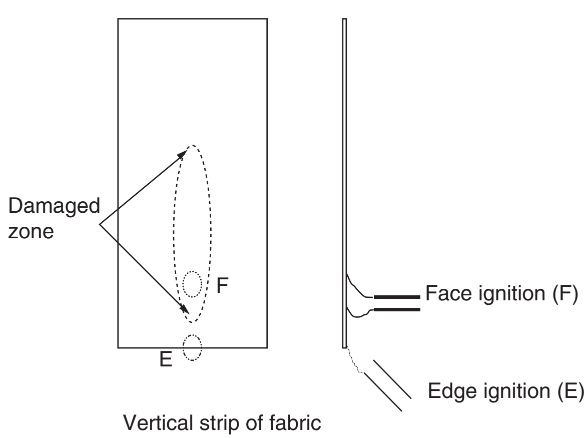
12.4 Standard testing methods

Ideally, all standard test methods should be designed such that the measurement of flammability parameters, such as time to ignition, rate of flame spread, afterglow times, etc., can be acquired in a reproducible and repeatable manner. The flammability principles on which the standard tests are established should be straightforward and easy to transform into a practically simple and easy-to-use test.[13] Some of the principle test methodologies are discussed below along with illustrative standard method examples.

12.4.1 Simple ignition tests

In standard test methods, fabric ignition is measured in terms of minimum ignition time, i.e. how long a flame needs to be applied to a given material so as to achieve ignition, normally to the nearest second. A simple ignition test includes a vertically oriented fabric subjected to a standard gas flame applied to the face or lower edge (depending on the severity of the test required) of the fabric specimen. Ignition is monitored by visual observations and the time taken to ignite the specimen is recorded. This test is used in many standards including BS 5438, EN ISO 6941, FAR Part 25, etc. A schematic diagram of a typical vertical strip test is shown in Fig. 12.1. For horizontal and inclined fabric orientations (e.g. 45°, 60° etc.), edge ignition is often preferred.



12.1 Schematic representation of a simple vertical strip test.

The minimum flame application times determined using Test 1 of BS 5438:1989[14] for ignition of selected different fabrics are given in Table 12.1. Initial analysis[6] of ignition time data in Table 12.1 suggests that the minimum flame application times are very similar for most of the fabrics in spite of different fibre contents, and that the time to ignition is lower for edge ignition in both warp and weft directions than the respective face ignition times. It is also evident from Table 12.1 that the time to ignition is directly related to area density. All fabrics ignite after 1–4 seconds, indicating their respective ease of ignition. This test method appears to distinguish ignitability of fabrics more on the basis of physical factors (relating to area density and specimen orientation) than on fibre chemistry for the examples listed. This can result in significant change in the ranking order of fabrics if the specifications such as physical form and orientation of fabrics are altered. Therefore, for a fuller understanding of the flame initiation process and the response of a material to it, the authors explored experimental methodology to determine the ignition temperature sensitivity of various fabrics. Details of this study are beyond the scope of this chapter, however, and are discussed elsewhere.[15]

For materials with a dripping tendency, the igniting flame burner can be inclined at 45° so as to avoid flame extinguishment by molten drips from the specimen. Such a test method may include a basket with filter paper placed under the vertically mounted specimen (see Fig. 12.2) to judge the hazard of a material burning with flaming drops.

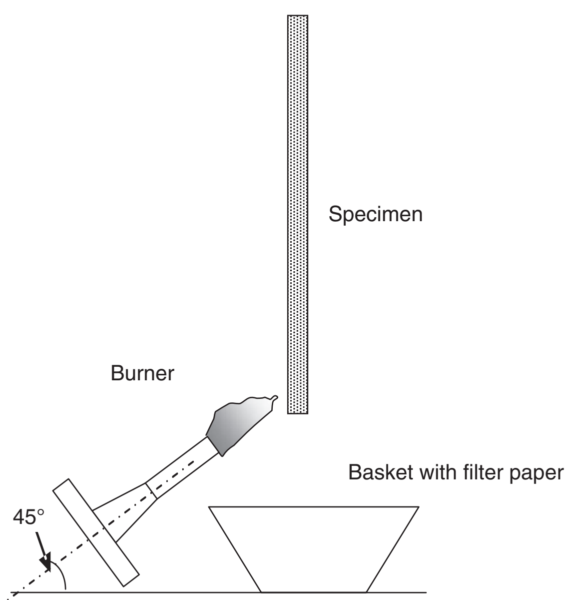
12.4.2 Flame spread

Rate of flame spread is usually calculated by measuring the distance and recording the time taken of the advancing flame front to sever threads placed at defined distances by the flame front. The flame spread test apparatus is shown in Fig. 12.3. The frame supporting the sample can be hinged (see Fig. 12.3(b)) such that the frame can be moved from the vertical to any other required angle. The frame can be fixed in an inclined position by fastening the screw on the supporting bar.

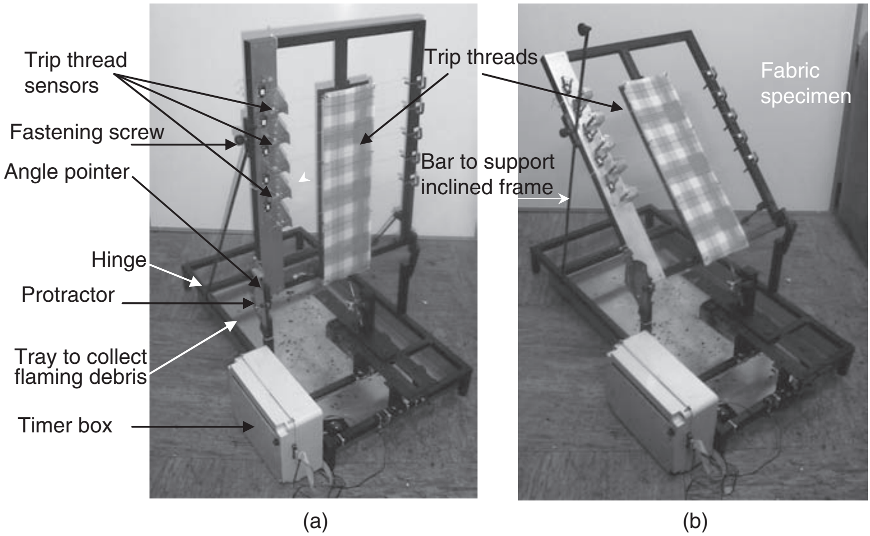
Table 12.1 Minimum ignition times using Test 1 of BS 5438

Fabric sample	Minimum flame application time, s			
	Warp direction		Weft direction	
	Face ignition	Edge ignition	Face ignition	Edge ignition
Light cotton	2	1	2	1
Heavy cotton	4	1	4	1
Poly-cotton (55:45)	3	2	1	1
Poly-cotton (65:35)	2	1	2	1
Polyester	*	*	*	*
Acrylic	2	1	2	1
Light silk	2	2	2	2
Heavy silk	†	3	†	3
Wool	3	3	4	3

* Fabric melted away from the flame.
† Flames extinguished when the flame was moved away.



12.2 Vertical strip test for dripping materials with inclined burner.



12.3 Flame spread test rig: (a) vertical; (b) inclined.

The upward fire spread is far more rapid than downward and horizontal flame spread and hence is adopted as a better means of measuring the fire hazard of a fabric. Therefore, most standards, including BS 5438:1989, standards for curtains and drapes (see Section 12.5.5) and BS EN ISO 15025:2002, use this type of bench-scale test method for measuring vertical flame spread properties of fabrics in particular.

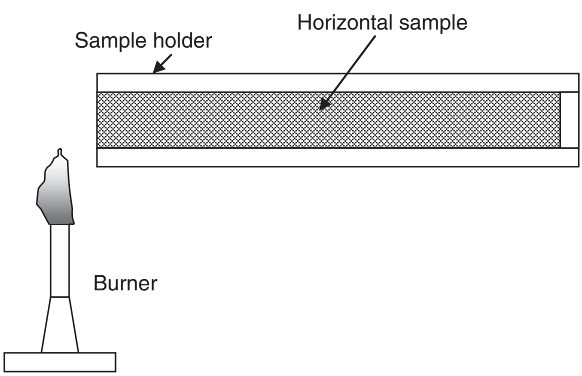
However, fabrics behave differently in different orientations, depending upon their composition and structure. Table 12.2 shows average rate of flame spread for various fabrics at different inclinations. For each fabric, the rate of flame spread decreases as the angle of inclination reduces to 0° as expected. Further analysis[6] of the data in Table 12.2 has shown that the nature and rate of flame spread vary with the angle of sample inclination, area density and fibre content. This is in agreement with theories of flame spread which state that the phenomenon of flame spread is controlled by the mechanism by which heat is transferred ahead of the burning zone, which in turn is strongly influenced by surface geometry and inclination as well as fibre or material type.

The flame spread test in horizontal orientation is relevant for applications where the textile material is used in flooring, ceilings or any other less hazardous horizontal applications. In this test method, the free end of a hori-

Table 12.2 Average rate of flame spread (m/s) for fabrics at different angles of inclination

Fabric sample	90°	60°	45°	30°	15°	0°
Light cotton	57	40	37	30	18	6
Heavy cotton	27	19	18	14	10	3
Polyester:cotton (55:45)	39	30	27	22	19	8
Polyester:cotton (65:35)	37	27	24	21	13	9
Polyester*	–	–	–	–	–	–
Acrylic	23	15	13	11	8	6
Light silk†	–	–	–	–	–	–
Heavy silk	–	–	–	–	–	–
Wool§	23	14	12	10	8	–

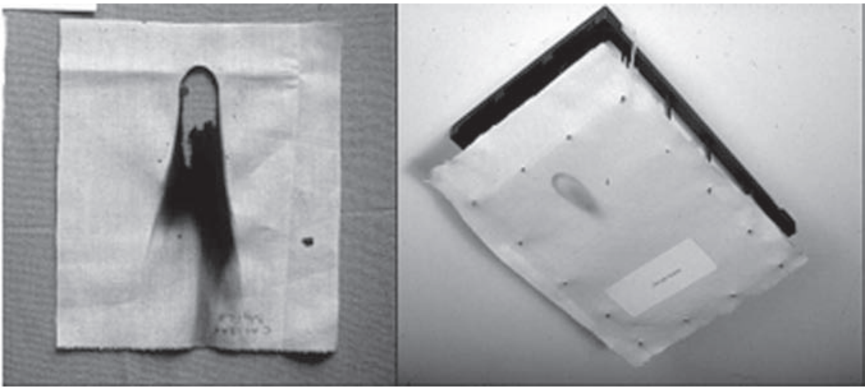
*The fabric did not ignite.
†The flames extinguished on removal of ignition source.
§The flames extinguished on removal of ignition source in horizontal orientation of specimens.



12.4 Horizontal flame spread test.

zontal sample is exposed to the low-energy flame for times up to 15 s in a combustion chamber (see Fig. 12.4). If the sample ignites, then the time to self-extinguish the flame or the time in which the flame passes a measured distance is recorded. This test method is used in various standards for determining the horizontal burning rate of materials used in the occupant compartment of road vehicles, typified by US standard FMVSS 302, BS AU 169a:1992 and ISO 3795:1989.

In the case of flame retarded textiles which are usually tested in vertical orientations, the flame spread is recorded as extent of damage as a hole, char length or weakened (damaged) length measurement of the specimen, and the test is often termed the limited flame spread test. Figure 12.5 shows a Kevlar® (DuPont) aramid and a flame retarded polyester:cotton (70:30) blend fabric specimen after testing in accordance with Test 2 of BS 5438:1989.



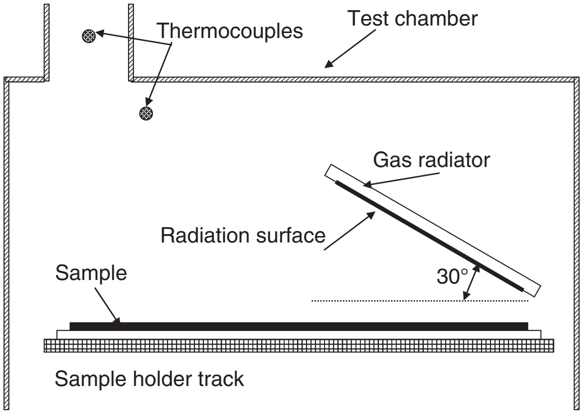
(a) (b)

12.5 (a) Kevlar® aramid fabric and (b) flame-retarded polyester:cotton (70:30) blend fabric.

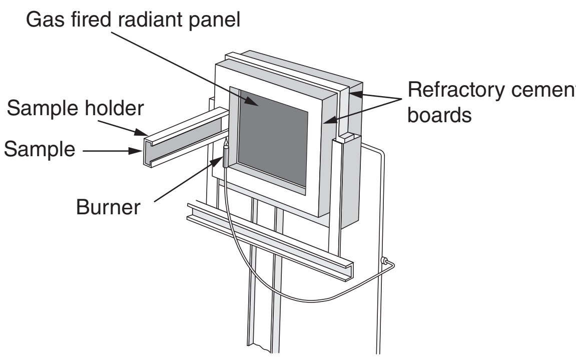
Note that the latter is hardly damaged as expected for such a high performance fibre, while the former has formed a hole and significant char accompanied by sooty smoke deposits.

12.4.3 Flame spread under external heat flux

Measurement of flame spread under external heat flux is necessary where thermal radiation is likely to impinge on the textile materials, for example in the flooring material of a building or in transport vehicles whose upper surfaces are heated by flames or hot gases, or both. This situation is usually encountered in a fully developed fire in an adjacent room or compartment. To simulate this scenario, the radiant panel test typically involves a horizontally mounted test specimen positioned at an angle to the radiant heat source shown in Fig. 12.6. The specimen is exposed to radiant heat from an air- or gas-fuelled radiant panel and the textile fabric specimen is at an angle typically of 30° to the panel face. The mounted specimen is thus exposed to a gradient of heat flux ranging from a maximum of 10 kW/m^2 immediately under the radiant panel to a minimum of 1 kW/m^2 at the far end of the test specimen, remote from the panel. The specimen closest to the panel is often ignited by a small flame and the distance burned until the flame extinguishes is converted into an equivalent critical radiant flux in W/m^2 related to the panel intensity at that point. This test method is the basis of that used by the FAA for assessing flammability of textile composites used in thermal/acoustic insulation materials (FAR 25.856(a)) used in aircraft and has also been included by the EU for fire test approval of floorings such as prEN ISO 9239 and BS ISO 4589-1.



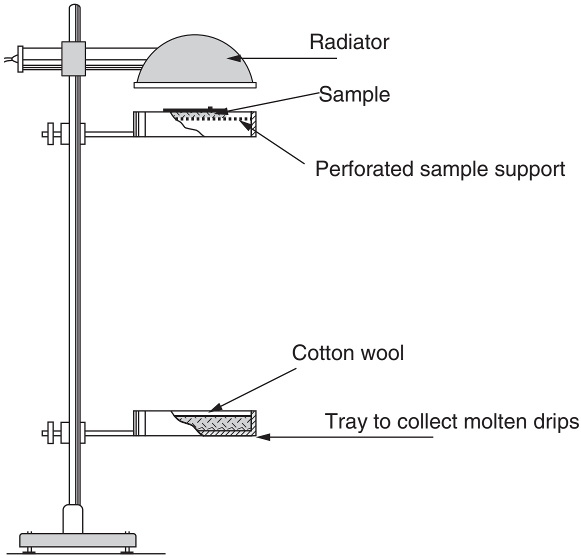
12.6 Schematic of flooring radiant panel test apparatus.



12.7 Radiant panel test for floor coverings as described in BS 476 Part 7.

For textile materials used as interior wall-coverings in UK buildings, including railway carriages, where the fabric could be in a vertical orientation attached to the wall panel, measurement of rate of flame spread under external heat flux is one of the requirements. For such applications, the test method (BS 476 Part 7) essentially requires a vertically oriented specimen (see Fig. 12.7) exposed to a gas-fired radiant panel with incident heat flux of 32.5 kW/m^2 for 10 min. In addition, a pilot flame is applied at the bottom corner of the specimen for 1 min 30 s and rate of flame spread is measured. The same principle is used in the French test for carpets, NF P 92-506.

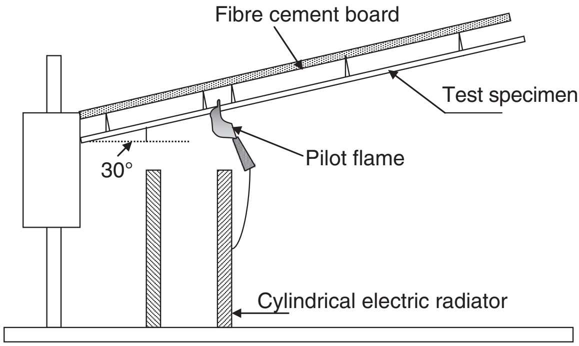
In the French suite of test methods (NF P 92-501–506) for testing building materials, the presence of a radiant panel is a significant test feature.



12.8 Dripping test with radiant heat flux.

Normally if the material shrinks away from the ignition source or away from the vicinity of the radiator without burning, in NF P 92-506, for example, then such materials can be further tested for dripping. The dripping test is defined in NF P 92-505 and is a complementary test to determine burning drops which cannot be assessed in the primary test.[16] The test is shown in Fig. 12.8 and the specimen supported on a horizontal grid is exposed to incident heat flux of 30 kW/m^2. For the specimen to pass the test, the materials should not melt, drip or ignite the cotton wool placed under the specimen holder.

One other particularly important test within this French suite that uses radiant heat flux is the NF P 92-503 Brûleur Electrique or 'M' test for flexible textile materials. The schematic of the test apparatus is shown in Fig. 12.9. The fabric sample is inclined at 30° to the horizontal and is subjected to a radiant heat flux for 5 min and a flaming ignition source is applied to the heated fabric. Time to ignition or time to hole formation, the presence of burning droplets and the length of the damaged specimen are recorded in order to classify materials from M1 to M4, where M1 textiles may be classed as non-flammable, M2 as low flammable, M3 as moderately flammable and M4 as highly flammable. While this test is mainly used in France, Belgium, Spain and Portugal to certify the use of flexible materials in buildings for public use, it affects many UK and other EU manufacturers supplying into EU markets.



12.9 NF P 92-503 electric burner (brûleur) test.