THIS DOCUMENT:

was originally published by The British Rubber Manufacturers' Association (BRMA) as a booklet on behalf of 20 member companies. The source document for this version was obtained during the early years of the 1980's.

It contains so much information given from the point of view of flexible foam manufacturers that cannot be given today – most of the companies have been swallowed by one company that is still active 40 years later - but the industry has changed far more than that. Nevertheless, much of what is written remains highly relevant today. The figures on production and value will have changed but are unchanged in ways that prove its importance as a material.
The Booklet has been reproduced here by **FRETWORK** as part of our Group's work on the Review of the UK Furniture Fire Regulations – the FFR - but originally known as 'The Upholstered Furniture (Fire) (Safety) Regulations 1988' - with amendments (SI No. 1324 1988 et al).

The text has been taken into a modern word processing format and checked to be as accurate as possible.

The Title:

FLEXIBLE POLYURETHANE FOAM THE FACTS.

Subtitle:

AN OUTLINE OF ITS USEFULNESS WITH A GUIDE TO THE BETTER UNDERSTANDING OF FIRE HAZARDS.

The original document was for some reason, not apparent today, printed in orange with a yellow page background. It is hoped that this version will provide easier reading than the original publication.

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FRETWORK comment:

This document was written during the late 1970's and it shows. Some parts of the document would not be considered 'helpful' in today's World and the burn tests have little relevance due to the change in style and design of Furniture during 40 years and therefore have not been included.

It is, for instance, unlikely that CMHR foam, as used today, was widely available – that fully commenced only after the issue of the present Regulations in 1988. The CONSUMER SAFETY REGUALTION, The Upholstered Furniture (Safety) Regulation, SI 725 was published in 1980.

The Booklet does provide useful data and comment that is still relevant today. The wide application of PUF has not apparently been changed by the concerns made real in the FFR but the issues remain to be properly addressed.

Risk Assessment is only a stage in the Risk Management Process.

It does make clear that PUF and similar materials have very wide and essential uses and, more importantly, seldom give rise to critical safety issues. Where there are problems there are solutions. The Industrial storage of PUF is addressed in terms of that time and that is reflected in modern regulation. (see https://www.hse.gov.uk/plastics/storing-celluar-plastics.htm)

The Booklet does record important details that reflect the debate that was ongoing at the time. The way wool fibre is considered, for instance, is not reflected in the modern belief held in some quarters that it is. A "Naturally flame retardant material".

This is offered as part of the FRETWORK Group's efforts to focus on the technical aspects of the regulations under review.

FRETWORK January 2021.

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The present document ends here.

DATA (not reproduced)

APPENDIX

GLOSSARY

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SECTION 1.

USES AND BENEFITS.

Production of flexible polyurethane started in the UK in 1954 and developed rapidly. By 1978 the estimated turnover of the industry was about £100,000,000, with large numbers employed in manufacture and fabrication.

The main applications for polyurethane foams are in the furniture, automotive, bedding and textile industries together with a wide range of industrial uses such as packaging, and heat and sound insulation.

Flexible polyurethane foams are manufactured by the reacting together of two liquid chemicals, an isocyanate and a polyol, in the presence of various additives. During the reaction gas bubbles are generated and trapped to form a cellular structure. Careful control of the types and quantities of reactants produces a full range of grades from very very soft foams to hard foams.

In 1978 the world consumption of polyurethane raw materials was approximately 2.8 million tons.
1.8 million tons of this was used in the manufacture of flexible and semi-flexible foams for furniture and mattresses (40%) and automobiles, The tremendous growth in the use of urethane flexible foam has been due to the material's unique properties.

These include:

1. Very good cushioning

2. Resistance to fatigue

3. Very good ageing resistance and flexibility between -20°C and 100°C

4, Resistance to mould growth

5. Ease of contouring and shaping by mechanical means

6. The facility of moulding into complicated shapes, even of moulding directly within covering materials.

Furniture

Flexible foams have many applications in upholstery, including chair seats,

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backs, arm rests, loose cushions, tops for stools, mattresses, pram cushions and padding, and carpet underlay.

They have brought comfort on a grand scale into sitting and sleeping, and into leisure activities such as camping and caravanning. They have also added cleanliness to comfort because they are made clean and stay bacteria statically clean.

The availability of urethane flexible foams in many different grades and forms allows a wide diversity of designs, not only affecting appearance but also enabling simpler construction techniques.

Urethane foams, as well as literally bringing new dimensions to styling and design, have undoubtedly reduced the cost of furniture particularly by lowering labour costs.

That is why approximately 95% of all upholstered furniture produced in the UK uses flexible urethane foam as the cushioning material.

Transport

In the automotive industry polyurethane foams give comfort, safety, design scope, manufacturing and processing economies and a reduction in weight, with money-saving benefits for the car owner.

Applications include seat cushions and backs, head rests, arm rests, door and roof panelling, sun visors, steering wheel surrounds, energy absorbing bumpers and external parts as well as some high-performance engineering items.

A typical Western European 1.5 litre car incorporates some 10 kilograms of urethane, a significant proportion of the 25 kgs. total plastic content of the vehicle. The seats of 90% of the automobiles produced in Europe contain polyurethane flexible foam, it can be combined with springs or webbing or be used for full-depth cushions supported on a rigid base. It can be fabricated from flexible polyurethane slab stock but, more frequently, cars today have cushion units moulded to the required shape.

The ease with which seat contours can be produced and the ability to specify properties such as hardness and resilience allows a design scope for production of seats that combine comfort, correct support and insulation of both driver and passenger from the car's vibration. This facility is of increasing importance with

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the trend to lighter, smaller cars.

Use of polyurethane foam in vehicles also enhances safety, since improved comfort means less driver fatigue and the reduction in noise and vibration lessens tension.

Textiles.

Foam-laminated textiles, now commonplace fashion and domestic materials have only been developed over the last decade.

Polyurethane foams are used for this purpose and modern machinery enables them to be peeled as thin as half a millimetre. Great advances have also been made in laminating procedures so that modern bonded fabrics are now easy to wash or clean.

Foam-laminated fabrics are used extensively in the domestic market for upholstery, loose covers and curtaining. In the automotive-industry, foam is bonded to PVC and similar materials for use in topper pads for seats, crash pads, head linings and similar applications.

Bedding.

Latex and polyurethane foams are now generally considered to be the most satisfactory materials for mattresses. They give a continuously supporting and very comfortable sleeping surface that yields exactly to the contours of the body: they are non-allergenic and hygienic; they do not require airing or turning; they are light in weight; they do not make dust or fluff, they are also noiseless. When used with the correct base they give completely individual support in double beds.

Many spring mattresses have foam toppings over the springs or use foam for quilting the cover. Various designs are in use including foam with springs inserted into punched holes.

Packaging.

Polyurethane foam is an ideal material for packaging where goods need to be protected from shock and vibration. It can be cut to the shape of the item to be packaged, and its elasticity and shape retention are especially useful in this context. The range of hardnesses provides a suitable grade for articles of all weights and thickness can be calculated to provide protection from most drop heights.

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Foam also fulfils other basic packaging requirements in that it is durable, resistant to changes in temperature and humidity, and retains its resilience over long periods. In any of these conditions there will be no chemical reactions between the foam and the packaged article.

Flexible foam helps to meet requirements for ease of production and assembly, reduced bulk and light weight. What is more, it is often re-usable.

Acoustic insulation.

Polyurethane foams are excellent sound absorbers. They absorb most of the sound striking the surface and prevent any reflection.

In rooms where people must work in high noise levels or in halls where echo would spoil performance, the foam is simply stuck to the walls or ceilings and covered with a well-perforated protective material or textile. For use as a transmission-loss medium, the foam must be laminated to a heavy flexible mass such as PVC or filled plastisol. This then gives a mass/spring damper system when the foam is fixed to a vibrating surface.

For testing installations, foam makes excellent acoustic wedges or linings for engine test cells. Surface coatings can be applied to prevent oil and/or water soakage.

Other uses

There are numerous other uses of Polyurethane foam such as, pipe lagging, filtration, sponges, seals, padding in sports' shoes, paint rollers, loudspeaker grilles, and many other varied applications but these are unlikely ever to create a hazard.

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SECTION 2.

REDUCTION OF FIRE HAZARD FROM UPHOLSTERED FURNITURE.

Most modern domestic soft furniture contains foam. So it is, of course, present in a high proportion of fires involving such furniture. However. it is far from true that the foam is the cause of all the fires. It is also not true that all soft furnishings were hazard free before the advent of polyurethane foam.

There is, however, clearly a problem with respect to the behaviour of some modern upholstered furniture in fires. Furniture manufacturers and suppliers of materials, such as polyurethane foams to the industry, fully accept the desirability of reducing casualties and damage caused by fires in upholstered furniture.
BRMA have carried out much research often in collaboration with Government and independent laboratories, e.g., in Universities, investigating the problem and suggesting solutions.

The proliferation of new materials and items introduced into modern dwellings often makes identification of the causes of fires in the home extremely difficult. Further complications are the very large increase in cases of arson and the part played by increased alcoholism.

The problem would not, as claimed by some politicians and journalists, simply be solved by banning polyurethane foam. Data published by the Fire Research Station and independent laboratories show that this is not so.

Statistics

The use of polyurethane foams in the UK grew from practically nothing in 1960 to 55,000 tons in 1973. Yet the deaths per 1,000 dwelling fires remained substantially the same as in the period before polyurethanes were available.

In West Germany the use of plastics in general and polyurethane flexible foams in particular is approximately three times as much as in the UK. Nevertheless T. Wilmot reported (European Fire Costs, Geneva Papers on Risk and Insurance, 1979) that fire deaths per 100,000 persons in West Germany were 1.15 against 2.08 in the UK. Clearly such statistics are not truly comparative because many factors are involved, but the figures do not support the direct link between foams and deaths claimed in emotive and misleading articles.

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"In studying changes in fire statistics in the home it is important to take into account not only changes in cushioning materials but also:

(a) Modern furniture production methods which have reduced the thickness of wooden frames etc. increased the amount of upholstery materials and introduced a greater variety of upholstery fabrics.

(b) The greater use of soft furnishings, wall-to-wall carpeting and more electrical appliances, together with central heating which has raised the temperature and reduced the humidity in dwellings.

(c) There has in recent years been a huge increase in cases of arson.

The Home Office states that fires by malicious and doubtful ignition have increased fifteen-fold in the last 20 years. A Home Office Working Party has concluded that 27,500 of some 93,000 fires in occupied buildings in 1977 could have fallen within the definition of vandalism. Leaving N. Ireland aside there were over 60 fatalities from malicious and doubtful ignitions alone in 1976 and a further 30 from children with fire. In dwellings the figures were 26 and 22 respectively (It should be noted that an increase in cases of arson is not restricted to the UK —in the USA it is the No. 1 crime.)

(d) Increased fire deaths due to drunkenness.

Work funded by the Fire Research Station at the University of Glasgow has shown that of the fire deaths so far examined approximately 50% of the victims were under the influence of alcohol at the time of death. The levels of alcohol found are often extremely high.

(It is of interest that anxieties have been expressed in the Russian Press on the increase of fires and fire deaths due to drunkenness.)

Continuing research

The UK foam industry fully recognises the continuing need to achieve improved safety for the consumer with all its products. However, BRMA believe the widespread tendency to focus attention exclusively on polyurethane foam as a fire hazard is regrettable because this tends to distract from other improvements in fire safety.

For more than ten years now the BRMA and government agencies have conducted major programmes of research and product development.

These have been designed
(a) To establish better understanding of the mechanics of foam behaviour in a fire
(b) To inform the industry's customers about the nature of hazards that occur when foam is misused, and
(c) To reduce such hazards both by increased resistance to ignition of the product and also by changing its burning characteristics once it has been ignited by a significant heat source.

Very large sums of money, including over £1 million in the UK alone, have been spent by industry in developing foams of improved fire resistance and foams giving such improvement are now being produced.

In addition to this research by industry, the foam industry, the Fire Research Station, FIRA, the BSI and other bodies have carried out a lot of cooperative work with the aim of promoting safety for upholstered furniture used in both public authority and domestic sectors. Just one positive result of the collaboration has been the BSI fire tests, a necessary step towards achieving this aim.

It is worth noting that the research programmes of the industry and the government both came to the same conclusion. This was that any approach to regulations and improved safety standards for upholstered furniture should be based not on the function and behaviour of individual components but on the combination of cover, filling and overall design. This practical attitude has led to the development of the test methods for the composite product.

These test methods —now BS5852 Part 1, 1979 - form an integral part of the Upholstered Furniture (safety) Regulations 1980 (see Appendix).

The Flexible Foam Group of BRMA, which represents the principal producers of flexible urethane foam, welcomes the approval by both Houses of Parliament of these regulations.

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SECTION 3

A COMPARISON OF THE SPECIFIC FIRE HAZARDS.

Before considering the behaviour of flexible foams and soft furnishings in fire, the consequence of specific hazards to people from real-life fires should be compared. Although this is still being debated, the following assessment probably represents the majority informed view at present.

Hazards in descending order of danger to life are:

1. Increase in carbon monoxide concentration.

2. Development of high temperature.

3. Smoke and/or lachrymators hindering escape.

4. Direct consumption by fire.

5. Presence of toxic gases other than carbon monoxide and a reduction of oxygen.

In assessing what effects changes in cushioning and covering materials have on these hazards the following properties have to be examined:

1. Ease of ignition (ignitability)

2. Speed of flame spread.

3. Heat evolution.

4. Evolution of smoke and lachrymators.

5. Evolution of toxic gases.

Flexible polyurethane foam is not generally meant to be used domestically without an adequate covering material.

The reasons are simple:

1. The porous cellular surface readily harbours dust. This can be difficult to remove and can assist fires to start more easily.

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2. Foam does not have an abrasive resistant surface and will not stand up to direct wear and tear.

3. Foam will discolour relatively quickly on direct exposure to daylight.

Except for small, usually disposable articles such as household sponges and hair curler rollers, flexible polyurethane foam should not therefore be left without an adequate covering material.

Flexible foams are normally used in combination with a variety of other component materials such as fabrics and other stuffing materials. Work by government and industry laboratories has shown that the flammability performance of one component material may bear no relationship to the actual flammability performance of finished products made up of a number of component materials.
The same foam with different covers will require a very different ignition source, the fire will proceed at a very different rate and the rate of smoke evolution will also be determined by the nature of the cover with any particular foam.
(See pages 8,9,10 & 13. – not reproduced, FRETWORK)

Contamination of the covering material with alcohol, dust and sugar can affect fire performance —and design of the furniture is also very important.
(See Figures 2&3.)

All the above factors must be taken into account when considering data on the fire performance of flexible foam.

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SECTION 4.

INTENSITY OF IGNITION SOURCES REQUIRED TO IGNITE UPHOLSTERED FURNITURE.

When considering ignition sources it is important to distinguish between smouldering ignition from such sources as cigarettes and other smoking materials and ignition of small open flames such as matches and cigarette lighters.

Research has demonstrated that there are substantial differences in the way fires develop in upholstered furniture depending upon whether ignition is caused by smouldering or open flame. Some materials with good resistance to small open flames have a tendency to give smouldering ignition and vice versa, and it is therefore important that both types of ignition be studied.

The Society of Plastics Industry in the USA have studied the statistics assembled by the US Fire Administration and have concluded that in the USA smouldering ignition of upholstered furniture from such sources as cigarettes and other smoking materials causes ten times as many fire deaths, five times as many injuries and four times as many fire incidents as ignitions caused by small open flames.

The State of California Bureau of Home Furnishings are also of the opinion that smouldering ignition is the cause of the majority of fires in upholstered furniture and have pointed out that cotton batting, one of the most extensively used filling materials in furniture and bedding for many years in the USA, has proved to be an insidious material in terms of smouldering combustion.

The fire-statistics available in Europe do not, at present, allow a distinction to be made between cigarette and match ignition. It is the opinion of BRMA, however, that **the substantial percentage of UK casualties in the early morning, 00.00 to 05.00 hours is a strong indication of smouldering ignition. (FRETWORK emphasis).**

The work by Harland et al in the fire fatality study by the team at the University of Glasgow has also established that many fire victims have levels of alcohol in the blood which would severely incapacitate them. This evidence would support the possibility of the careless discarding of cigarettes or of victims going to sleep still holding a cigarette.

Uncovered flexible foams even without flammability modifying additives are normally resistant to smouldering ignition by cigarette ends. This is an

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important advantage over some conventional filling materials such as cellulosics. This property is retained when the foam is covered with many of the fabrics used in modern soft furnishings, although smouldering can occur with some covering fabrics, e.g. cellulosics.

Uncovered NFR foams can, however, be ignited by open flame ignition sources such as matches. This is perhaps not too surprising when one considers the finely divided nature of foam and can be compared with the ease of ignition of wood chips compared to a solid block of the same wood. !

The earliest attempts to make foams resistant to small open flame ignition sources was by the use of flame retardant additives containing phosphorus and halogens. These additives increase cost but bring some improvement in esistance to small open flames such as matches. With some foams they can, however, lead to increased smoke and gas evolution when they are involved in a fire,

Care is necessary when generalising on the effect of these flame retardant additives on smoke and gas evolution. In recent years two types of foam have been developed which give improved flame retardance when small flame sources are used, These foams are usually referred to as 'High Resilience' foams and Neomorphic foams. These two types of foam have changed melt and decomposition characteristics so that when exposed to high temperatures they melt or decompose below the temperature of ignition and 'shrink away' from the flame source.

While an improvement is obtained against small flame sources, protection is not given against larger sources such as sheets of burning newspaper.

Another approach to improve ignition resistance (and fire spread) has been the incorporation of large quantities of inorganic materials such as aluminium hydrate. Although major effects on ignition resistance can be achieved, the effect on cost, density and physical properties are such that this solution is only practicable for certain end uses and such foams are often used as a wrapping around a foam interior.

As stated previously, however, when flexible foam is used in soft furnishings the degree of provocation required to set fire to these constructions is determined by the size of the fire source and by the complete construction, i.e. in the case of furniture, the cover, the fillings, the design and, of course, the surrounding materials.

In the period 1973/75, before a BS method was being developed, BRMA conducted a series of upholstered furniture burn tests in which 72 combinations of covers and fillings were tested for ignitability and spread of burning. (Spread of burning is discussed in Section 5. The results of the ignitability tests are given in Figure 1.)

The following conclusions were drawn:

1. The cover is significantly more important than the interior in determining the ease or difficulty with which upholstered furniture may be accidentally set on fire by, for instance, a lighted match or cigarette, or a radiant heater.

2. The extent to which smoke is produced by burning is related to the speed of combustion. The cover is much more significant than the interior filling in determining the rate of burning and the amount of smoke produced.

3. Covering fabrics capable of smouldering can, in certain circumstances, cause flexible polyurethane foam to smoulder as well, although on its own the foam is not normally capable of supporting this slow form of combustion.

4. Covers capable of smouldering which can also readily undergo transition to flaming combustion will expose the upholstery filling to a greater fire hazard.

5. Synthetic covers, whether of fibres or continuous coatings, may expose the upholstery fillings to greater fire hazard if such covers readily melt or shrink back when exposed to intense heat sources.

More recently the performance of a great variety of textile covering materials over foam and other filling materials have been reviewed by Marchant (FIRA Manual No. 17 —June 1979) and Damant, State of California— Bureau of Home Furnishings, Report No. SP 77-1 (Jan. 1977) and Report No. SP 81-1 Feb 1981

In the FIRA Manual No. 17 of June 1979, Marchant has reported on the FIRA work on the ignitability of domestic upholstered furniture.

The report covers a range of fabrics and fillings. Using broad groupings of fabric construction and fibre type, covers are categorised into nine different types. Similarly fillings are grouped into types based on a large number of tests using the cigarette and simulated match

SECTION 5.

SPEED OF FLAME SPREAD (RATE OF FIRE DEVELOPEMNT).

The rate of fire development of furniture containing urethane foam is, as stated previously, a function of the composite not merely the foam alone.

Storage of uncovered foam in plants and warehouses does require care and a fire involving large quantities of foam is a serious and hazardous affair. The Fire Research Station have carried out tests on this subject to illustrate the hazard to manufacturers of insufficient precautions in storage of large quantities of foam.

The temperatures and gas concentrations found by the FRS in its investigations of the bulk storage of foam (Dept. of Employment Data Note 29) have been misquoted repeatedly by the emotive critics of urethane foams in relation to domestic fire hazard.

Although it is impossible to generalise about the development of fires in upholstered furniture, extensive programmes of upholstered furniture burn tests by BRMA, FRS and others have given data as to how fire spread in furniture can vary.

Four particular factors may play a significant part in determining the rapidity of spread of fire where an upholstered article of furniture is the first to become ignited:

1. The nature of the covering materials used.

2. The design and geometry of the article in question.

3. The type of flexible polyurethane foam employed.

4. The ventilation available to the location.

The last factor is outside the control of the furniture manufacturer, but consideration should be given to the other three for the following reasons:

(a) Upholstery Covering Materials

The cover of any item of furniture is not thick and any material capable of easy penetration by a flame or smouldering source of combustion will expose the

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upholstery filling. If the covering material is capable of being consumed rapidly by flames, it can make a significant contribution to the heat evolved, the fire spread and its growth in intensity will also be rapid, affording no real protection to the upholstery filling beneath.
Similarly, covering materials which melt in the presence of heat or flame may readily expose the upholstery substrate, leading to a more rapid spread of flame.

Ideally a covering material, when subjected to a fire source, should char without splitting or melting and should retain some thickness and preferably form or retain a continuous skin to help prevent flame penetration.

Some natural materials, such as wool in moquette construction, fulfil most of these requirements, whereas other natural materials, like cotton, do not unless specially treated.

Synthetic materials, whether man-made fibres or plastic coatings, will behave differently according to their chemical formulation, the construction of the cloth, and the backing combination.

These factors are illustrated in Figure 2 where the speed of burning of chairs covered with different fabrics and upholstered with different materials has been monitored from BRMA Furniture Burn Tests at RAPRA. Additional reference may be made to the FIRA publication referred to previously and to the following government publications listing upholstery and furnishing materials, with their relative burning rate:

BUILDING RESEARCH ESTABLISHMENT CURRENT PAPERS CP 18/74, CP 3/75 and CP 21/76.

Report CP 21/76 reports on burning full-scale simulations of fully furnished rooms. The authors state that furniture of modern construction, i.e. light-weight frames, foam cushions covered with synthetic fabrics, are more easily ignited and burn more fiercely than heavy furnishings of traditional construction. They report, however, that improvements in the fire properties of modern furniture are readily obtainable technically. They also note that traditional furniture smoulders whereas modern products generally do not.

The International Isocyanates Institute in their report RP-75-1-13 have also shown the major effect of fabrics and interliners in large-scale fire trials using a standard polyurethane foam. Major differences in the rate of development of temperature and carbon monoxide concentrations were observed. (See Figures 8 & 9.)

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(b) Chair Design

This is not a field in which the flexible polyurethane foam industry claims any expertise. However, as a result of the extensive research programme BRMA has conducted on the fire behaviour of upholstered furniture, the following data were observed and may be of interest to the specialists in the trade. It is possible that some of these data may be more appropriate to the contract furniture sector where the element of fashion in design may have to be subordinated to functional and safety requirements in multiple occupancy locations.

1. Vertical surfaces generally burn three times faster than horizontal.

2. Burn rates in vertical planes are reduced where the surface is broken by sufficiently wide “furrows”.

3. Where there is a gap at the juncture of the back and the seat cushions, a cigarette ‘trap’ is obviated.

4. Where a void exists between the angle of the back cushion and the fabric which forms the back of a chair or settee it can intensify a fire that may have been caused by a smouldering ignition source at the base of the back cushion because additional (although hidden) ventilation is present.

5. Combination of some covering materials placed over foam can create an insulation layer so that if a smouldering cigarette burned its way through to a foam cushion core, **the insulation effect could cause the foam to continue to smoulder undetected, resulting in a delayed fire. (FRETWORK emphasis)**

6. If upholstery covers are under undue tension, they may split when subjected to sufficient heat, thus exposing the foam fillings and permitting them to contribute more rapidly to the development of a fire.

7. If flexible polyurethane foam ‘crumb’ is used as an upholstery filling, its containment by an inner covering acts as an additional protection in case the outer cover is damaged by fire, accident or general wear.

8. Research work by the International Isocyanate Institute in particular and and others into the behaviour of upholstered furniture in fire has shown that the use of an interlayer between the upholstery fabric and the filling affords a

degree of extra protection to the inner core of the upholstery and can reduce the rate of flame spread by a significant extent.
Consumer protection and safety is an issue gaining increasing attention. Design and the properties of combinations of materials are important factors in the fire performance of furniture and improvements in fire safety are likely to be most effective when requirements are considered at an early stage of furniture design. However, consumers must realise that some compromise with cost and aesthetic factors may well be necessary.

(c) Grades of Flexible Polyurethane Foam

The formulation of foams with fire safety considerations in mind has always been part of the foam manufacturers' policy, as referred to previously.
When such foams are used in furniture and bedding they can confer some benefits towards resisting ignition and reducing fire spread but the primary role of the cover in such a situation has to be stressed.

Some critics of polyurethane flexible foams appear to contend that all other more conventional cushioning materials are very difficult to ignite and if they are ignited do not generate heat, smoke or toxic fumes. This viewpoint is not supported by the evidence available.

As stated previously with reference to ignition, it is now widely accepted that polyurethane flexible foams and many synthetic fabrics are not readily ignited by a smouldering cigarette whereas cotton fabrics and cotton batting materials are. Since many experts believe that cigarette ignition is the cause of the majority of fires leading to fatalities this is clearly important.

While some flexible foam/synthetic covering materials burn fiercely once ignited, others do not. Many conventional materials also bum and the difference in hazard between them and polyurethane furniture is not necessarily significant in affecting the degree of hazard.

For instance, in one set of tests in the USA, J. Fang of the National Bureau of Standards has compared the performance of chairs bought from a local furniture outlet. The results (J. Fire and Flammability, 1976, Vol. 7, p.368) show that the fire temperatures measured were not greatly different for polyurethane foam padding, cotton padding and a wood crib control.

A further most important point should be made in relation to data available on fire spread in upholstered furniture. Many of the tests carried out use lighted newspaper ignition - sometimes several sheets of newspaper. This technique, while valid in gathering data, does tend to cover small but important differences in ignition resistance and also leads to a more rapid rate of fire development than would be met if smaller ignition sources were used.

It is sometimes assumed that polyurethane materials evolve a much greater amount of heat for a given weight than other materials. This is not so as is shown by the following:

(a) The heat of combustion of polypropylene used in fabrics and plastics is 44 MJ/Kg compared to polyurethane flexible foam 28 MJ/Kg.

(b) When comparing foam with wood comparison can be on a weight/weight basis or more sensibly on a volume-to-volume basis.

(1) Weight basis

Polyurethane Foam	= 28.2 MJ/Kg
Oak	=16.7 MJ/Kg
Beech	= 17.5 MJ/Kg

(2) Volume basis

Polyurethane Foam (Density 22 Kg/m^3)	= 620 MJ/cu. metre
Oak	= 12,800 MJ/cu. metre
Beech	= 13,400 MJ/cu. metre

The heat of combustion {calorific value) should not, of course, be confused with the rate heat is evolved in a fire since this is also affected by the speed materials burn.

Fire Spread in Bedding and Mattresses.

The proportion of all foam mattresses in the country as a whole is still relatively small (about one in five) but in hospitals the great majority of mattresses are foam because it has been found to give immobilised patients support with a more adequate distribution of weight.

The Department of Health considers that the 'made-up' bed is the unit to assess for fire hazard and that, whatever the construction of the mattress, the bed should be covered with bedding materials that will not support smouldering combustion or flame.

It is important that ignition and rate of fire growth should be reduced by the use on the top of the bed of fire-retardant blankets and counterpanes that will effectively cover the flammable components.

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The results of the government sponsored research programme on furniture flammability indicate that selection of bedding is one of the most significant factors in reducing the fire hazard in bedrooms, the other factor is the proximity of bedroom furniture units.

The government is funding work aimed at devising fire tests for assessing bedding materials and fire testing funded by the National Bedding Federation is also in progress.

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SECTION 6.

SMOKE.

The most important effects of smoke in fires in buildings are to:

(a) Impede the escape of the occupants by obscuring vision and therefore prevent the location of exits. This delay increases the risk of exposure to toxic gases or fire.

(b) Impede fire-fighting.

Some smoke particles have irritating coatings of aldehydes, acids etc. They may lodge in the nose, mouth and throat or be swallowed, producing nausea and vomiting, thus lowering escape efficiency, This factor is not, however, as vital as the reduction of visibility.

A limited amount of smoke can be a visible warning that something is wrong but any significant fire generates large volumes of smoke and this is one of the major fire hazards.

Butcher and Parnall provide in their book, 'Smoke Control in Fire Safety Design', a startling illustration of the rapidity with which smoke can fill a small room. It shows that a lecture room 100 $metre^2$, 6 metres high, would, in the event of the fracture of a glass apparatus containing a flammable liquid, fill with smoke down to shoulder height in 20 seconds.

They also point out that in a small domestic lounge (35 m^2) one pound of wood or polyurethane burning would produce enough smoke to reduce the visibility to about a metre.

Work by Thomas of the Fire Research Station is quoted which compares the result of burning 220mm x 220mm samples of building materials in a room 34 m^2 for 20 to 40 minutes. This work showed:

(a) That the variation in smoke produced can also depend upon how the material burns, i.e., smouldering or flaming.

(b) That the visibility in metres when polyurethane foam was burnt was not significantly different from birch plywood, chipboard and hardboard.

When flexible polyurethane foam burns it produces dark smoke and, if large quantities are alight, the smoke output will be considerable. Taken in isolation, standard grades of flexible polyurethane foam are far from being the highest generators of smoke but, in a typical furniture fire, it is likely that several materials will be burning at once and so comparison of individual smoke levels for separate materials is not relevant. As with rate of fire development, smoke development is a function of the composite.

The importance of composites can best be illustrated by the following data quoted by Dr. Woolley et al, Fire Research Station, in the Building Research Establishment Paper CP 30/78:

(a) Page 10 The total volume of smoke obtained with standard uncovered polyurethane foam is about 25 cu. metre.
When covered the range lies between 10 (F R cotton) to 196 cu. metre for PVC.
(b) Extract from Table 13, Table 17:

	Maximum Smoke Density Smoke ODM.	**Integrated Smoke at 10 Mons. M^3 OD ml.**
Standard p.u. foam	0.36	249
Standard p.u. foam/wool fabric	0.19	14.1
Standard p.u. foam/polypropylene fabric	0.74	56.2

BRMA tests on burning upholstered furniture have concentrated on measuring the time taken for smoke generation to reach dangerous levels, namely those which are likely to result in victims being trapped in a building by smoke cutting off escape routes, this has been termed the "Escape Time' in our work. The way this has been done is to use the visibility limits determined by the Home Office Fire Inspectorate based on the optical density of smoke necessary to render an internal area 'smoke logged; i.e, when visibility is reduced to 4.5 metres.

It has been noted already that flexible polyurethane foam is not generally in use without a covering material and that the latter plays a significant role in determining the speed at which smoke will develop from, say, a chair on fire. Figure 3 shows how upholstered chairs set on fire produced different visibility 'escape times' and the significances of the type of covering material used in contributing to the smoke levels produced can be seen in perspective. Thus the 'escape times' for chairs containing flexible polyurethane foam filling were of a very similar order to those for chairs containing traditional material fillings and the results show that, in completely closed rooms with no ventilation, 'smoke logging' is likely to occur within to 8 minutes, whether the chairs consist of traditional or man-made materials. The escape times shown in Figure 3 were recorded at ‘head height’ but there was no significant difference when the readings were taken at ‘crawling height’ In laboratory comparisons of smoke evolution the reduction of light as it passes through smoke is measured. It must not be assumed, however, that comparative figures obtained by this method define the hazard to fire victims in obscuring vision and hindering escape.

Measurements of optical instruments can be misleading in that irritation of the eye by some types of smoke particles or gases can cause more obscured vision than would be indicated by the readings. Reference is, for instance, made on page 17 to the finding in 400 actual fires studied in Boston that Acrolein, which is generated from wood and cellulosic products, was present in significant amounts and in over one half of the samples analysed the Acrolein concentration exceeded levels capable of causing significant eye and respiratory injury.

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SECTION 7.

TOXIC GASES

Fire deaths which are not caused by direct consumption by flames can be attributed to the following:

(a) High temperature of inspired gas
(b) Smoke
(c) Oxygen depletion
(d) Toxic gases.

Any or all of these factors can be exacerbated by pre-existing disease such as cardiac condition, infirmity, drugs or by the frequent involvement of alcohol.

(a) High Temperature of Inspired Gas
Fire gases may be very hot and although the upper respiratory tract is an excellent air conditioning unit, it can be overloaded, and pulmonary burns can result. Wet air is more dangerous because of its higher heat content. Prolonged breathing of air at a temperature of 100°C can damage the respiratory tract.

(b) Smoke
Smoke, here defined as the airborne products of combustion, contains liquids and solids in aerosol form. Aspects to be considered are obscuration of vision and transport of particles into the lung.

(c) Oxygen Depletion
During combustion oxygen is consumed and the concentration in the air near a fire is lowered from a normal value of 21%. Oxygen lack can be rapidly fatal if it falls below 6%. Slightly higher concentrations, in the region of 6-10%, will result in collapse, unconsciousness and irreversible damage if prolonged. 10-12% oxygen will severely impair mental function, which will in turn stop effective escape action. Even concentrations of 12-15% oxygen will cause some impairment of higher conscious functions and could impair escape (Kimmerle, 1974). Prolonged exposure lo toxic gases could therefore result.

(d) Toxic Gases
Toxic gases are evolved from all organic materials when they bum whether natural or synthetic. Carbon monoxide and carbon dioxide, see page 15, are produced in various proportions according to the material and combustion conditions. All nitrogen-containing polymers (including wool, leather and polyurethanes) give off hydrogen cyanide (see page 16).

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The toxic gases given off when flexible urethane foams burn have been the subject of much incorrect, inaccurate and emotive comment. The products of plastics combustion in general and urethane in particular have been well documented in work done by government, Universities and the chemical industry itself. Some critics have taken these data and passed emotive comment on them without putting them into context against data on traditional materials such as wood, paper. wool etc.
The subject of the gases given off when materials burn is, of course, a proper subject for debate and study. since (a) Changes in fire precautions and fire fighting facilities have improved the chances of escape from the primary fire, with reduction in the number of fatalities due to direct contact with flames. {b) Those who escape from the flames may now be seen to be overcome by fumes, whereas before they could have been classified as burnt. Diagnostic procedures are now more discriminating.

(c) Changes in social habit and improvements in standard of living have led not only to higher density of furnishings and fittings but also the increasing use of a variety of new materials, not only in furnishings but in electrical appliances, TV sets etc.
This can lead in some instances to a more rapid development of fire and the consequent more rapid build up of gases.

In assessing these new materials they must be assessed both relatively and absolutely; relatively in the extent to which they produce more toxic gases than traditional materials and absolutely in so far as they may generate toxic products not hitherto encountered in fires and in quantities which will introduce a hazard additional to or greater than that represented by the gases ordinarily found in fires.

It is important at this stage to distinguish between “toxicity” and “toxic hazard” since ignorance of this difference has led to a great deal of confused comment in relation to fire gases.

Toxicity may be defined as the adverse effect of foreign materials) upon the body. An assessment can be made after one short exposure (acute toxicity) or after multiple or prolonged exposure (chronic toxicity).

Toxic hazard places the toxicity of the material into the context of its use, which takes into account:
amount present (concentration)
mode of use
duration and frequency of exposures
toxicity

Dr. J. Doe has suggested that the distinction between the toxicity and the toxic hazard can be appreciated from the following example; a widely experienced combustion process releases the following compounds into the atmosphere:

Human Toxicity
(parts per million)
Carbon monoxide 4000 ppm fatal 1 hr
Hydrogen cyanide 130 ppm fata 1 hr
Nitrogen oxides 250 ppm fatal 1 hr
Acrolein 10 ppm fatal 1 hr
Benzpyrene known human carcinogen
Polyphenols known human carcinogen

Thus the toxicity of the combustion products from this material is very high. However, the toxic hazard is judged by many people to be very slight for the table represents a portion of the products of tobacco smoke. To assess the toxic hazard dispassionately, tobacco smoke would be graded:
acute toxicity —low, chronic toxicity — fairly high.

With the development of highly sensitive techniques of chemical analysis a very great number of different products, some of them 'toxic, may be identified in fire gases but the hazard, if any, is determined by 'how much' and what rate it is produced.

The gases given off when polyurethane flexible foam and many other natural and synthetic materials burn can be divided into two headings reflecting their principal mode of action:

(a) Immediately Acting Systemic Poisons
e.g. carbon monoxide, hydrogen cyanide, carbon dioxide.

(b) Irritants
irritants have at least two actions. They can cause incapacitating sensory irritation of the mucous membranes of the eye, nose and upper airways. This will restrict vision and can lead to panic but, in itself, sensory irritation is not life threatening and may even provide an early warning of hazard.

However, irritants may ultimately damage tissue by their corrosive effects. Compounds such as hydrogen chloride, sulphur dioxide, oxides of nitrogen and acrolein can provoke not only sensory irritation but cause oedema of the upper airways and the lung itself after severe exposure. This is characterised by the | build up of fluid in the lungs, which interferes with the diffusion of oxygen into

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the bloodstream and can be fatal. This can take up to three days to reach a peak although the effect can occur more rapidly at higher concentrations. The

effect of these gases is often determined by the total dose received which is a product of both concentration and duration of exposure. This contrasts with systemic poisons such as carbon monoxide which reach equilibrium quickly and usually cause few delayed symptoms.

Carbon Monoxide
Carbon monoxide is the most commonly found toxic gas in fires and will be formed whenever incomplete combustion of organic materials takes place. It reacts preferentially with haemoglobin, the oxygen carrying pigment in the blood, to form carboxyhaemoglobin (COHb) and causes death by oxygen lack.

The combination of carbon monoxide with haemoglobin is reversible and carbon monoxide will be exhaled as the victim breathes clean air. A complete recovery usually occurs, except when there has been so severe an anoxia that brain damage has occurred.

Flexible polyurethane foam, like most other plastics and natural materials, is a carbon-based substance and when burnt will release carbon monoxide, a colourless and odourless gas. Carbon monoxide is, in fact, the most significant gas released during the burning of all organic materials, including flexible poly-urethane foam. It is present in any fire atmosphere and is generally accepted as being the cause of the majority of deaths among victims from fire.
An indication of the variation of carbon monoxide concentrations with different constructions is shown in Figure 8.

Flexible polyurethane foam is extremely light in relation to the volume it occupies, and its prime role is to fill volume and give support in that space. Although it will give off more carbon monoxide when burning than the same weight of say wool, nylon and acrylics, the actual release of carbon monoxide may be no greater and could well be less than more dense materials which may be burning at the same time. On an equivalent weight basis, the release of carbon monoxide from burning flexible polyurethane foam is of much the same order as from burning cellulosics such as cotton, as can be seen from Table 1.

Table 1 Toxic Products of Burning Materials

Materials	Carbon Monoxide Released (mg/g of sample)
Wool	0.232
Acrylic Fibres	0.297
Nylon	0.436
Cellulose (Cotton)	0.500
Flexible Polyurethane Foam	0.505—0.580

(Source: Fire Prevention Journal, No.99, August 1973)

Carbon Dioxide
This gas will be produced when most organic materials bum though the quantity will depend on such factors as the amount of moisture and oxygen present. The toxicity levels for carbon dioxide are much less critical, being some fifteen times lower than for carbon monoxide, and flexible polyurethane foam burning will not normally create any undue hazard from carbon dioxide release.

Hydrogen Cyanide
When burning all nitrogen-containing polymers {including wool, silk, gelatine, hair, tobacco, leather, nylon, ABS and polyurethanes) give off hydrogen cyanide and nitrogen oxides. Hydrogen cyanide inhibits cellular enzymes which are vital for the utilisation of oxygen and depresses respiration leading to unconsciousness and death. Concentrations over 100 ppm are dangerous to life. Recovery usually occurs if the victim is rescued from the HCN-containing atmosphere before death or brain damage occurs.

Both hydrogen cyanide and carbon monoxide cause incapacitation, loss of consciousness and mental impairment and therefore can hinder escape from a fire. This means that the victim remains longer in the fire and is at greater risk of being burned or exposed to other toxicants.

The release of hydrogen cyanide by burning flexible polyurethane foam has been the subject of very ill-chosen analogies, which have led to such phrases as ‘Gas Chamber’ being used.
Any organic material containing nitrogen will release hydrogen cyanide when burned. It was seen on page that wool, nylon and acrylics released less carbon monoxide than polyurethane foam, but these same materials will generate several times more hydrogen cyanide than will the same weight of flexible polyurethane foam. (The rate of weight loss of materials in a fire will, of course, determine their contribution to the total gas concentrations.)

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Table 2 Toxic Products of Burning Materials

Materials	Hydrogen Cyanide Released (mg/g of sample)
Polyurethane Foam	0.031—0.041
Nylon	0.116
Wool	0.124
Acrylic Fibres	0.260

(Source; Fire Prevention Journal, No. 99, August 1973)

Table3 Hydrogen Cyanide (HCN) measured in Pyrolysis Products

Material	HCN Released (ug/gramme of sample)	
Materials	In Air	In Nitrogen
Cotton	93-130	85
Nylon	780	280
Paper	1100	182
Flexible Polyurethane Foam	1200	134
Wool	6500	5900

(Source: Modern Plastics, February 1973. 'Fires, Toxicity and Plastics')

Additionally, it should be pointed out that it is only at temperatures above 750°C that hydrogen cyanide starts to be released significantly from burning polymers, with maximum release in the temperature range 900°C—1000°C. At this level, combustion products such as carbon monoxide will already have been given off in considerable quantities (CO starts to be released at about 300°C) and this, coupled with the high temperature level in question, means that human life will very probably be endangered from carbon monoxide levels and elevated temperature atmosphere before hydrogen cyanide release reaches hazardous levels in a burning room.

Harland et al of the University of Glasgow are carrying out a fire fatality study under contract from the Fire Research Station. Although still in progress they have determined that

{a) Carbon monoxide was present in fatal levels in one half of all cases.

(b) Alcohol was found in the blood of many fire victims and approximately

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50% were intoxicated. The level was often high enough to produce incapacitating intoxication except in habitual heavy drinkers.

{c) The range of HCN in the blood observed in fire fatalities varied from zero to 130 p mol/1 with a mean level of 30 p mol/1. Harland et al observe that levels in excess of 100 p mol/1 (5% of all cases) can be regarded as potentially dangerous although a high cyanide level was usually accompanied by high CO levels.

BRMA would point out that the limited number of cases with significant levels of HCN and the absence of significant levels in the study of gas concentrations in 300 actual fires in Boston, USA, (page 17) should be contrasted with the emotive and often hysterical statements made by the anti-urethane lobby concerning the evolution of HCN from foam.

High concentrations of hydrogen cyanide have been measured in fire tests by the Fire Research Station involving large industrial quantities of flexible polyurethane foam, but in small scale fire tests by the International Isocyanates Institute on fully furnished rooms containing polyurethane-foam-filled furniture, high concentrations were not measured.

It is important, however, to recognise that as with carbon monoxide concentrations of hydrogen cyanide, which are not fatal in themselves, may lead to mental impairment and therefore hinder escape.

Nitrogen Oxides

Burning flexible polyurethane foam will release much the same amount of : nitrogen oxides as the same weight of wool, leather and nylon.

As with hydrogen cyanide. Nitrogen oxides are only released from burning nitrogen containing materials at high temperatures when carbon monoxide concentrations and hot gases will already represent the major hazard.

Isocyanates

The vapours from this chemical can be very harmful to inhale, causing respiratory irritation. It is used in the manufacture of flexible polyurethane foam and strict care is taken to protect operatives who work with it. This must not be confused with the fact that when flexible polyurethane foam burns it can release very small quantities of isocyanates.

In a typical flexible polyether urethane foam, about 25% of the weight of the foam is contributed by the TDI {toluene di-isocyanate).

Work by Woolley at the Fire Research Station has indicated that when heated in pyrolysis tubes in the laboratory up to approximately 1% of the weight of flexible foam may be released as free isocyanate. Some part of this is not free TDI. Extensive large scale fire trials on furnished rooms carried out by the International isocyanate Institute have shown that in most situations free isocyanate is not present and, if present, is at levels of approximately 3 ppm rather than the 200 ppm predicted on the basis of the laboratory experiments in closed tubes. Experimental evidence indicates that at the temperatures and conditions in a real fire, any TDI formed reacts further to nitrogen oxides etc.

A number of emotive comments have been made with regard to the evolution of isocyanates from burning flexible foams. Critics appear to confuse isocyanate and cyanide, and are also ignorant of the reason for fixing a low TLV for isocyanates.

Experiments with Animals

Farrar et al, University of Utah, Hilado et al, University of San Francisco and Kimmerle in Germany have carried out experiments with animals, such as rats and mice, to compare the toxicity of the pyrolysis products of natural materials such as wood, cotton etc. with a number of plastics including polyurethane. These comparisons have demonstrated that long established natural products will, when burning, emit toxic gases, that their potency is similar to that from polyurethane foams and the claims that the types and mixture of gases given off by burning polyurethanes are specially hazardous is not true. Such tests measure toxicity, not toxic hazard in real fires, and as stated on page 14 (sic) it is important to distinguish between toxicity and toxicity hazard.

A criticism levelled at flexible polyurethane foam concerns the speed with which its combustion products may be evolved. The release of combustion products is directly related to the speed of burning; and when uncovered flexible polyurethane foam is burned it will allow rapid release of combustion gases. In the home the speed with which upholstered furniture burns depends on several factors such as the relative resistance to combustion of the components making up the upholstery fabric, the design, the quantity of furniture, the other combustibles as well as the amount of ventilation.

Gas Concentrations in Real Fires

Gases found in 300 fires in Boston, USA, have been studied recently. Researchers collected gas samples with unique devices worn by firemen during 300 actual fires.
The study showed that the detected concentrations of hydrogen chloride, hydrogen cyanide and nitrogen dioxide did not present a significant hazard. This study showed, however, that as expected carbon monoxide is the most serious hazard but also showed for the first time that acrolein, a very toxic irritant gas emitted from natural cellulosic materials such as wood and paper, was present repeatedly in life threatening concentrations. In 52% of the fires it was present at concentrations greater than the recommended short term exposure limit of 0.3 ppm and the highest concentration observed was 88.0 ppm. (Concentrations of 10 ppm of acrolein are lethal in a short time.) In over one half of the samples analysed for acrolein, the concentrations exceeded levels capable of causing eye and respiratory injury.

Conclusions on Toxic Gases

The preceding section has tried to present some of the facts currently known regarding the combustion products of flexible polyurethane foam.
The industry in no way denies that, like any other organic materials burning, flexible polyurethane foams do evolve toxic gases and may therefore present a life hazard to rescuers and persons involved in a fire. Evidence from the three-year programme of research undertaken by BRMA shows that there is often an increase in the toxic combustion products when flexible polyurethane foams are involved in a fire compared with traditional fillings. However, this is largely attributable to the speed with which the upholstery filling is permitted to burn if covered with a material which gives inadequate protection from flames rather than being due to flexible urethane foam as such producing any especially toxic combustion products.

This opinion is supported by the views expressed by P C Bowes of the Fire Research Station who has stated:

‘On firmer ground one may compare the numbers of fatal and non-fatal casualties among those overcome by gas or smoke. For the period studied, the proportion of non-fatal casualties overcome by gas or smoke has remained fairly constant at slightly more than 60% of the total overcome, in other words the probability of surviving exposure to gas or smoke in a fire has remained at about 60%. This suggests that there has been no major increase in the toxicity of fire gases during the period covered, otherwise the proportion of casualties surviving exposure to fire gases would surely have decreased markedly’

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This opinion is of particular significance since it does not support the view widely expressed by the 'anti-urethane' lobby that more highly toxic types of gas are emitted from fires involving polyurethane materials.

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SECTION 8

THE MYTH OF SPONTANEOUS COMBUSTION.

It is essential to dispel the misunderstanding which has been fostered by some spokesmen that flexible polyurethane foam, and furniture upholstered with it, is capable of spontaneous combustion.

During manufacture the exothermic reaction which produces the cellular structure and cures the foam gives rise to high temperatures of the order of 140°C. It is possible, if faulty formulation occurs, for this temperature to exceed 170°C which could lead to a 'runaway' reaction likely to result in a fire starting. Any such fire would be confined to the foam manufacturers' premises since regulations require the containment of foam blocks in a safe area until the danger from any overheating of this type is passed.
Such exothermic reactions are, of course, very common and occur when large numbers of inorganic and organic substances are formed.
It should be noted that any subsequent heating of flexible polyurethane foam has to reach very much higher temperatures {in excess of 220°C) before there is any risk of igniting the foam.
The following conclusions on the exposure of uncovered flexible foam to radiant heat are taken from the work sponsored by the government at RAPRA on the Fire Hazard of Plastics in Furniture and Furnishings, and published in Building Research Establishment Current Paper CP 18/74:

1. Standard uncovered flexible polyether foam was subjected to radiant heat exposure from a 3 KW heater, and the following conditions were necessary before ignition was sometimes obtained:

Distance from heater © Not more than 20 cm

Thickness of foam blocks © Not less than 15 cm

Minimum exposure time © 30 minutes.

2. No evidence was obtained that exothermic conditions developed in the flexible standard polyether foam below 210°C foam temperature, and it was necessary for the foam temperature to reach 265°C before exothermic reaction led to runaway conditions and self-ignition.

3. It was recognised that these conditions represented an extreme situation and reports from the Fire Research Station, BRE Paper CP 3/75, and from RAPRA show that traditional materials such as rubberised hair, rubber latex, fibre-

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board and sawdust would also ignite under these test conditions.

4. None of the flexible polyether foams, specially formulated to be more difficult to ignite from small sources, self-ignited when exposed to the same radiant heat source at distances from as little as 5 cm to 50 cm,

BRMA have also investigated the effect of radiant heaters up to 3 kW at distances of 15 cm to 46 cm from polyurethane flexible foam cushions covered with (a) unsupported pve and (b) polyurethane coated fabric. In no case did the cushion upholstery ignite spontaneously.

Despite the fact that work by the Fire Research Station and by BRMA has shown that claims by the anti-urethane lobby on the spontaneous combustion or instability of urethane foam have no foundation, in fact emotive statements on this topic continue to be made. Such critics appear willing to accept any data from the FRS which support their claims of fire hazard but ignore parts of the FRS data which does not fit with their preconceived ideas.

They are also apparently without any basic knowledge of chemistry despite their use of chemical terminology. They argue that because an exothermic reaction occurs when foam is manufactured (which can as already explained lead to runaway reaction if faulty formulations are used) such a reaction can also occur at any subsequent time without provocation. They appear ignorant of the elementary facts: that the formation of (a) common salt NaCl, from caustic soda and hydrochloric acid and (b) the formation of water from sparking a mixture of hydrogen and oxygen are both violent and dangerous exothermic reactions. Both common salt and water are used for fighting fires, thus showing that materials formed by exothermic reactions are not necessarily unstable subsequently.

In organic chemistry, many organic compounds burn or explode when treated with fluorine gas and yet some aliphatic compounds containing fluorine are used in fire extinguishers and others are used in aerosol propellants because of their stability.

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SECTION 9.

THE MYTH OF SPONTANEOUS COMBUSTION.

Far from ignoring the problems of flammability of foam and soft furnishings as some critics of the urethane industry accuse the manufacturers of doing, a wealth of approaches have been, and continue to be, explored by individual companies and by BRMA itself. As stated earlier, these have covered the use of chlorinated and brominated phosphorus additives, polymer modification, high resilient and neomorphic foams. As requirements for some applications have become more severe, aluminium hydrate impregnated foams and intumescent polyesters have been developed. While there are property and cos! considerations to be taken into account with many of these developments, the industry cannot justly be charged with failing to embark on large scale and costly research.

Work by BRMA, UK and USA government agencies and by the International isocyanates Institute agrees, however, that the ignitability, spread of flame and escape time is a function not of the foam behaviour but of the foam and cover combination and of design. Armed with these and many other facts arising out of its own research and that of other organisations, BRMA have for some years been involved in an intensive educational campaign. The first edition of 'Uses and Misuses', the previous BRMA publication on this subject, was published in 1975.

BRMA have co-operated with representatives of government, FIRA and other organisations in developing test methods for composites of filling material and cover which is the basis of BS 5852.

In addition, BRMA has, for the past five years, been engaged in sponsoring fundamental research work into smoke and toxic gas emission at Queen Mary College. The aim of this work is to establish the nature of the smoke and toxic gas evolution from urethane foam, the inter-relationship between the foam and cover and, most important of all, to find smoke suppressants which will reduce the amount of smoke and chemical modifiers which will reduce or change the nature of toxic gas formation.

Potential smoke suppressants for foam have been identified but the work has also shown that, in smoke and toxic gas evolution, the cover as well as the foam plays a vital role. The research gives rise to the possibility that foam/cover combinations can be found where the two supplement each other so that once again it is the combination which has to be explored. In the light of these observations, BRMA are now sponsoring a fourth phase of the work at

QMC. This will attempt to reproduce some of the promising small scale work with smoke suppressants by trying these on furniture size products with a variety of covers.

The work will also investigate other possible smoke suppressants and gas modifiers.

Utilising the work by BRMA, government and others it is now possible to build up seat constructions with resistance to ignition anywhere between 3 and 3,000 Kilojoules. This covers a range from a burning match around 3 kilojoules to some 150 gms of wood burning on top of the furniture construction.

There are inevitably cost and possibly design penalties. Designers, manufacturers and potential purchasers will need to do their risk analysis to determine which applications the additional costs are justified,

It is the BRMA view that careful consideration should be given to providing information that will give people a more accurate appreciation of fire hazards.

Educational activities, similar to the programmes relating to the influence of drink on driving, should be continued to make the public aware of fire hazards, It is interesting to note that recent investigations indicate that drinking and smoking are also a primary cause of fires involving textiles in the area of home furnishings. Smoking is a prevalent cause of fires in the homes of the elderly. In many fires, flame retardant textiles will only buy time while potential fire victims can escape. There are other effective means of providing this type of protection such as smoke detectors and sprinkler systems, particularly in public buildings.

Industry believes that in determining the need for and the scale of regulations in connection with fires involving soft furnishings, the authorities should make full use of the newly-developed technique of risk data analysis. The industry is trying to make sure that the public receive appropriate protection at a minimum cost, both in financial terms but also measured against the requirements of comfort and aesthetics expected for current living standards.

Combustibility performance standards should clearly vary with the end-use envisaged. Standards for penal institutions, old people's homes and mass transportation may well require to be different from residential use or private cars. In the higher risk areas there is a greater chance of open flame ignition - sometimes deliberate - and such other problems as limited mobility.

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BRMA believe it is essential that the criteria used are based on the performance of the composite rather than individual materials, since by this approach ptimum prot*ection is obtained at minimum cost.