are not appropriate to use.

The material is tested under laboratory bench-type procedures to determine if it is combustible, and if automatic sprinklers are needed to protect large quantities from fire. While sustained ignition of the material is an obvious indication of combustibility, failure to achieve ignition is not proof of noncombustibility. One or more large-scale tests may be necessary.

In the bench-type laboratory tests, several aspects of the fire behavior of materials are examined. These include ignition, chemical heat release rate, flame spread, rate of burning, generation of smoke and toxic products, and extinguishment by reducing oxygen. Based on one or more of these aspects, adverse behavior of the material under actual fire conditions can be predicted. Judgment is sometimes made as to the need for automatic sprinkler protection. Large-scale tests might be necessary to determine the required sprinkler density and similar details.

If the flame ceases to spread along the surface of the material being tested, a decision on its combustibility is more difficult to make. Many materials incapable of achieving self-supporting fire in bench test configurations prove to be highly combustible when subjected to larger-scale testing. When doubt exists, a more severe small-scale test can be performed. In the event the material passes the second small-scale test, a large-scale fire test may still be in order. However, more expensive large-scale tests can be eliminated if the material burns under the small-scale tests.

Bench-type tests are useful in determining which materials are highly combustible, but they are generally not a proper method for proving low combustibility.

The fire spread rate is another criterion sometimes used to judge the fire hazard of a material. This is the distance the flame spreads on the sample, divided by the time it takes to travel that distance. When the material burns rapidly, there is no question about its fire hazard. If it burns very slowly or self-extinguishes, an erroneous assumption concerning the hazard of the material under actual fire conditions can be made. This same material may burn vigorously and have rapid flame spread under actual fire conditions or when exposed to a larger ignition source during testing.

3.1.1 Fire Retardants

Fire-retardant chemicals are commonly added to polymeric solids in an attempt to reduce flammability. One approach is the addition of a heat-absorbing inorganic filler, such as calcium carbonate. Another approach is to add a chemical, often a phosphorus compound, that promotes char creation and reduces volatile formation during pyrolysis of the polymeric solid. A third approach is to add a chemical that vaporizes and inhibits the gas-phase combustion; this is often a halogenated compound. Sometimes, several of these functions are combined in fire-retardant treatments.

Fire-retardants often perform well in small-scale tests. However, when the retardant material is exposed to a more intense heat source (one radiating over a larger area, or one that persists for a longer time), intense burning may result.

Fire-retardants may raise the ignition threshold, but they cannot ensure noncombustibility. Also, fire-retardant chemicals initially present in a material may sometimes be lost over a period of time because of leaching or volatilization. For further information on the fire retardancy of wood, see Data Sheet 1-61, *Fire-Retardant-Treated Wood*.

3.2 Test Data

3.2.1 Tunnel Test/ASTM E84

A widely used method for evaluating the combustibility of building materials is the Tunnel Test prescribed in ASTM Specification E-84. FM is equipped to run this test. A sample of the material 22 in. (0.56 m) wide by 25 ft (7.62 m) long is placed on the underside of a removable cover that forms the top of the 25 ft (7.62 m) long test tunnel. One end of the sample is exposed to a gas flame under regulated fuel and draft conditions. Flame spread, fuel contribution, and smoke are measured. These factors determine the product rating numerically on a scale where cement-asbestos board is 0 and red oak is 100. Flame spread is observed through windows in the side of the tunnel. Table 1 lists test results of several types of materials tested under this method.

The testing laboratory makes no judgment of the product's suitability. Recommendations on flame spread index for a particular application are primarily established in building codes.

This test produces useful results when working with interior finishes. The usefulness of the test is questionable when the material is plastic or when the interior trim is installed using material different from the test assembly.

Table 1. Typical Test Results on Combustibility of Selected Materials

Product	*Flame Spread*	*Fuel Contributed*	*Smoke Developed*
Cement asbestos board	0	0	0
Gypsum board	15	15	0
Protected metal	35-40	10	80
Acoustical tile:			
Mineral	10-15	10-15	0-10
Wood fiber	160	125	105
Treated wood fiber	20	20	0
Painted glass fiber	10-15	15	0-10
Fir plywood:			
Untreated	138	85	60
Treated with fire retardants	15	0	0
Fiberboard	300	125	55
Plastic panels:			
PVC	25	—	Over 500
Polyester, glass fiber-reinforced fire retardant	25-75	—	Over 500
Red Oak	100	100	100

The material tested is considered acceptable if the product does not produce a self-propagating fire within the limits of the structure (as evidenced by flaming or material damage).

3.2.2 FM Duct Test

The FM Duct Test is designed to test a representative section of duct for which FM Approval is desired. The fire test is intended to simulate actual building fire conditions. A fire exposure is placed directly below the inlet of a duct. During the test, the fire is drawn into the duct where it has the opportunity to ignite the duct and propagate along its entire length.

This test uses a 24 ft (7.32 m) length of the specimen duct placed in a horizontal position (Fig. 1). As part of FM Approval testing the ducts are tested with a maximum diameter of up to 12 in. (305 mm) and then Approval can be granted on up to 60 in. diameter (1.5 m) per FM 4922. The duct is supported 32 in. (813 mm) above the floor. The duct intake end is inserted into a draft shield, flush with the inside surface of the enclosure wall.

The exhaust end is connected through a steel transition piece to a blower which pulls air through the duct at specified air velocities.

The fire exposure consists of a 4 in. (102 mm) depth of heptane in a 12 in. (305 mm) square pan. Heat output from the heptane is approximately 10,000 Btu/min (176 kW).

For ducts handling environmental air, an induced draft velocity of 600 linear ft/min (3.05 m/s) is used. Chemical or corrosive fume exhaust ducts are tested at 600 ft/min (3.05 m/s) and in some cases, 2000 ft/min (10.2 m/s).

The performance is considered satisfactory if, during all tests, flaming does not spread from the fire end to the 24 ft (7.32 m) point during the 15-minute test, and providing interior duct temperatures recorded at the far end do not exceed 1000°F (538°C).

A large number of plastic ducts have been tested and failed the Duct Test. For the most part, the materials from which the ducts were made had low ASTM E-84 flame spread ratings of 25 or less.

Figure 2 shows a test of a plastic duct that failed this test, despite a flame spread rating of 25 per the ASTM E-84 test.

FM also conducts a horizontal/vertical fire test, where a 24 ft (7.3 m) long horizontal segment is connected to a 15 ft (4.6 m) vertical segment by an elbow. See Figure 4. The two ducts shall be 12 in (305 mm) in diameter. The ignition source is the same as the horizontal duct test. A custom vertical duct fire test can also be conducted per FM 4922 to assess vertical runs greater than 15 ft (4.6 m).

In a test similar to the FM Duct Test, a 3 ft (0.914 m) dia. by 30 ft (9.14 m) tall vertical glass-fiber-reinforced stack was used. The exposure fire was a 10 ft^2 (0.929 m^2) pan of heptane located under the stack bottom.

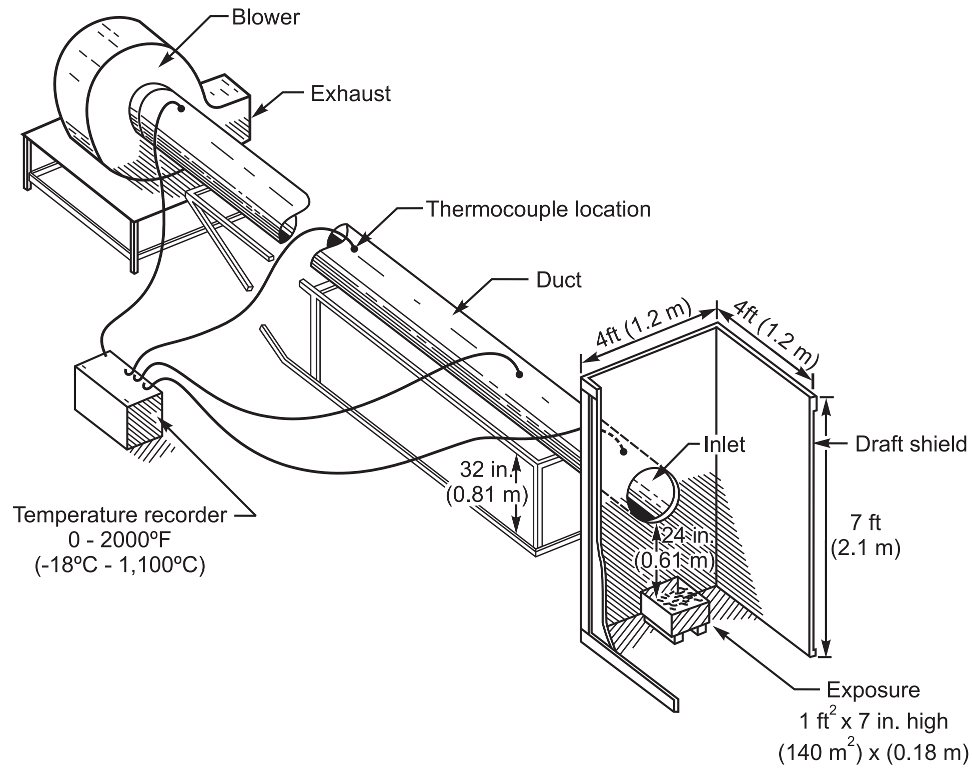

Fig. 1. FM apparatus for the evaluation of air handling duct work

Fig. 2. FM duct test (This fibrous glass specimen has a 25 flame spread.)

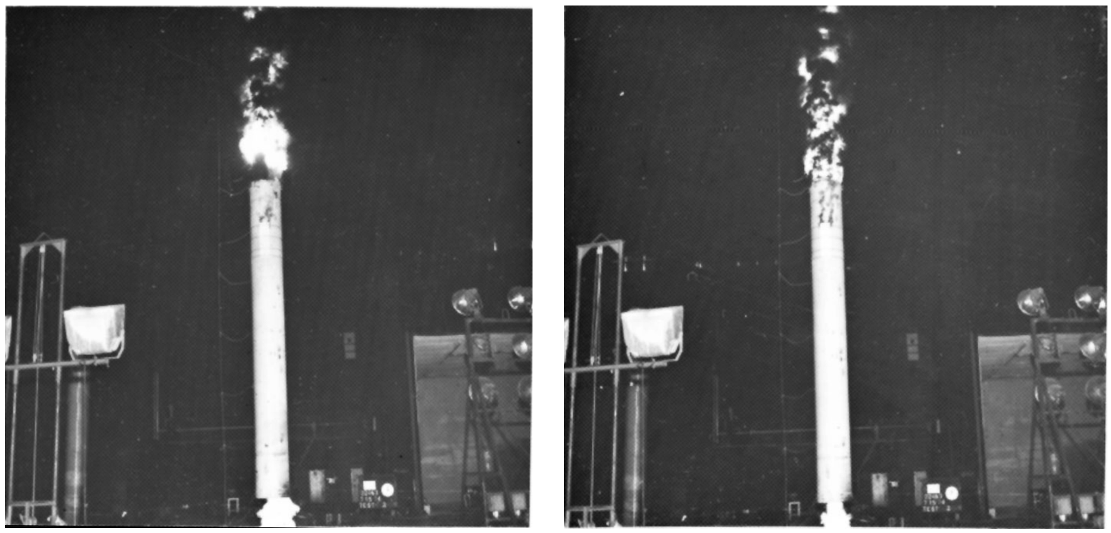

Fig. 3. Vertical duct test (Passed Parallel Panel Test and had 25 flame spread.)

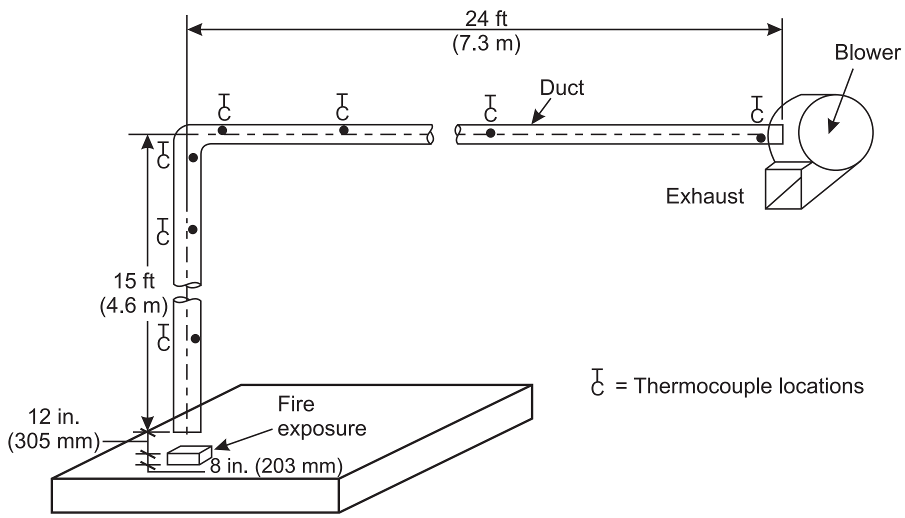

Fig. 4. FM vertical/horizontal duct test

The flame travelled vertically through the stack and came out at the top. This test differs from the Duct Test previously described, as the stack was in a vertical position and no fan was present. See Figure 3.

Neither the American Society for Testing Materials (ASTM) nor Underwriters' Laboratories, Inc. (UL) presently have fire tests that bear any similarity to the FM Duct Test.

3.2.3 FM Fire Propagation Apparatus (FPA) Test

The FM fire propagation apparatus (FPA) is a test apparatus and associated test protocol developed by FM and manufactured commercially by Fire Testing Technology LTD. It is used to test a wide range of materials and components. Through the years of use and data correlation, it has been shown to accurately simulate the characteristics of large-scale fires at a small-scale level. The American Society for Testing and Materials (ASTM) has recognized the FPA as ASTM E2058, Measurement of Synthetic Polymer Flammability. Additionally, the National Fire Protection Association (NFPA) has incorporated the FPA in NFPA 287, Measurement of Flammability of Materials in Cleanrooms and is also referenced in ISO as ISO 12136. The FPA is used as a small-scale fire testing approach to evaluate the flammability of cleanroom materials, plastic ductwork, plastic wall and ceiling panels, conveyor belts, and cables. (See Figure 5.) The FPA has been designed from the start to measure key characteristics of large-scale fire behavior, including the following:

- Response of materials to an external radiant heat source isolated from the test specimen
- Chemical heat release rate, mass loss rate, and smoke generation rate
- Combustion air for both well-ventilated and ventilation-controlled enclosure fires

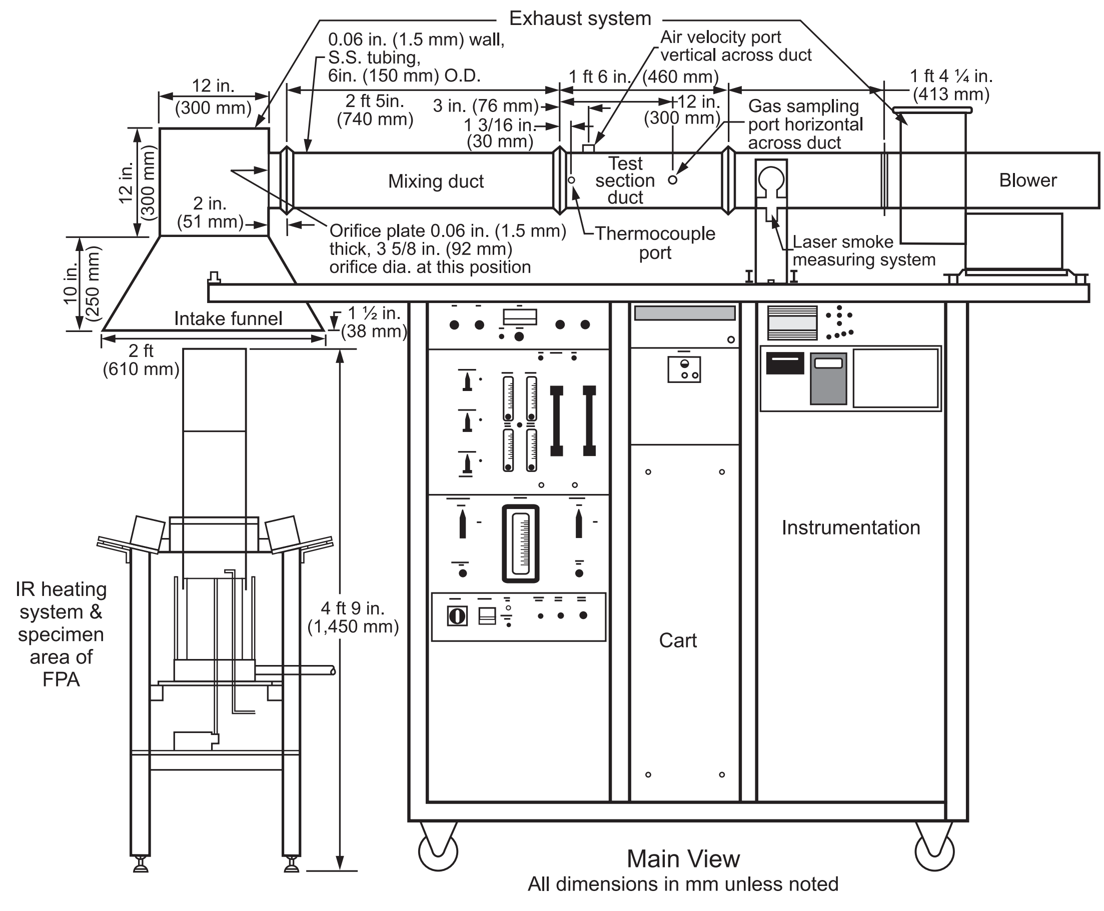

Fig. 5. Fire propagation apparatus

Many fire-testing laboratories around the world utilize various types of fire products collectors associated with their testing. Whereas the fire products collector captures fire yields for the fuel package undergoing large-scale fire testing, the FPA applies these capabilities to a small-scale test that exposes the sample to simulated large fire conditions. This additional capability creates a more reliable way to test materials and products for large-scale fire performance. It also eliminates the need for many of the more costly and traditional large-scale tests for many products (although a few intermediate-scale or large-scale fire tests may still be needed to confirm small-scale results).

FPA is used to derive the material flammability properties described below. The measured flammability properties of a material can be compared against that for a variety of materials listed in the Chapter 4 of the SFPE Handbook.

- FPI (Fire Propagation Index): Parameter to measure vertical fire spread propensity. Higher value represents high propensity.

- SDI (Smoke Development Index): Parameter to measure smoke generated during vertical fire spread. Higher value represents high propensity.
- TRP (Thermal Response Parameter): Parameter to characterize resistance to ignition. High value for materials difficult to ignite.
- CHF (Critical Heat Flux): Minimum heat flux required to sustained ignition. Lower value material ignites easily.
- FSP (Flame spread parameter): Can be used to measure flame spread propensity of certain insulation materials. Higher value represents higher propensity.
- Chemical/Effective heat of combustion: Heat of combustion of material measured under fire conditions.

Fig. 6. FPA testing apparatus

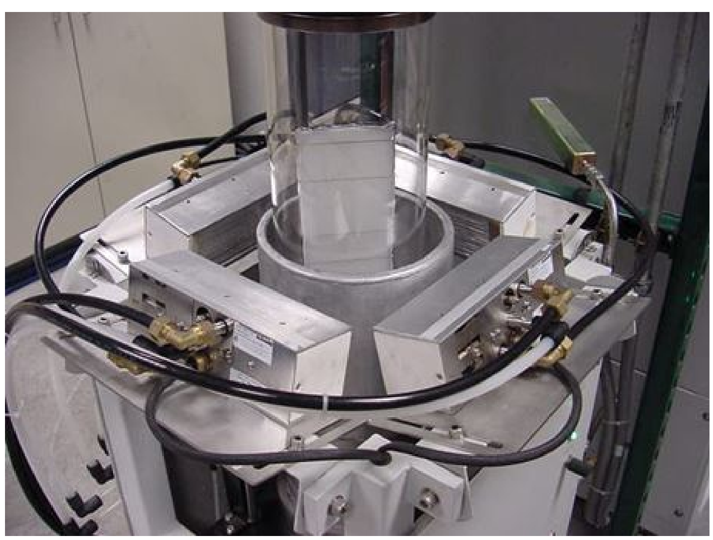

Fig. 7. FPA testing apparatus

3.2.4 FM Roof Calorimeter Furnace Test

The FM roof calorimeter furnace test is utilized to test an intermediate-size roof sample and make a determination on how it will behave in a fire in a large-scale field condition. The calorimeter test is further used to classify a roof as Class 1 or Class 2 based on the testing results from this 30-minute fire test. Details on the preparation and shipping of a roof test sample are outlined in FM Data Sheet 1-5, *Removal and Shipping of Roof Deck Samples for Calorimeter Testing*. It is critical that the roof sample measure a minimum of 4 1/2 ft x 5 ft (1.4 m x 1.5 m). See Figure 8 for layout of the testing furnace. The National Fire Protection Association (NFPA) has incorporated this roof calorimeter furnace test in NFPA 276, *Standard Method of Fire Tests for Determining the Heat Release of Roofing Assemblies with Combustible Above-Deck Roofing Components*. Heptane fuel is supplied to the main burners for the furnace testing.

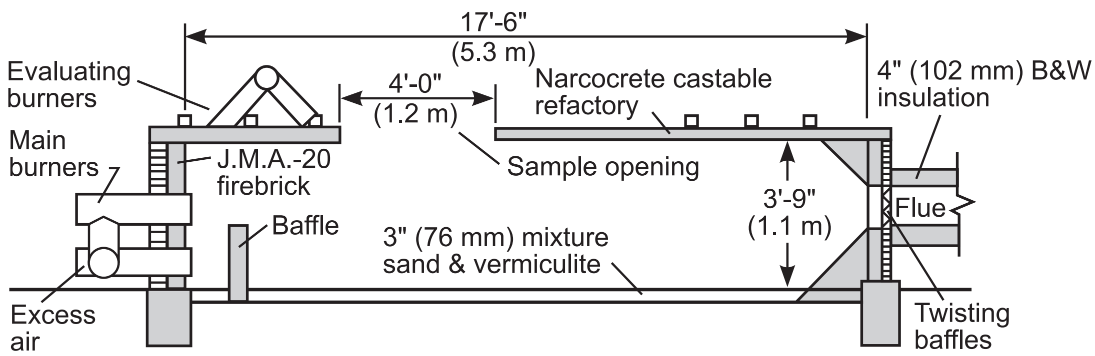

Fig. 8. Roof calorimeter furnace

3.2.5 Single Burning Item Test

The Single Burning Item (SBI) test is a fire test developed within Europe for reaction-to-fire product classification. See Figure 9 for a layout of the SBI test apparatus. From an FM perspective, the products of interest being tested and classified per SBI include wall and ceiling panels, and skylights. In Europe, SBI testing is a cornerstone of the Construction Products Directive (CPD), which is a product certification requirement for sale of products within European markets. This SBI test is referred to as EN 13823 and is part of the EN 13501 (European building material classification) test series. (See Appendix D.)

The test method involves a small corner-test structure within an enclosure using two walls to form the corner, and no ceiling. The size of the long and short wings comprising the structure are 40 in. by 60 in. (1000 mm by 1500 mm) and 20 in. by 60 in. (495 mm by 1500 mm), compared to the 8 ft (2.4 m) room test, which uses two 8 ft by 8 ft (2.4 m by 2.4 m) walls to form the corner, and has a ceiling (see Figure 9). The ignition source for the SBI test is a 30 kW propane gas burner, and the test duration is 20 minutes.

FM has a single burning item test apparatus and the capability of conducting this testing.

The European fire classification scheme that has been developed for construction products is documented in EN 13501-1:2007. This scheme, going from least-combustible to most-combustible/no performance determined, is A1, A2, B, C, D, E, and F. Noncombustible and limited-combustible products, such as metal-faced, mineral wool core panels are included in A1 and A2. Some categories require small-flame ignitability testing (EN ISO 11925-2), as well as the reaction-to-fire SBI testing. Key parameters measured during the SBI test include FIGRA (heat release), SMOGRA (smoke rate), THR (total heat release), and LFS (lateral flame spread).

3.2.5.1 EN 13501-1: European Building Material Classification Test Series

Classification of fire performance of building materials in many countries, particularly in Europe, is conducted per the series of tests described in EN 13501-1. Table 2 below provides the test method requirement for each classification. Performance criteria for each classification is provided in EN 13501-1 standard.

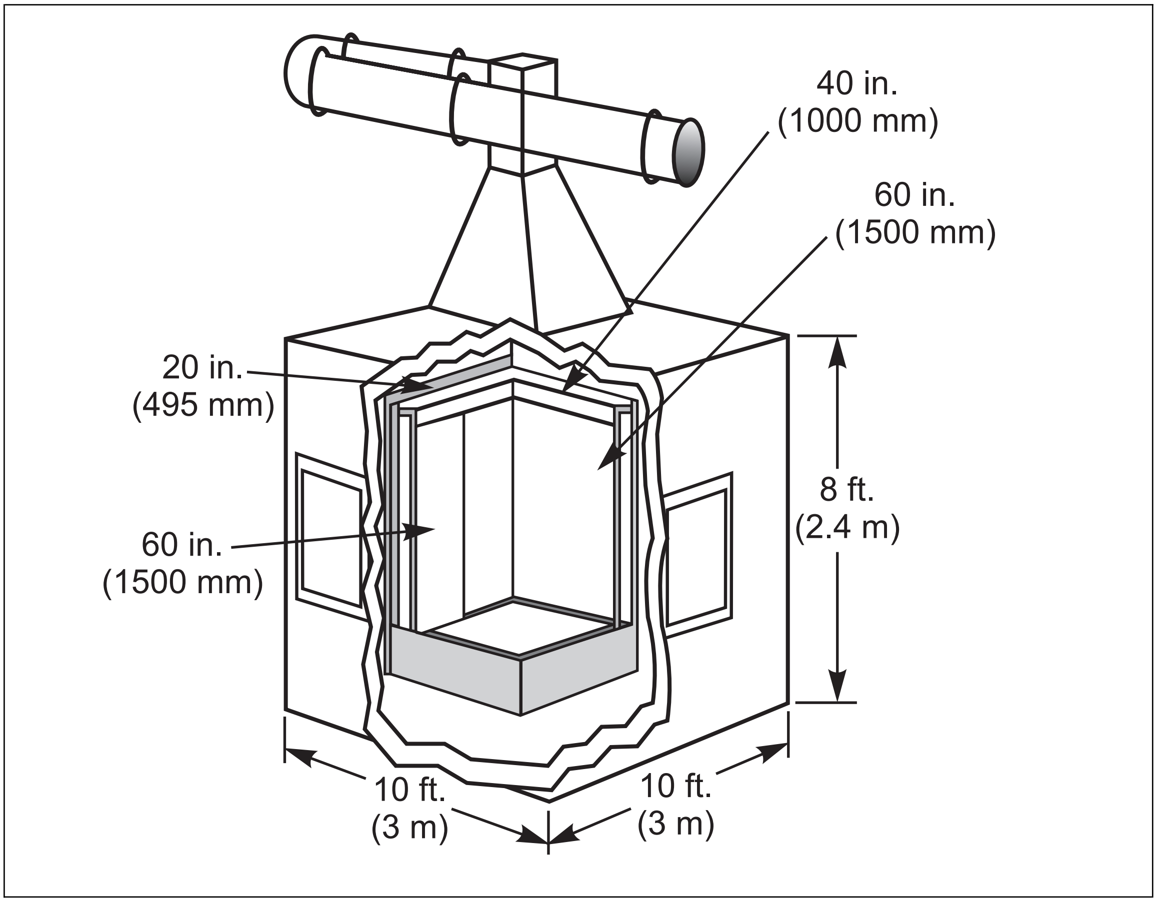

Fig. 9. Single burning item test apparatus

Table 2. EN13501-1 Classifications

Class of Material	*Test Method*
A1	ISO 1182: 750°C furnace test
	ISO 1716: Heat of combustion test
A2	ISO 1182: 750°C furnace test
	ISO 1716: Heat of combustion test
	EN 13823: Single Burning Item (SBI) test
B	EN 13823: Single Burning Item (SBI) test
	ISO 11925-2: Direct flame impingement test
C	EN 13823: Single Burning Item (SBI) test
	ISO 11925-2: Direct flame impingement test
D	EN 13823: Single Burning Item (SBI) test
	ISO 11925-2: Direct flame impingement test
E	ISO 11925-2: Direct flame impingement test
F	No classification

Currently FM has greater confidence in fire test protocols such as the fire propagation apparatus and UBC room test to evaluate construction material combustibility (reaction to fire) than the SBI protocol.

3.2.5.2 Direct Flame Impingement Test: ISO 11925-2, DIN 4102-1

The direct flame impingement test uses a 3.5 in x 10 in. sample mounted in vertical orientation, as shown in Figure 10. A small propane burner, with 20 mm long flame source, is used to directly impinge flame at the base of the vertical sample for a specified duration. There is no additional heat flux to the sample. Flame impingement duration can be varied to either 15 seconds or 30 seconds, based on code requirements. Once the burner is removed, the ignitability of material, vertical flame spread distance, and liquid droplets are noted. Direct flame impingement test is a part of the EN 13501 (European building material classification) test series (refer to Appendix D).

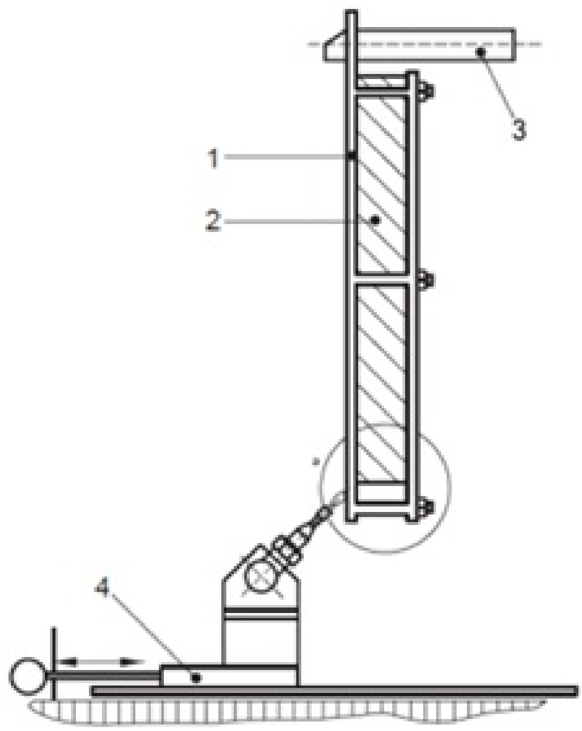

Fig. 10. Direct flame impingement test (©ISO. This material is reproduced from ISO 11925-2 2010, with permission of the American Standards Institute (ANSI) on behalf of the International Organization for Standardization. All rights reserved.)

3.2.5.3 750°C Furnace Tests for Noncombustibility: ASTM E136/ISO 1182

ASTM E136 and ISO 1182 are 750° vertical furnace tube tests. These tests are used in many building codes to determine the non-combustibility of construction materials. Samples are cut of dimensions 1.5 in x 1.5 in. x 2 in. The sample is dropped inside a furnace maintained at 750 °C for 30 minute duration. Thermocouples are attached to the surface of the sample. The temperature rise, mass loss, and flaming duration of sample are used to determine noncombustibility of material. The test method cannot be applied to coated/laminated materials, and samples that may soften, flow, melt, or intumesce on heating.

FM does not consider tests per ASTM E136/ISO 1182 standards to be adequate for determining noncombustibility.

3.2.5.4 FM Noncombustibility Tests: Part of ANSI/FM 4880

Based on research conducted at FM, the present FM guidelines for a noncombustible insulation material include meeting all three of the following tests and limits:

A. The minimum ash content of the material per ASTM D482 test must be 90%.

B. The maximum gross heat of combustion per ISO 1716 (bomb calorimeter) test must be 2 kJ/g.

C. Fire propagation apparatus (FPA) combustion test at 40% inlet O_2 atmosphere must not reveal any visible flaming for a 15-minute exposure at 50 kW/m^2 heat flux.

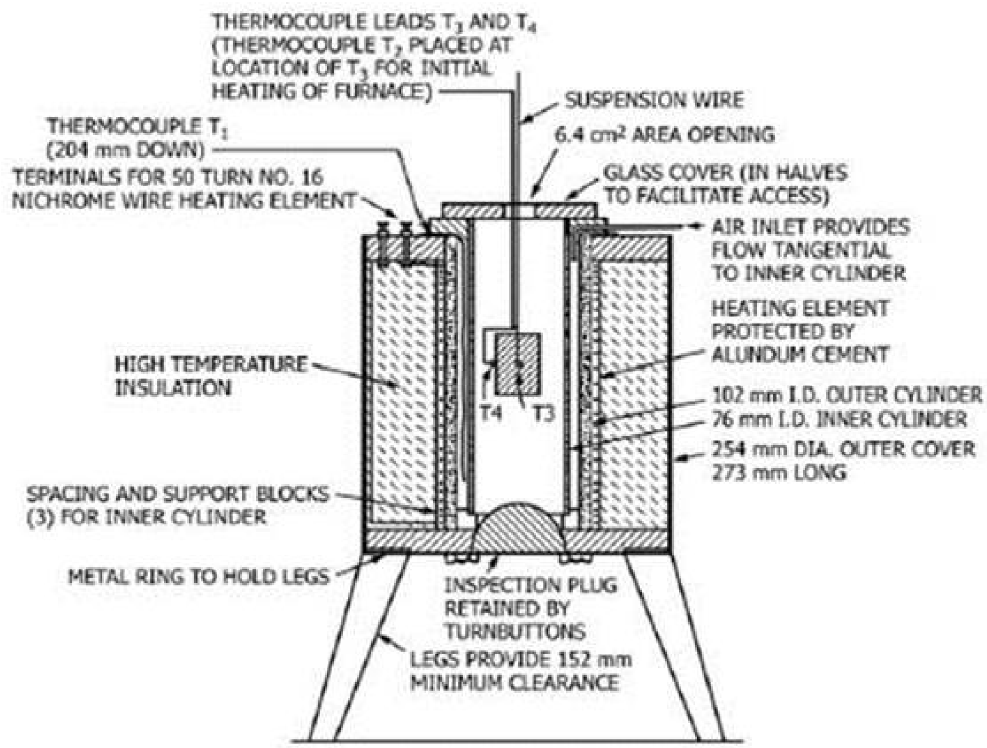

Fig. 11. Vertical tube furnace
Reproduced, with permission from ASTM E136 Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C, copy right ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428)

The FM requirements for noncombustibility of a material are specified in the ANSI/FM 4880 standard.

3.2.6 UBC 26-3 Room Fire Test

The UBC 26-3 room fire test is a test utilizing an enclosure of 8 ft (2.4 m) x 12 ft (3.6 m) x 8 ft (2.4 m) high with a single size personnel door opening on the far wall from the ignition corner. The ignition source is a 30 lb (13.6 kg) wood crib located in the room corner. Testing materials are typically affixed to the two 8 ft (2.4 m) x 8 ft (2.4 m) walls at the ignition corner and on the 8 ft (2.4 m) x 8 ft (2.4 m) room ceiling. This is an intermediate-scale fire test and is often used as a means of evaluating the fire behavior of materials where a clear-cut determination can't be made from a small-scale fire test, or for materials that don't lend themselves to being evaluated in a very small-scale fire test array with a limited ignition source. See Figure 12 for a layout of the UBC 26-3 room fire test enclosure.

3.2.7 FM 8 ft (2.4 m) Parallel Panel Test

The FM 8 ft (2.4 m) parallel panel fire test is a test utilizing two 8 ft (2.4 m) high by 2 ft wide (0.6 m) vertical panels separated by 1 ft (0.3 m). The ignition source is located at the bottom between the panels and consists of a propane sand burner adjusted to provide a heat release of 60 kW. This test is conducted under the FM 5 MW Fire Products Collector and the test duration is 15 minutes with burner on and 5 minutes with burner off for total of 20 minutes. During the test, measurements are made for the following:

1. Chemical heat release rates of material vapors
2. Heat fluxes to the panel at 4 ft (1.2 m) height
3. Flame height
4. Smoke generation rate

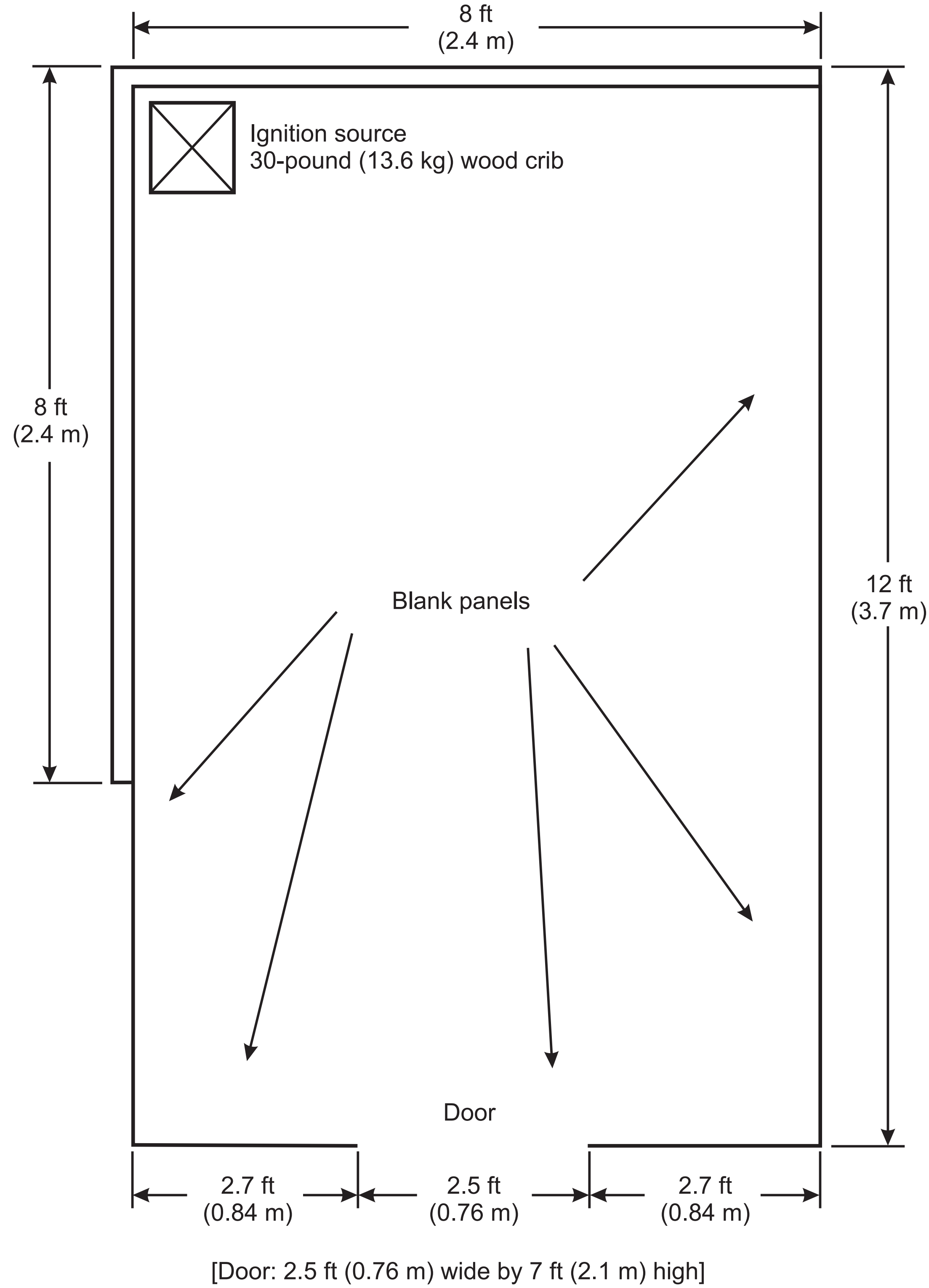

Fig. 12. UBC 26-3 room test enclosure

See Figure 13 for a diagram of the test apparatus.

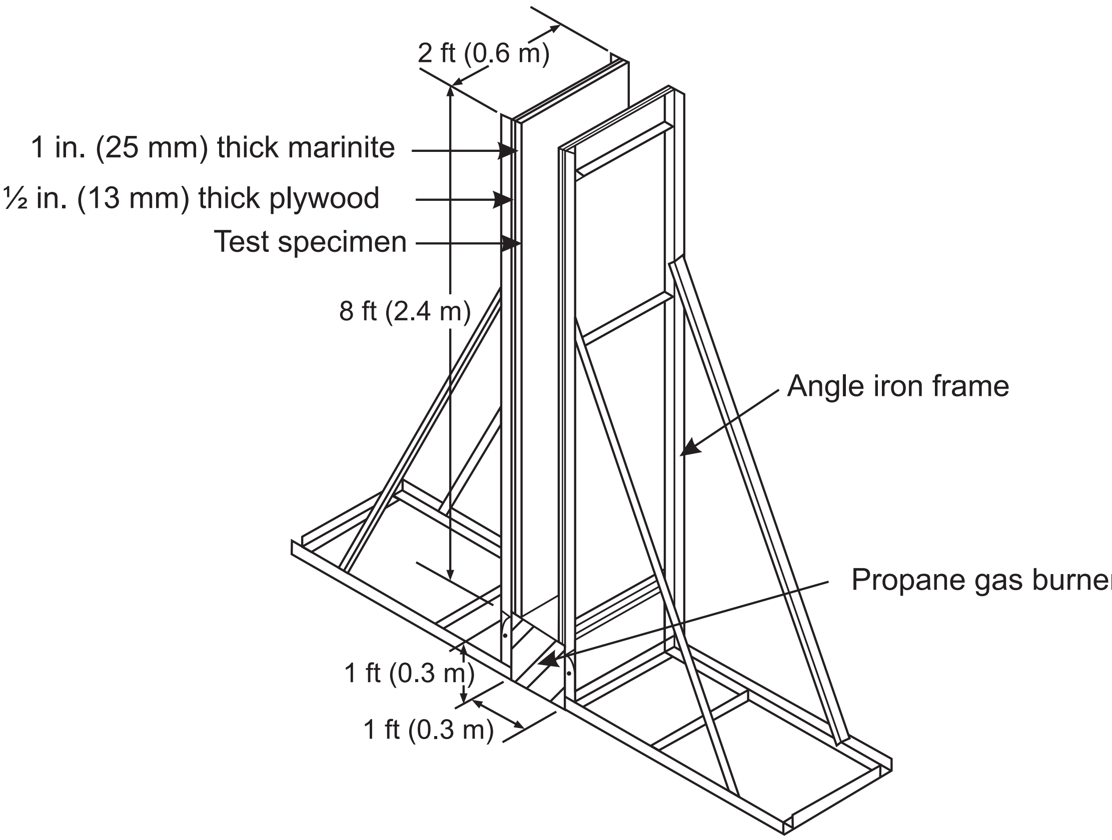

Fig. 13. FM 8 ft (2.4 m) parallel panel test

3.2.8 ASTM E108 Test

The ASTM E108 test is used to test roof coverings and their potential for surface flame spread. The test methods measure the surface spread of flame and the ability of the roof covering material or system to resist fire penetration from the exterior to the underside of a roof deck under the conditions of exposure. The test also provides criteria to help determine if the roof covering material will develop flying burning material, identified as ″flying brands″. The potential ratings from this fire test for the roof covering is Class A, Class B, or Class C. See Figure 14 for diagram of this test apparatus.

FM also uses the ASTM E108 test apparatus to evaluate photovoltaic modules under FM Approval Standard 4476, *Approval Standard for Flexible Photovoltaic Modules*.

3.2.9 FM Pipe Chase Test

The FM pipe chase test apparatus is used to evaluate pipe insulation materials. Three insulated pipes are installed side-by-side in a 24 ft (7.2 m) long horizontal chase constructed with a top and two sides around the pipes. There is also a small 5 ft (1.5 m) vertical section of the chase as well, with a 1 ft^2 (0.09 m^2) pan of heptane located on the floor beneath the cluster of vertical pipes, and serving as an ignition source. See Figure 15 for a diagram of this pipe chase test apparatus.

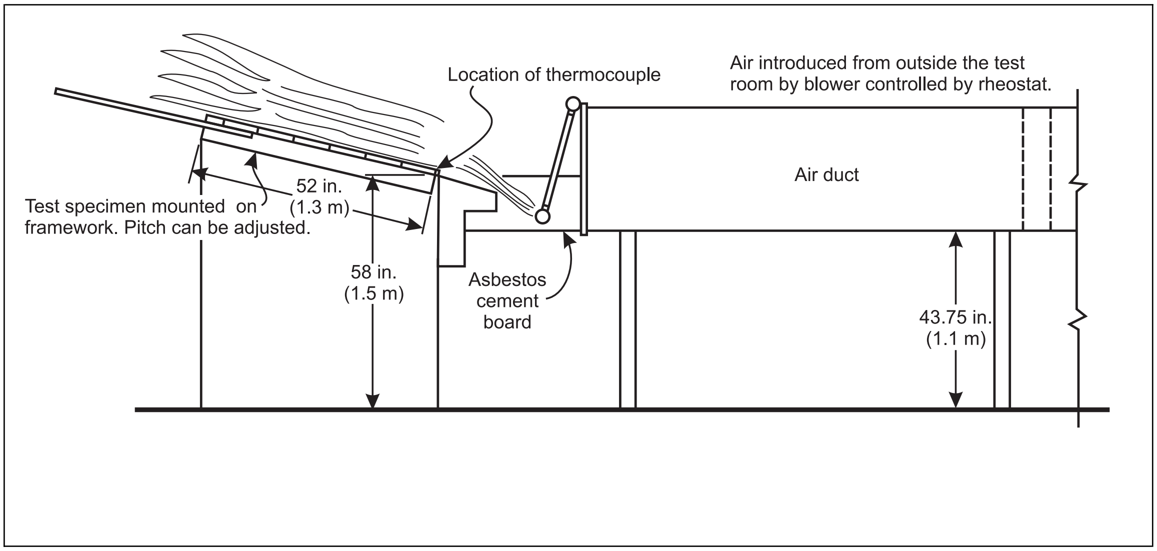

Fig. 14. ASTM E108 test apparatus

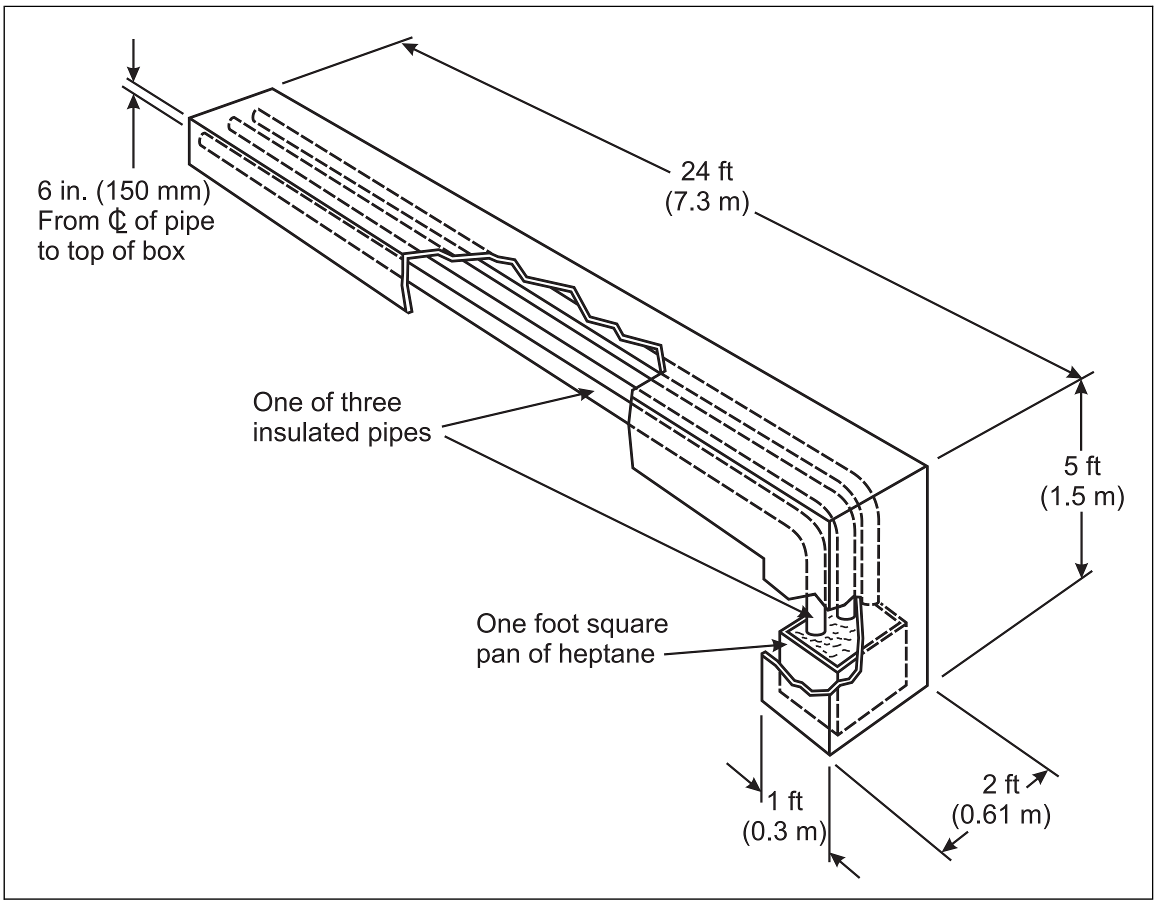

Fig. 15. FM pipe chase test

3.2.10 Other International Fire Tests

Within Europe, the Single Burning Item Fire Test (see Section 3.2.5) has evolved as the primary reaction-to-fire product classification. However, many existing installed construction materials may have been evaluated to BS 476 in the United Kingdom, DIN 4102 in Germany, NFP 92-501 in France, or some other local country fire testing protocol. The key in evaluating these other testing procedures and what their ratings mean as a way of predicting fire behavior, is how these tests have been performed. Many of these testing procedures utilize very small test samples and/or very limited ignition sources making it very difficult to confidently use their results as a true predictor of the fire behavior of the building material.

China uses GB 8624-2012 as a means of classification for burning behavior of building materials and products. These standards are based on the European DIN 4102 and BS 476 fire tests and use classifications of A, B1, B2, and B3. This classification system is also tied to EN 13501.

3.2.11 FM Channel Test

The FM Channel Fire Test procedure used a 3-sided, inverted U-shaped channel having a total length of 24 ft (7.3 m). The underside of the horizontal section was 8 ft (2.4 m) above floor level. The channel walls were 30 in. deep (760 mm) and spaced 30 in. (760 mm) apart. The material to be evaluated was applied to the interior surfaces of either the walls or ceiling, or both, depending on its projected end-use when field applied. This test is not currently utilized by FM.

The fire exposure was a 12 in (305 mm) square pan of heptane fuel, which produced a constant fire exposure of approximately 10,000 Btu/min (42,000 cal/s). Air temperatures of approximately 1400°F (760°C) are attained at the channel ceiling by the end of the ten-minute test.

The time and distance of maximum flame spread over the sample during the tests were the principal parameters measured. From these values, and taking into account the number and geometry of the surfaces tested, a judgment was made as to the degree of fire protection the product would need for it to successfully pass the FM Corner Test. The Channel Test was used primarily as a screening test. It was not used as a basis for FM Approval.

3.2.12 NFPA 285

NFPA 285 is a two-story apparatus that evaluates an external wall façade assembly under a spill plume from a flashover fire scenario. The test wall is 17.5 ft high (5.3 m) and 13.5 ft (4.1 m) wide, as shown in Figure 16. Each floor has one room, with the bottom room including a window opening of dimensions 2.5 ft (0.8 m) high x 6.5 ft (2 m) wide. One propane burner is placed in the bottom room and other is located under the window opening.

During the test, the heat flux to wall is gradually increased from 10 kW/m^2 to 40 kW/m^2 within the span of 30 minutes, with 40 kW/m^2 heat flux applicable only during the last 5 minutes of the test. Temperatures are monitored in front of the external wall, inside air cavities (if present), and inside the insulation. The pass criteria for a wall assembly is:

A. Exterior temperatures at 10 ft (3.0 m) height above the window and 5 ft (1.5 m) horizontally from the vertical centerline of the window shall be less than 1000 °F (538 °C).

B. Air cavity temperatures at 10 ft (3.0 m) height above the window and 5 ft (1.5 m) horizontally from the vertical centerline of the window shall be less than 1000 °F (538 °C).

C. Insulation temperature at 10 ft (3.0 m) height above the window and 5 ft (1.5 m) horizontally from the vertical centerline of the window shall be less than 750 °F (399 °C).

D. Temperature in the second story room shall be less than 500 °F (260 °C).

In the US, the IBC and the NFPA 5000 building codes require compliance with NFPA-285 for buildings of unrestricted heights; IBC is a model building code adopted by most US states while NFPA 5000 is an alternate building code with some use in the Middle East and Latin America.

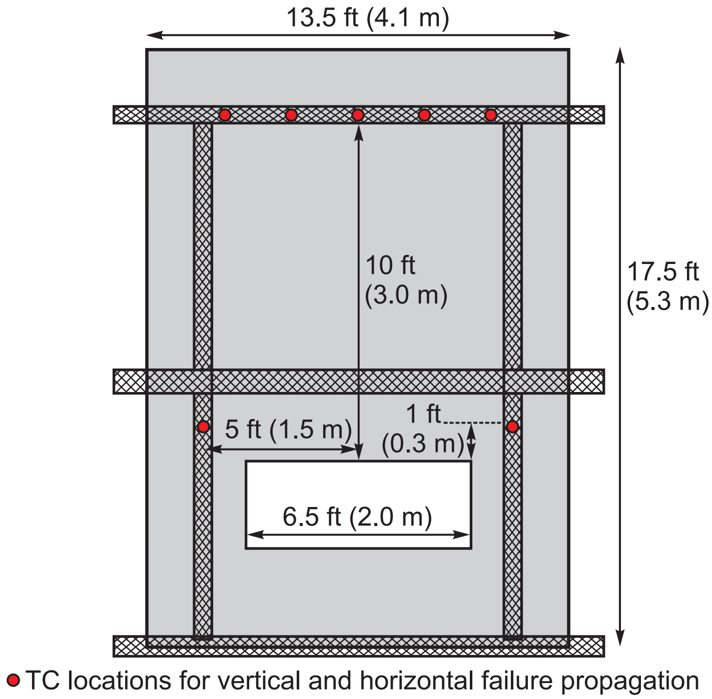

Fig. 16. Schematic of setup and dimensions in NFPA 285 (not to scale)

3.2.13 BS 8414

BS 8414-1 and BS 8414-2 large-scale fire tests are used in the UK for testing external wall systems attached to masonry walls or structural steel frames, respectively. These standards define the dimensions, procedures and test protocols. A separate document defines the performance criteria for both tests; Fire performance of external thermal insulation for walls of multistory buildings, BR 135 Third Edition.

The test setup consists of minimum 26 ft (8 m) high main and wing wall specimens arranged in a corner situation. The width of the main wall and wing wall are at least 8 ft (2.4 m) and 4 ft (1.2 m), respectively. A combustion chamber, located at the base of the main wall, houses a wood crib. The wood crib fire produces approximately 75 kW/m^2 peak heat flux on the external wall.

During the 30-minute fire test, temperatures are monitored in front of the wall, inside air cavities, and inside insulation at Level 1 and Level 2; Level 1 and Level 2 locations are 8.2 ft (2.5 m) and 16.4 ft (5.0 m) heights above the window opening, respectively. The fail criteria detailed in BR 135 for a wall assembly are detailed below:

A. Exterior temperature at Level 2 is 1110°F (600°C) above the ambient temperature, for at least 30 s duration within 15 minutes of fire spread start time.

B. Air cavity or insulation temperature at Level 2 is 1110°F (600°C) above the ambient temperature, for at least 30 s duration within 15 minutes of fire spread start time.

3.2.14 FM Corner Fire Tests (ANSI/FM 4880)

At FM, from the 1970s to the early 2000s, 25 ft and 50 ft corner fire tests were used to evaluate the fire performances of external and internal wall assemblies. The corner fire tests simulate realistic-scale fires for scenarios where a combustible load is present in a vertical corner situation, e.g., dumpster fire.

Figures 18 (a) and (b) show schematics. In the 25 ft (7.6 m) corner test, two 25 ft (7.6 m) high test walls form a right-angle corner; one wall is 50 ft (15.2 m) long, while the other is 40 ft (12.2 m) long. In the 50 ft (15.2 m) corner test, the two 50 ft (15.2 m) high test walls are 20 ft (6.1 m) long and form a right-angle. Thermocouples are mounted onto the external wall of the assembly, as marked in Fig. 18a.

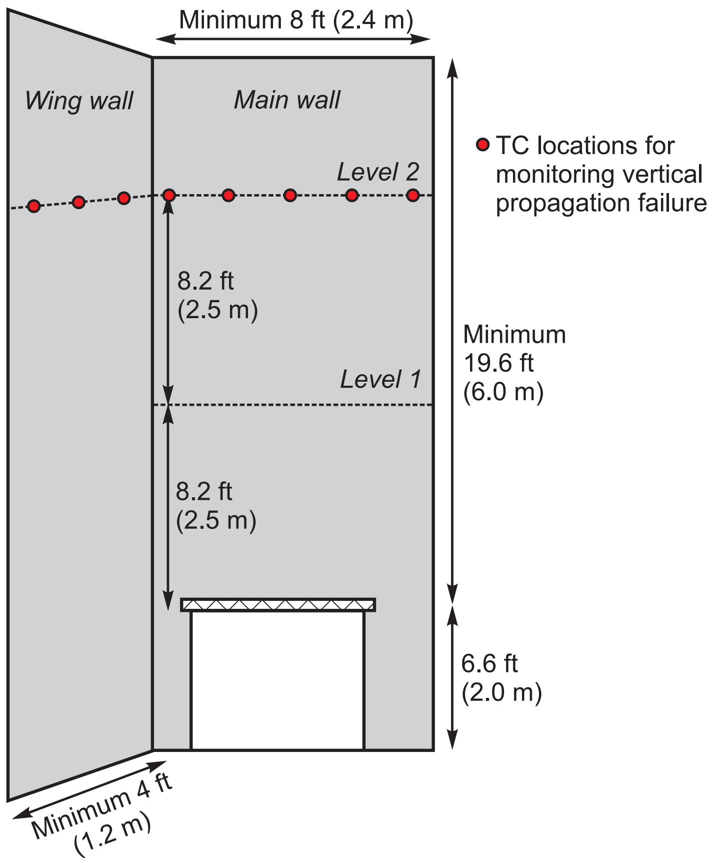

Fig. 17. Schematic of wall specimen and dimensions in BS-8414-1 (not to scale)

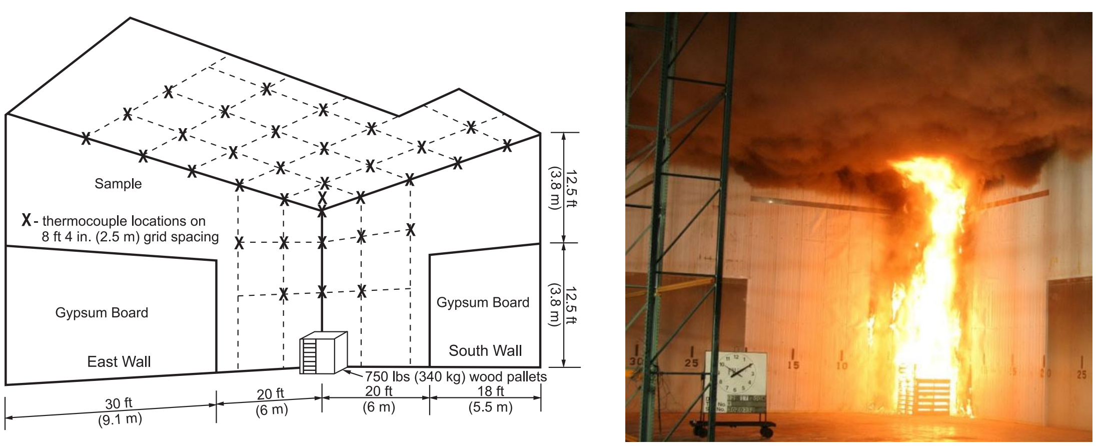

Fig. 18(a). ANSI/FM 4880 corner fire test - 25-ft test

Both corner fire tests use 750 ± 10 lb (340 ± 4.5 kg) oak wood pallets as the fire source. The pallets are placed 1 ft (0.3 m) away from each wall, and imparts approximately 100 kW/m^2 peak heat flux to the wall surfaces. The test duration is 15 minutes. The wall assembly performance is based on the extent of fire propagation. Approval of wall assembly for up to 30 ft (9.1 m), 50 ft (15.2 m), or unlimited installation height is provided, as shown in Table 3.

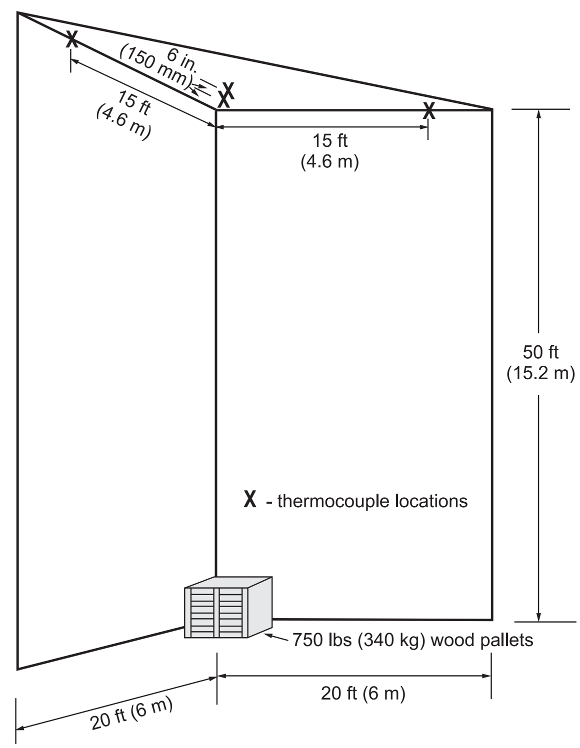

Fig. 18(b). ANSI/FM 4880 corner fire test - 50-ft test

Table 3. ANSI/FM 4880 Performance Criteria for Wall Assemblies Based on Corner Fire Tests

Approval Height	*Test Type*	*Test Criteria*
30 ft (9.1 m)	25 ft corner fire test	Fire does not reach eave wall extremities of test setup.
50 ft (15.2 m)	50 ft corner fire test	Fire does not reach eave wall extremities of test setup.
Unlimited	50 ft corner fire test	Fire does not reach ceiling of test setup.

Figures 19, 20 and 21 depict typical 25 ft (7.6 m) corner tests on plastic materials. See Figure 22 for a layout of the FM 50 ft (15.2 m) corner fire test.

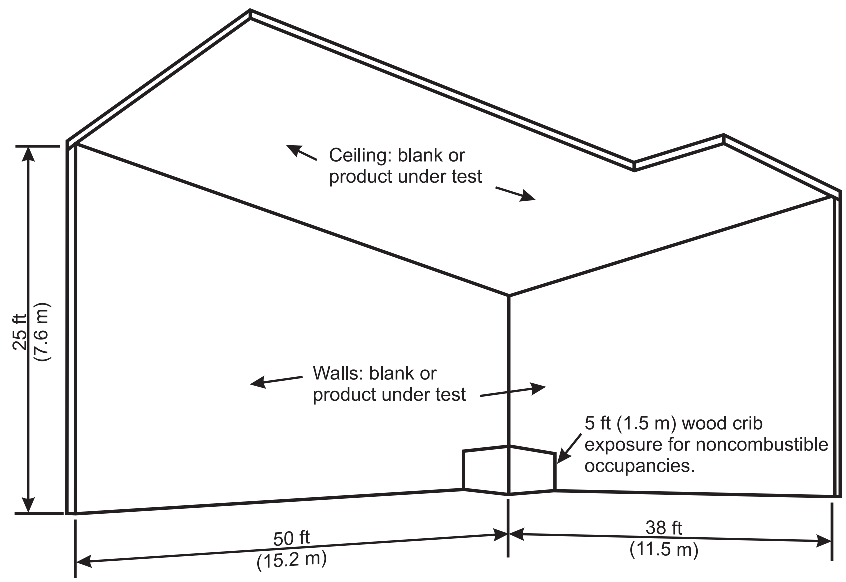

Fig. 19. FM 25 ft (7.6 m) corner fire test.

Fig. 20. FM corner test of reinforced plastic (flame spread = 25).

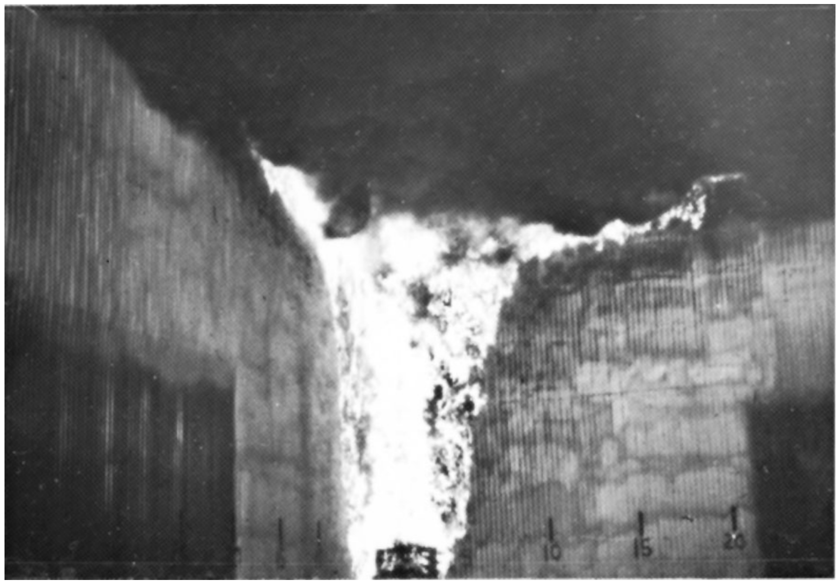

Fig. 21. FM corner test (This polyurethane was rated "self extinguishing" by a small-scale test.)

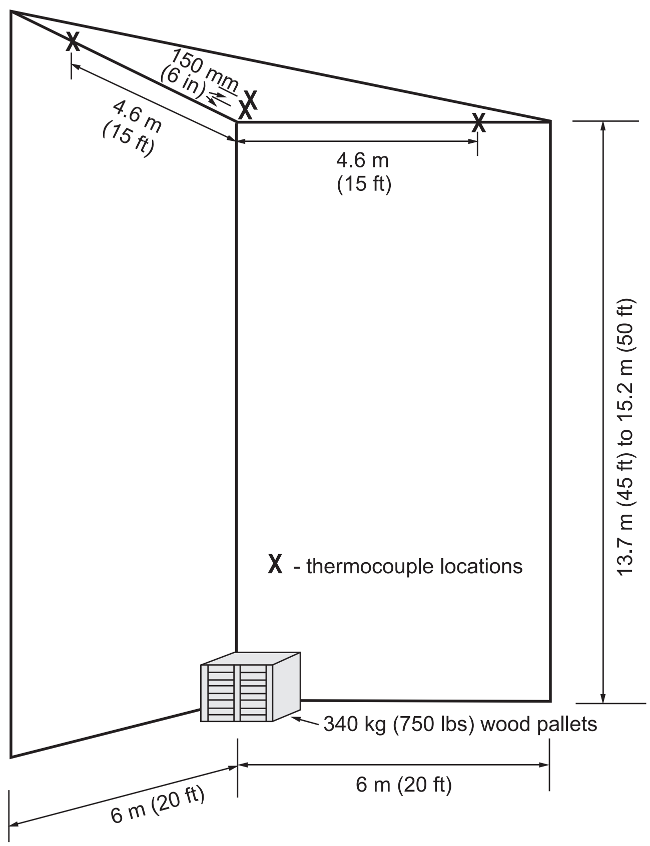

Fig. 22. FM 50 ft (15.2 m) corner test

3.2.15 FM 16 ft Parallel Panel Tests (16 ft PPT) (ANSI/FM 4880, FM 4882)

The 16 ft (4.9 m) high parallel panel tests (16 ft PPTs) were developed in the early 2000s to incorporate features of corner fire tests and, therefore, correlate well with the results from corner tests. 16 ft PPTs are cost-effective, faster to setup, and repeatable. The test method is used to test interior and exterior wall assemblies, including sandwich panels, ACM/MCM systems, and single skins.

A 16 ft PPT consists of two 16 ft (4.9 m) high and 3.5 ft (1.1 m) wide wall panels mounted on insulated boards, and kept at 1.75 ft (0.5 m) separation as shown in Fig. 23. The ignition source is located at the bottom between the panels and consists of a sand burner with a heat release rate of 360 kW. The propane sand burner imparts approximately 100 kW/m^2 peak heat flux to the wall panels. The test setup is placed under a 5 MW fire products collector to measure heat release rate (HRR) and smoke.

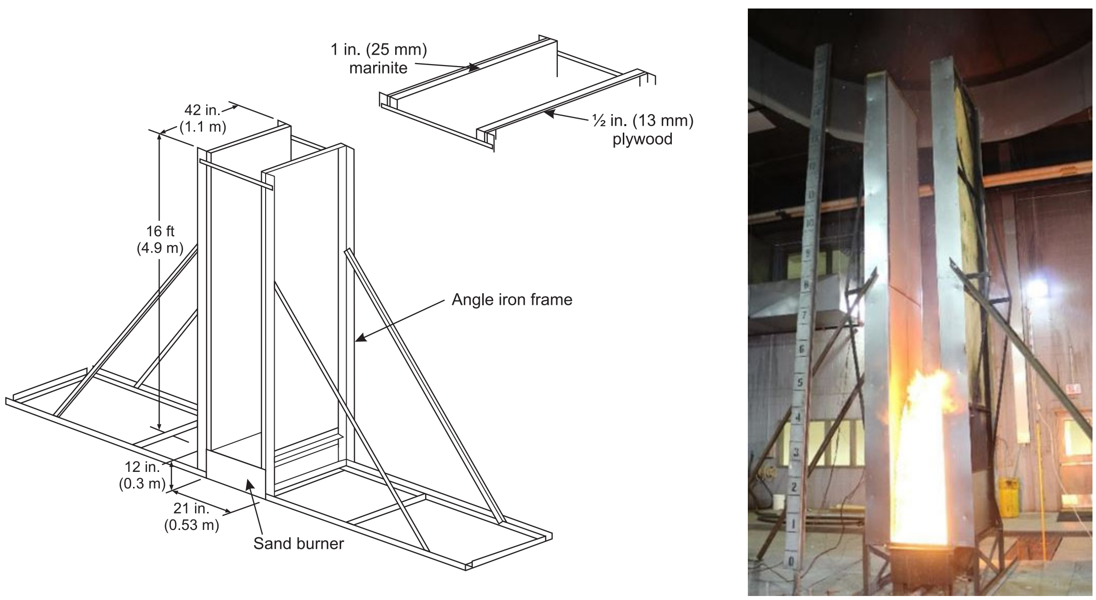

Fig. 23. Schematic and picture of a 16 ft (4.9 m) PPT

The fire performance wall assembly is based on the peak HRR generated during the first 15 minutes of the test. Approval of wall assemblies up to 50 ft (15.2 m) or unlimited height are provided, as shown in Table 4. The wall assembly fails the test if the peak HRR is greater than 1100 kW.

Table 4. ANSI/FM 4880 Approval Criteria for Wall Assemblies Based

Approval Height	*Test Type*	*Test Criteria*
50 ft (15.2 m)	16 ft PPT	830 < Peak HRR ≤ 1100 kW
Unlimited	16 ft PPT	Peak HRR ≤ 830 kW

More recently, 16 ft PPTs have been used to evaluate the smoke hazard of the internal wall assemblies used in smoke sensitive occupancies (including cleanrooms, pharmaceutical manufacturing and storage areas, food preparation and storage areas, and other occupancies susceptible to smoke damage). The approval criteria for smoke-generation performance of wall assemblies are detailed in FM 4882 Approval Standard.

This test is the next step beyond the previously developed 8 ft (2.4 m) parallel panel test. The test is used as part of FM Approval Standard 4882 to evaluate the suitability of building materials for use in highly smoke-sensitive occupancies as well as a means of testing for FM Approval for FM 4880 and FM 4411. It has also been developed as an alternative test to the 25 ft (7.6 m) or 50 ft (15.2 m) corner fire testing for most building materials as a means of FM evaluation and FM Approval.

3.2.16 Comparison of Key Façade Fire Tests

This section compares the features of the 16 ft PPT, BS 8414 test, and NFPA 285 test. Figure 24 shows examples of the façade fire tests, and Table 5 compares key attributes for the three tests.

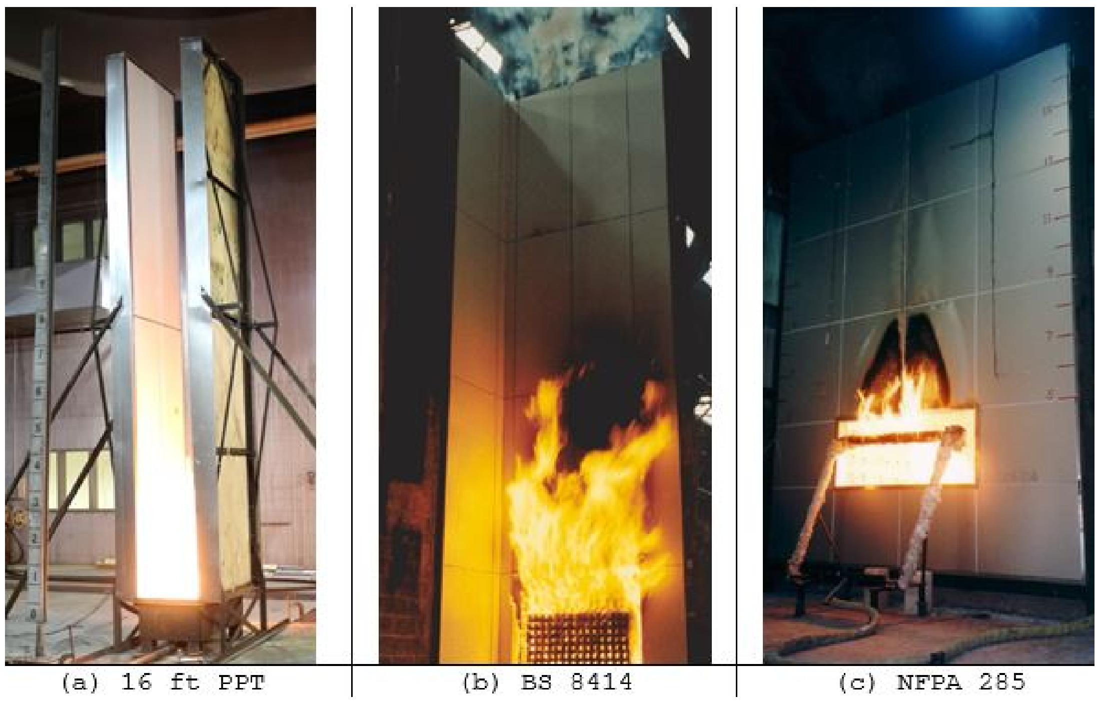

Fig. 24. Fire test examples

Table 5. Comparison of the Main Characteristics of Three Façade Fire Tests

Large-Scale Test	*Burner and HRR*	*Peak Heat Flux to Panels*	*Wall Height Above Window/Burner*	*Primary Criteria for Failure*
16 ft PPT	Propane burner: HRR = 360 kW	~100 kW/m^2	16 ft (4.9 m)	Peak HRR > 1100 kW
BS 8414	Wood crib: HRR = 3 ± 0.5 MW	~75 kW/m^2	20 ft (6.0 m)	Temperature at 16.4 ft (5 m) height rises 1110°F (600°C) above ambient
NFPA 285	2 Propane burners: HRR = 1.3 MW	40 kW/m^2	13 ft (4.0 m)	Temperature at 10 ft (3 m) height >1000°F (538°C)

The length-scale for the three tests are similar. But, the peak heat flux from the 16 ft PPT is considerably higher than that from the NFPA 285, and relatively close to that of BS 8414 test. Literature studies have shown that the heat flux of the order of 100 kW/m^2 are realistic representation of post-flashover and exterior fires.

Figure 25 compares the peak heat flux from ignition sources in various large-scale exterior wall fire tests.

4.0 REFERENCES

Data Sheet 1-5, *Removal and Shipping of Roof Deck Samples for Calorimeter Testing*
Data Sheet 1-57, *Plastics in Construction*
Data Sheet 1-61, *Fire-Retardant Treated Wood*

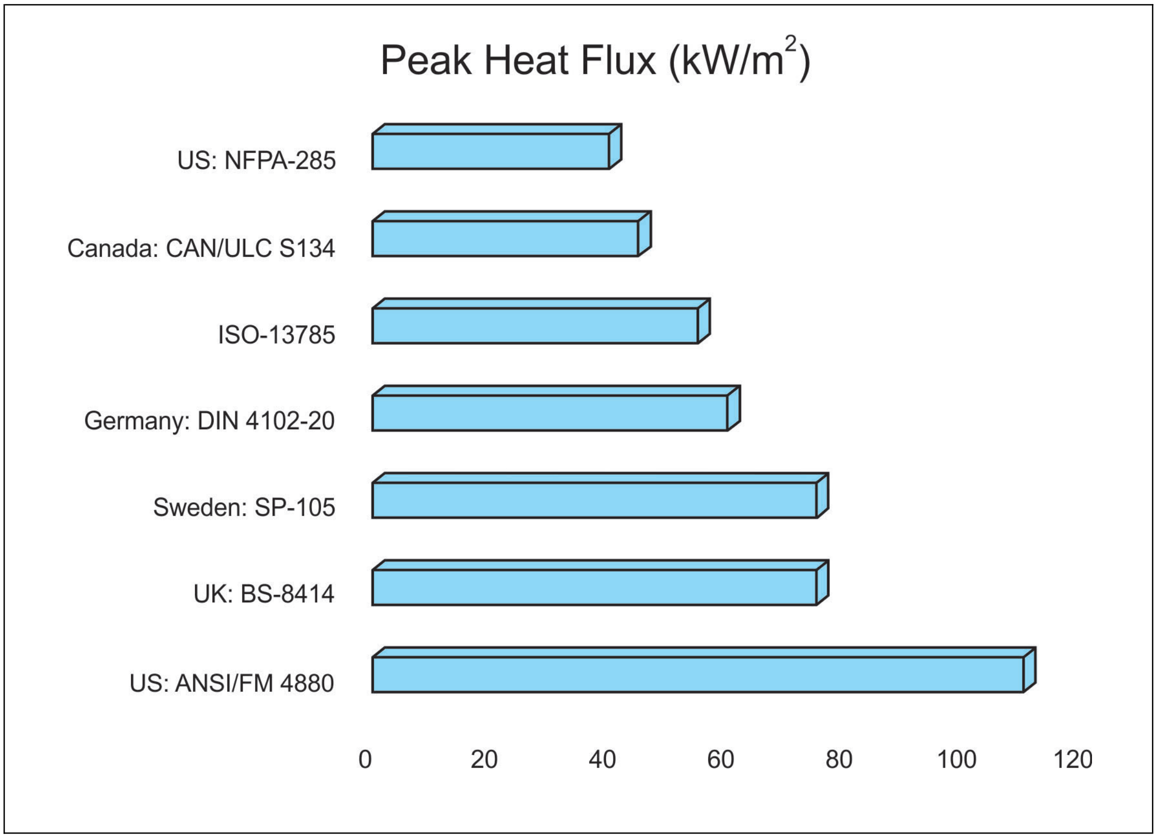

Fig. 25. Comparison of peak heat flux from ignition source in various exterior-wall large-scale fire tests

APPENDIX A GLOSSARY OF TERMS

FM Approved: Products and services that have satisfied the criteria for FM Approval. Refer to the Approval Guide, an online resource of FM Approvals for a complete listing of products and services that are FM Approved.

Heat flux: Thermal exposure experienced by test material (kW/m^2).

Heat release rate: Rate at which heat is released during a fire (kW).

Intermediate-scale tests: Includes the UBC room fire test and the FM roof calorimeter test.

Large-scale tests: Includes the tunnel test, 16 ft parallel panel test, 8 ft parallel panel test, FM corner tests and FM duct test.

Noncombustible material: Material that will not ignite, burn, support combustion, or release vapor when subjected to fire or heat.

Small-scale tests: Includes bench-type tests such as UL 94.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

April 2019. The scope of this document was clarified, and new information was added on NFPA 285 and BS 8414 exterior wall system fire tests.

January 2012. The document has been expanded to describe additional fire tests normally encountered in the evaluation of building materials.

January 2000. The document has been reorganized to provide a consistent format.

May 1998. Editorial changes were made.

February 1981. First publication of this document.

APPENDIX C SMALL-SCALE FIRE TESTS

Note: No attempt should be made to conduct the following small-scale fire tests based upon the brief descriptions contained herein. The appropriate complete FM, ASTM, or UL test method should be followed.

C.1 UL94 (Tests for Flammability of Plastic Materials)

These tests were designed primarily for testing small plastic parts for use in appliances and other products. They do not cover plastics used as building materials. However, they have been improperly used by groups other than Underwriters' Laboratories for products such as duct insulation and reinforced plastic panels. The ratings resulting from these tests are meant to guide the manufacturer, and are not meant to be given to the final consumer as an indication of hazard. Building codes do not accept a UL 94 rating in lieu of the other fire ratings specified in the codes. Also, the results of most UL 94 flammability tests are not applicable to materials whose thickness exceeds 0.5 in. (13 mm).

Several different types of tests are used by Underwriter's Laboratories under UL94. Smooth plastics are tested both in the horizontal and vertical positions; foam plastics are tested only in the horizontal position.

All specimens are conditioned in a prearranged temperature and humidity atmosphere prior to testing to meet the necessary standard.

Vertical Burning (UL94 V-0, -1, -2)

Test specimens are 5 by 0.5 in. (127 by 13 mm). Maximum thickness is 0.5 in. (13 mm).

The specimen is suspended (longitudinal axis vertical) within a ring stand by clamping the upper edge of the specimen. The ring stand is enclosed in a laboratory hood with glass window and exhaust fan. A layer of dry, absorbent cotton is placed on the bench under the specimen.

A specified flame from a Bunsen burner is placed centrally under the lower edge of the test specimen. After 10 sec the flame is withdrawn. The duration of flaming of the specimen is noted. When flaming ceases, the test flame is immediately replaced under the specimen for another 10 sec. Duration of flaming and glowing is noted.

Materials shall be classified 94 V-0, 94 V-1, or 94 V-2 providing the test shows that:

1. No specimen burned with flaming combustion for more than 10 seconds (Test 94 V-0), 30 seconds (Test 94 V-1), or 30 seconds (Test 94 V-2) after each application of the flame.

2. No specimen had a total flaming combustion time exceeding 50 seconds (Test 94 V-0), 250 seconds (Test 94 V-1), or 250 seconds (Test 94 V-2) for ten flame applications of each set of five specimens.

3. No specimen burned with flaming or glowing combustion up to the holding clamp.

4. No specimen dripped flaming particles that ignited the dry absorbent surgical cotton located below the specimen.

5. No specimen glowed with flaming combustion that persisted beyond 30 seconds (Test 94 V-0), 60 seconds (Test V-1), or 60 seconds (Test V-2) after the second removal of the test flame.

6. *Test 94 V-2 only.* No specimen continued to burn to the 4 in. (102 mm) reference mark when subjected to the 94HB test.

If only one specimen out of five fails to comply, another set of five specimens shall be tested. (See appropriate UL 94 standard.)

C.2 Vertical Burning (94-5V)

Test specimens are 5 in. by 0.5 in. (127 by 13 mm) and are limited to 0.5 in. (13 mm) thickness.

The Bunsen burner is positioned on a mounting block sloped so the axis of the burner may be 20° from the vertical. The specimen is suspended (longitudinal axis vertical) within a ring stand by clamping the upper edge of the specimen. The ring stand is enclosed in a laboratory hood, free from drafts and having a glass window.

The burner flame height is 5 in. (127 mm) and the blue cone tip of the flame is 1½ in. (38 mm). It is applied to one of the lower corners of the specimen at an angle of 20° so the blue cone tip just touches the specimen. The flame is applied for 5 seconds and taken away for 5 seconds. The operation is repeated until the specimen has been subjected to five applications of the test flame.

Materials shall be classified 94-5V providing the test shows that:

1. No specimen burned with flaming and/or glowing combustion for more than 60 seconds after the fifth flame.

2. No specimen dripped particles.

3. No specimen in the area of the test flame was destroyed to any significant degree.

If only one specimen out of a set of five specimens fails to comply, a second set shall be tested. All specimens from the second set shall comply.

C.3 Horizontal Burning 94HB

The specimens are 5 in. by 0.5 in. (127 mm by 13 mm). There are two ranges of thickness, from 0.120 to 0.125 in. (3.1 to 3.2 mm), or less than 0.120 in. (3.1 mm). Each specimen is marked across its width with two lines, 1 in. (25 mm) and 4 in. (102 mm) from one end of the specimen.

The specimen is clamped in a draft-free laboratory hood. The major axis is horizontal and the minor axis inclined at a 45° angle. The specimen is clamped at the end farthest from the 1.0 in. (25 mm) mark.

Wire gauze is clamped in a horizontal position a distance of ⅜ in. (9.5 mm) below the specimen. A Bunsen burner is ignited and the flame adjusted to a specified length. The flame is applied to the free end (away from the clamp) at the front and lower edge of the specimen to a depth of approximately ¼ in. (6.1 mm) for 30 seconds, without changing the position of the burner. The burner is then removed. If the specimen burns to the 1 in. (25 mm) mark before the flame has been applied for 30 seconds, the flame application is discontinued.

If the specimen continues to burn past the 1 in. (25 mm) mark (during the 30 second period the flame is on it) to the 4 in. (102 mm) mark, the time is recorded and the burning rate established.

Materials shall be classified as 94 HB, providing the test shows that:

1. No specimen had a burning rate exceeding 1.5 in. (38 mm) per minute over a 3 in. (76 mm) span for specimens having a thickness 0.120 to 0.125 in. (3.1 to 3.2 mm).

2. No specimen had a burning rate exceeding 2.5 in. (64 mm) per minute over a 3 in. (76 mm) span for specimens having a thickness less than 0.120 in. (3.1 mm).

3. No specimen continued to burn until the flame reached the 4 in. (102 mm) reference mark.

C.4 Horizontal Burning 94HBF, 94HF-1, 94HF-2

This test is applicable to foam plastics. The specimens are 6 in. by 2 in. (152 mm by 51 mm), maximum thickness 0.50 in. (13 mm). Each specimen is marked across its width with three lines: 1 in. (25 mm), 2.25 in. (57 mm), and 5 in. (127 mm) from one end.

The burning test is conducted in a draft-free laboratory hood or equivalent device. The foam specimen is placed on horizontal wire hardware cloth having 8 x 3 in. (203 x 76 mm) dimensions. The end of the cloth where the burner flame will be applied is bent upward 0.5 in. (13 mm). The cloth is supported by clamps from two ring stands and is 0.5 in. (13 mm) above the top of a wing tip burner and 12 in. (305 mm) above a 3 x 3 in. (76 x 76 mm) horizontal layer of dry absorbent cotton.

The specimen is placed on the cloth, one end of it against the upturned end of the hardware cloth. The wing tip burner flame is adjusted to give a blue flame 1.5 in. (38 mm) high. The burner is then positioned under the hardware cloth so that one edge of the flame is in line with the upturned end of the cloth. The center of the width of the wing tip is in line with the longitudinal axis of the specimen.

The flame is applied for 60 sec and then removed. If the material continues to burn after removal of the test flame, the time for the flame to travel from the 1 in. (25 mm) mark to the 5 in. (127 mm) mark is determined. The rate of burning can then be calculated. If the specimen ceases to burn before the 5 in. (127 mm) mark is reached, the duration of burning after removal of the test flame and the distance of burning from the end exposed to the test flame are recorded.

Materials shall be classified 94HBF providing the test shows there are:

1. No specimens that had a burning rate exceeding 1.5 in. (38 mm) per minute over a 4 in. (102 mm) span; *or*

2. No specimens that continued to burn until the flame reached the 5 in. (127 mm) mark.

3. No specimens that met the requirements for Class 94HF-1 or 94HF-2.

Material shall be classified 94HF-1 providing the test shows that:

1. Not any portion of four specimens out of five tested continued to flame for more than 10 sec after removal of the test flame.

2. No part of any test specimen continued to flame for more than 10 sec after removal of flame.

3. No test specimen was affected for a distance greater than 2.25 in. (57 mm) from the end exposed to the test flame.

4. Specimens did not drip flaming particles that would ignite the dry, absorbent surgical cotton placed 12 in. (305 mm) below the test specimen.

5. There are no test specimens with glowing combustion that:

   (a). Persists beyond 30 seconds after removal of test flame.

   (b). Travels past the 2.25 in. (57 mm) mark.

Materials classed 94HF-2 meet the same criteria as 94HF-1, except that in item 4, specimens may drip flaming particles that burn only briefly, some of which ignite the dry, absorbent surgical cotton placed 12 in. (305 mm) below the test specimen.

If only one specimen out of a set of five specimens fails to comply with the requirements, five more specimens are tested. All specimens from this set shall comply.

Like the other small-scale tests, the test results from the UL 94 Series can be misleading when they indicate limited burning.

C.5 Total Heat of Combustion Test, ISO 1716

This is an industry-standard material characterization test. The total heat of combustion of a material is calculated using the ISO 1716 test. This is used by FM as a part of 3-test series to determine noncombustibility (see FM noncombustibility tests section). In this test, a 500 mg sample is completely burned under oxygen atmosphere and high pressure (3 MPa) in a constant volume chamber. The heat generated by the combustion process is used to determine the total heat of combustion or the net calorific value of the fuel. For nonhomogenous fuels, all subcomponents may be required to be tested separately.

C.6 Ash Content Analysis Test, ASTM D482

This is an industry-standard material characterization test. The ash (noncombustible) content of a material is calculated using the ASTM D482 test. This method is used by FM as a part of 3-test series to determine noncombustibility (see FM noncombustibility tests section). In this test, a sample is placed in a 120 ml dish and completely burned using an electric muffle furnace maintained at 775°C ± 25°C.

Fig. 26. ISO 1716 (Courtesy of Fire Testing Technology)