

Fabric flammability burning accidents and the relevance of BS 5438

Accidents de brûlage dûs à la flammabilité des textiles et la pertinence
de la norme BS 5438

Durch Textilflammbarkeit verursachte Brandunfälle und die Bedeutung
der Norm BS 5438

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Foreword

The preparation and publication of this revised Published Document stems primarily, but not exclusively, from the issue of new methods of test in BS 5438.

Much of the information contained in the previous edition remains both valid and valuable and the opportunity has been taken to retain this, but to up-date it wherever possible and broaden its scope. The text now deals more widely with the role of textiles in a fire but although no longer confined to apparel fabrics the emphasis is still on such textiles.

The document is divided into four sections.

- Section one. The reaction of textiles to fire.
- Section two. Statistics relating to the involvement of textiles in burning accidents.
- Section three. The relevance of BS 5438.
- Section four. Conclusions.

The first two sections contain information which will be valuable to a wide readership including all those engaged in the design, testing, marketing and application of textiles and textile products, as well as to those with responsibilities for drafting regulations and legislation concerning the use of such items.

The third section is more specialized in that it endeavours to establish guide-lines for the application of the test methods contained in BS 5438. It is therefore primarily directed towards those responsible for the preparation of performance specifications based upon these test methods, and towards those who may need to cite such specifications in contracts, regulations or legislation. In addition there are points for those engaged in the testing of textiles against prescribed performance requirements.

Section four draws some conclusions from the statistics given in section two and gives recommendations concerning

the preparation of performance requirements linked with BS 5438.

Concern about the misuse and misinterpretation of fire tests and the dire consequences that can result led to the formation of Committee OC/10, Coordinating Committee on Fire Tests. The importance of the role assigned to Committee OC/10 is recognized and one aim of this document is to minimize the dangers of misuse and misinterpretation of the test methods contained in BS 5438. Committee OC/10 has devoted considerable time and effort to problems that stem from the use of misleading or ambiguous terms. Although the final philosophy towards terminology is still developing, Committee OC/10 has recommended that certain words should no longer be used and others should be used only with caution and with qualification. Due consideration of these recommendations has been taken in this publication with regard both to the new material and to that based upon sections of the original PD 2777.

It is stressed in BS 5438 that the results of the test may not apply in situations where there is restricted air supply or prolonged exposure to large sources of intense heat as in a conflagration.

The basic principles discussed in this Published Document still apply in situations which are outside the scope of BS 5438, but attention is drawn to additional factors which may be involved in certain situations, particularly with large ignition sources or large textile structures (e.g. large (non-camping) tents, awnings and inflatable structures), where the results of BS 5438 may not give a true or complete picture of the probable fabric behaviour.

NOTE. The titles of the standards publications referred to in this document are listed on the inside back cover.

Fabric flammability burning accidents and the relevance of BS 5438

Section one. The reaction of textiles to fire

1. General

Textiles are used very widely in the human environment as covering materials: as apparel, floor and wall coverings, upholstery, bedding, tenting and awnings. Because of their exposed situation in these end uses, they are liable to come into accidental contact with flame or sources of heat and their behaviour under such conditions must be studied.

The various processes which may take place when a textile is exposed to a heat source are illustrated in figure 1.

The important factor in this behaviour is that a relatively small heat input is normally required to bring about thermal decomposition and to initiate combustion whilst the heat output from the burning fabric is usually sufficient to maintain the combustion of the textile, and to cause more extensive damage than the original heat source.

Input

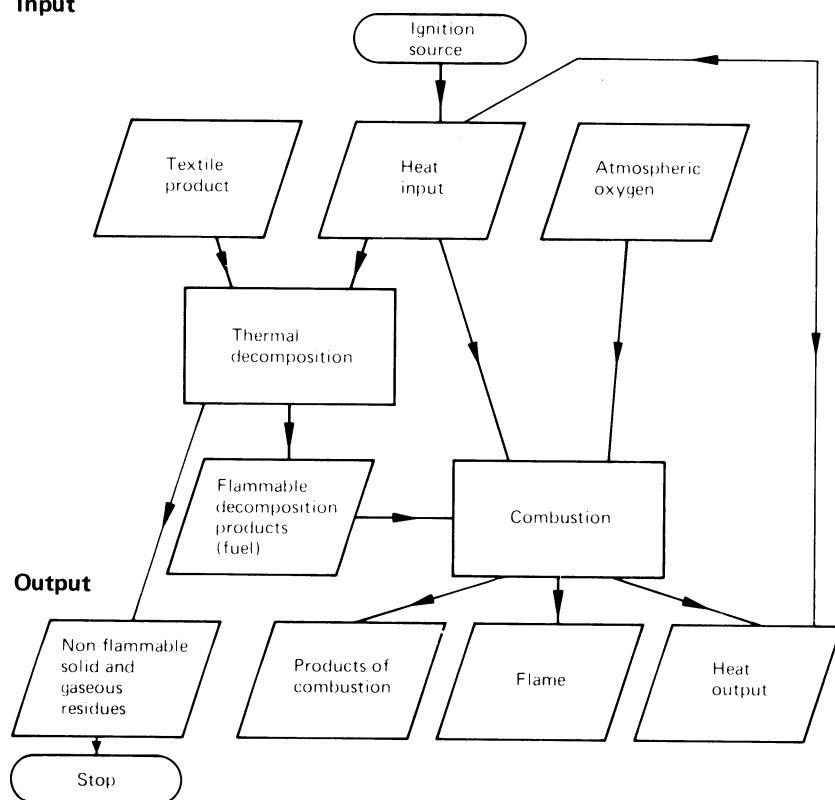


Figure 1. Burning behaviour of textiles

2. Stages in the burning reaction

2.1 Thermal decomposition. When a textile fabric is exposed to heat of sufficient intensity it will decompose to give a complex mixture of solid, liquid and gaseous products, the composition of which is dependent on the chemical nature of the fibres used in its construction, any finish applied to it and rate of heat input. Most commonly used textiles can be decomposed at least locally by a very small heat source, such as a match flame or a glowing cigarette.

2.2 Ignition. Ignition occurs when flammable decomposition products from the textile material are heated in the presence of oxygen. Because textiles are used mainly in the form of thin fabrics, there is normally a large excess of available air, and a small heat source is usually sufficient to cause ignition with flaming, although in some cases only glowing or smouldering may be caused.

Generally, the heavier the fabric the longer the igniting flame must be applied in order to initiate combustion, most of this time being required to bring about sufficient thermal decomposition. However, thermal decomposition does not always lead to ignition (see clause 4).

2.3 Propagation. If a fabric has been ignited locally by the source it will usually continue to burn, since the heat produced by its combustion exceeds that required to bring about the thermal decomposition of adjacent fabric and thus maintain the thermal reaction. Flaming will spread rapidly, the size of the flame and the rate of production of heat both increasing until they are restricted by lack of further flammable material, and the fabric is almost completely destroyed.

The rate of flame spread, when measured on a strip of fabric of a specified width will rapidly accelerate until it reaches a steady state. The size of the flame and its speed of travel up the fabric strip will generally then remain fairly constant until the flame starts to die down when all the fabric has been burned away.

In order to measure the rate of flame spread under the steady state condition, the flame spread over the central portion of a long strip has to be timed. Measurement of the time for the flame to spread a specific distance after application of the igniting flame will give a somewhat lower average rate of flame spread, since it will include the initial acceleration period. In practice, textiles are used in a relatively wide form and the main concern is with this acceleration in flame spread, and the build up of flame intensity. For practical and safety reasons it is not in general possible to observe this unrestricted burning of textiles.

2.4 Termination. Burning of a flammable textile material does not normally cease until all the fabric in the area of combustion has burnt away. In certain circumstances, when in an enclosed atmosphere, burning may be extinguished because of lack of oxygen before all the fabric is consumed. Some fabrics exhibit restricted flammability, that is they cease to burn without being completely consumed. This behaviour is described in clause 4.

3. Hazards arising from burning textiles

3.1 Heat transfer. The burning of textiles is largely dependent on their ability, once ignited, to produce sufficient heat to cause thermal decomposition of additional fabric and combustion of their decomposition

products. A large excess of heat is produced from a burning textile and this is sufficient to cause ignition of other flammable material in the near vicinity, or to cause severe burns to the skin over the short separation distances of normal apparel.

Certain fabrics remain unaffected by heat exposure, or form a solid residue. The insulating effect of this fabric or fabric residue may be important in preventing heat transfer from the igniting source to other materials or to the skin. On the other hand, certain fabrics produced from thermoplastic fibres which melt and shrink away from the ignition source forming a hole without igniting do not provide this barrier effect. Since such fabrics generally do not readily propagate flame, the hazard from small ignition sources is low. Where large ignition sources are present, however, little protection is provided by thermoplastic materials because of their melting characteristics. A hazard may also be caused if debris falling from the textile is flaming and can thus cause ignition of adjacent material.

3.2 Combustion characteristics. When textiles burn, most of the gaseous decomposition products are toxic and when large quantities of fabric are burning the volume of such products may be sufficient to endanger life. Other gaseous products and smoke particles irritate the eyes, making it difficult to find an escape route, and affect the respiratory tract, making it difficult to breathe. Whilst these effects may not be dangerous in themselves, they cause panic and fear in fire situations which can considerably increase the danger.

3.3 Hazards arising from conflagrations. Under certain conditions the effect of burning textiles on the surrounding atmosphere is important (e.g. storage of fabrics). This is particularly so when the burning is extensive, as in a conflagration, when most textile fabrics can be expected to burn and when the number of people involved is large, for example in public buildings and transport. One effect of burning textiles is to decrease the amount of oxygen available in the surrounding atmosphere, partly by consuming the available oxygen and partly by dilution of the available oxygen with decomposition products. However, the effect of the non-textile products which are burning is likely to be greater than the effect of the textile part of the conflagration.

It is not yet possible to predict the behaviour of textiles under conflagration conditions other than by full scale testing. The main concern is that fabrics for use in communal situations should not permit the development of an extensive fire as the result of contact with the small sources of ignition to which the textile may be exposed.

4. Restricting the flammability of fabrics

4.1 Restricted flammability. Certain fabrics exhibit the following degrees of restricted flammability.

- (a) The fabric does not ignite, or
- (b) the fabric ignites, but flaming extinguishes rapidly, or
- (c) the fabric ignites and the flame continues to spread but without significantly increasing in intensity.

This behaviour is the result of limitations in the availability of flammable products and/or oxygen to maintain the heat transfer cycle illustrated in figure 1. It depends not only on the chemical nature of the fibres present but also on other conditions involved in the fire situation (see

clause 5). Changes in the igniting source, restrictions in the dispersion of flammable decomposition products and variation in oxygen supply can alter the type of behaviour observed.

4.2 Methods of modifying fabric flammability. The flammability properties of a given textile may be modified by two basic methods, one involving modification of the fibre and the other involving chemical addition to the fibre.

4.2.1 Chemical modification of the fibre. This treatment may be carried out at the fibre, yarn or fabric stage or, in the case of synthetic fibres, the actual components of the fibre polymer may be modified.

4.2.2 Chemical addition to the fibre. Flame retardant chemicals are applied as additives to synthetic or regenerated fibres prior to the fibre extrusion stage, or as finishes to fabrics. The flame retardants need not be chemically fixed to the textile as they function by reaction on heating to a temperature somewhat below the ignition temperature of the textile. They may be rendered durable to normal wear and cleaning by chemical fixation to, or physical entrapment within, the fibre.

4.3 Action of flame retardant modifications or treatments. The action of any of these modifications or treatments is to interfere with the basic cycle of thermal decomposition and combustion chain reaction. There are several ways in which this can be done and more than one mechanism may operate at the same time.

4.3.1 Insufficient flammable products of decomposition. Some 'high temperature resistant' fabrics owe their performance to their thermal stability which prevents their decomposition when in contact with small ignition sources. Flame retardant modifications or treatments may be used to alter the proportion of non-flammable to flammable products, thereby reducing the ability of the textile to support combustion.

4.3.2 Decrease in thermal decomposition temperature. Thermal decomposition takes place at a low temperature so that the flammable products produced are dispersed before reaching their ignition temperature. Certain thermoplastic fibres with low melting points are difficult to ignite because they melt and shrink away from the ignition source. Flame retardant treatments frequently decrease the decomposition temperature of the fabric, enabling the flammable gases produced to disperse without igniting as long as the ignition source is small.

4.3.3 Oxygen starvation. The supply of oxygen to the flame may be decreased by the action of decomposition products which either act as a physical barrier or chemically react with oxygen. Halogen compounds liberated either from the fibre or from a flame retardant are particularly effective in this way where the fabric is in contact with small ignition sources.

4.4 Additional considerations. Fabrics which restrict flame spread often create larger amounts of smoke and toxic products than fabrics which burn completely. Their use to restrict flame spread has therefore to be balanced by consideration of any increased fume hazard when used in large quantities in potential conflagration conditions e.g. fabric furnishings.

5. Other factors affecting flammability

5.1 Fabric construction. Fabric construction, physical finishing and mass per unit area significantly affect ease of ignition and rate of flame spread; in general, heavy, dense, non-thermoplastic fabrics are less easily ignited

and spread flame more slowly than light, open-structured fabrics of the same composition. However, the rates of loss of mass and consequent heat production are virtually independent of fabric mass for fabrics of a given composition, so that the heavier fabrics will produce more heat per unit area decomposed and more heat from their complete combustion.

5.2 Oxygen supply. Fabrics which will not support combustion in a normal atmosphere may continue to burn in an oxygen enriched atmosphere, whilst the rate of burning of flammable fabric increases as the oxygen concentration is increased. Conversely, decreasing the oxygen supply may decrease the ability of a fabric to support combustion.

5.3 Intensity of ignition source. Increasing the intensity of the heat source beyond the level needed to ignite the fabric does not alter significantly the ignitability threshold of a flammable fabric. However, exposure to intense heat radiation can lead to large scale thermal decomposition and subsequent 'flash over'. Conversely, certain fabrics of restricted flammability are more readily ignited by a small ignition source applied for a short period than by exposure for a longer period or to a more intense source of ignition.

5.4 'Scaffold effect'. Fabrics which do not ignite because they melt away from the flame may ignite if restrained by a non-melting support or 'scaffold'. Small amounts of certain dyestuffs or finishes, blending with non-melting fibres, the use of non-thermoplastic sewing thread or the use of combinations of different fabrics may be sufficient to produce the so called 'scaffold effect'.

5.5 Dispersion of flammable gases. As the gases produced by thermal decomposition normally disperse upwards by convection they are fed into the flame front as it moves up a vertical sheet of fabric. If the fabric is not in a vertical position the gases may be dispersed away from the fabric, or they may be trapped under the fabric and be unable to disperse, thereby affecting the flame spread mechanism.

5.6 Effect of use. The performance of fabrics with restricted flammability can be impaired by the effects of use including soiling, weathering and cleaning processes. There are several possible reasons for this loss in performance including the following.

- (a) Removal of the flame retardant component by physical or chemical action, e.g. chemical action stimulated by ultra-violet in sunlight; physical removal in washing.
- (b) Conversion of the flame retardant to an inactive state by chemical action, e.g. conversion of phosphate flame retardants to the inactive calcium phosphate by ion exchange in hard water.
- (c) Deposition of flammable products such as lime soap, greasy soil, oil and grease on to the fabric during laundering or use can adversely affect the flammability performance of fabrics. This can be a particular problem in certain end uses, for example, workwear, and can be further exacerbated by the fact that such deposits may, in some cases, be difficult to remove by normal cleaning processes.
- (d) Deposition of materials on to the fabric which subsequently react with the flame retardant and deactivate it when an igniting flame is applied. This effect is termed 'antagonism'. Certain alkali or alkaline earth salts may produce this effect on phosphorus based flame retardants.