Fire safety of textile products

Legislation and standardization

Stichting Consument en Veiligheid

FIRE SAFETY OF TEXTILE PRODUCTS
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PREFACE

The fire safety of textile products for private use is since long a matter of public concern. In many countries all over the world a great number of safety standards and laws are in force or in process of being issued soon. However, the approaches in the different countries show considerable variations, and the development of international standardization proceeds slowly.

In Europe the Member States of the European Communities agreed to remove all national trade barriers in order to have a free internal market by the year 1992. It can be foreseen that a strong public debate will develop by that time if the years to come do not lead to a common understanding in Europe about the required fire safety levels for textiles. For example, the strict regulations for several textile products (children's clothes, furniture, mattresses) in the United Kingdom at present prevent import of many products that are legally marketed in other EC Member States.

This study provides a basis for discussion about fire safety requirements for textile products. In order to facilitate the application of the research results, the legal approach of the European Communities has been chosen as the basic philosophy of this study. This means that two sets of essential safety requirements are being developed for clothing and soft furnishings, which are subsequently elaborated into suggestions for standardization. The essential requirements can be used as the starting points for discussions about the contents of a European Directive for the fire safety of textiles, and the suggestions for standardization can be used as the starting points for discussions about the development of the relevant European standards.

This study was carried out on request of the Commission of the European Communities (DG XI) by the Consumer Safety Institute (Stichting Consument en Veiligheid) in the Netherlands. Several persons contributed to the accomplishment of the report in its present form, in particular dr V. Babrauskas (National Institute of Standards & Technology, USA), dr J.A. van Aken and mrs Th. van Harberden (Vezelinstituut TNO, Netherlands), and mr F. Wood (Fire Service College, Moreton-in-Marsh, United Kingdom), who commented upon earlier versions, mr J.K.J. van der Vorm (Dutch Ministry of Health), mrs A.P. de Graaf (Consumer Safety Institute) who provided valuable suggestions in the starting phase of the project, and mr W. van Weperen who supervised the project. Many thanks are expressed to them and all other persons who assisted in the accomplishment of this study.

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SUMMARY

The principal aim of this report is to provide the basis for a conceptual framework for fire safety regulations concerning textile products involved in domestic fire accidents. An analysis of the fire hazards and the fire performance characteristics of such textile products, supporting the processes of legislation and standardization under the New Approach of the EEC, is presented.

A framework for fire safety regulations should be developed in the context of the accident mechanisms and fire hazards. In order to provide the basis for such a framework the general aspects of the fire behaviour of textile products and the specific fire behaviour of the involved product groups are analyzed, as well as the domestic fire accident mechanisms concerned. The victims and injuries of domestic fire accidents are characterized briefly on the basis of the available fire accident data.

From the specific accident mechanisms of domestic fire accidents involving soft furnishings and clothing textiles, and their respective fire hazards, principles for the fire safety of these two product groups are derived. Elements from this fundamental approach may be used in a European Directive on the fire safety of textile products for consumers, once it were decided under the New Approach to issue such a directive.

The proposed fire safety principles are used as a guideline to formulate essential requirements for the fire safety of soft furnishings and clothing textiles. These requirements may be implemented in a future European Directive; then they would have to be worked out by the European Standardization Institute CEN in the form of European standards. For that purpose a set of suggestions is developed at the end of the report that can give guidance to the work of standardization groups once it were decided to give a mandate to CEN on the basis of a European Directive concerning the fire safety of textile products for consumers.

Furthermore a survey of the relevant standards and legislation, including a brief summary of their contents, is added. This survey consists of sections about textiles in general, soft furnishings - including upholstered furniture, mattresses and bedding materials, curtains and textile floor coverings - and clothing textiles.

1 INTRODUCTION

The Commission of the European Communities entrusted the Consumer Safety Institute to carry out a study on the fire safety of textile products that would support the processes of legislation and standardization concerning the fire behaviour of textile products. Much research has already been carried out and much has been written about the flammability of certain textile products in particular; many standards were developed. However, a recent overall study on the flammability of textiles supporting the processes of legislation and standardization was not available. Therefore the task to provide such an overall view was given to the Consumer Safety Institute.

The principal aim of this report is to provide the basis for a conceptual framework for fire safety regulations concerning textile products involved in domestic fire accidents. The contents of this report can be used to develop European legislation for the fire safety of textile products for consumers, in particular to issue a European Directive on this subject. According to the so called New Approach of the European Community the Community legislation will confine itself to the establishing of essential requirements in the form of European Directives. The detailing of these requirements is left to the standardization bodies (CEN and CENELEC); they are requested to provide the necessary test methods and criteria in the form of European standards.

It appears that under the New Approach a close collaboration between the legislative and the standards setting bodies is most desirable. This report contributes to provide a common basis for these two activities. It may therefore further the development of a consistent system of regulations for the fire safety of textile products, not only for the benefit of consumers, but also for the benefit of other involved parties, like designers, manufacturers and retail organizations of textile products.

A framework for fire safety regulations can only be developed in the context of the accident mechanisms and fire hazards involved. Therefore the general aspects of the fire behaviour of textile products and the specific fire behaviour of the involved product groups, as well as the domestic fire accident mechanisms are analyzed in chapter 2. A brief characterization of victims and injuries is also presented in this chapter, based on the available fire accident data. A proposal for the fire safety principles of soft furnishings and clothing textiles is worked out in chapter 3, derived from the specific accident mechanisms of domestic fire accidents involving soft furnishings and clothing textiles respectively.

Once it were decided to issue a European Directive on the fire safety of textile products for consumers, elements from chapter 3 concerning the principles of fire safety may be used in such a European Directive. These fire safety principles are used as a guideline to formulate essential requirements for the fire safety of soft furnishings and clothing textiles in chapter 4. These requirements may be implemented in a future European Directive on the fire safety of textile products for consumers; then they would have to be worked out by the European Standardization Institute CEN in the form of European standards. Finally a set of suggestions will be developed in chapter 5 that can give guidance to the work of standardization groups once it were decided to give a mandate to CEN on the basis of a European Directive concerning the fire safety of textile products for consumers. A survey and a brief summary of the relevant standards and legislation concerning the flammability of textiles in the Member States of the EEC and various other Western countries is presented in Annex 1. The basic terminology is defined in Annex 2.

2 FIRE BEHAVIOUR, ACCIDENT MECHANISMS AND FIRE HAZARDS

In this chapter combustion processes involving textile products will be discussed in general. The principles of ignition and the progress of a fire will be characterized. The specific burning behaviour of both soft furnishings, including upholstered furniture, mattresses and bedding materials, curtains, textile floor coverings and textile wall coverings, and clothing textiles will be discussed. Accident mechanisms of residential and clothing fires will be analyzed and a brief characterization of the victims of domestic fire accidents and injuries will be presented. The basic terminology is defined in Annex 2.

2.1 Fire behaviour of textile products

2.1.1 General aspects

2.1.1.1 The burning process of textile fibres

Because of their chemical composition all textile fibres are more or less flammable. Faasen (in: Rogmans and Klasen, 1984) describes the burning process of textile fibres in general as follows (see also the ISO Draft Technical Report-DP 9122, 1987; Ryan, 1987)).

Textile fibres catch fire via the gaseous phase. By means of externally supplied heat a chemical decomposition ("pyrolysis") of the textile fibres takes place. The high-molecular fibre material is decomposed and low-molecular gaseous compounds are formed. These gases mix with the air surrounding the fibre material and after reaching a certain concentration they can be ignited. The temperature at which the gasmixture can be ignited - for instance by a flame - is called the "critical pyrolysis temperature". Without an ignition source the concentration of decomposition products will rise by continuous heating until spontaneous burning occurs. The temperature at which this happens, is called "self ignition temperature", or "spontaneous ignition temperature". After the ignition of the gasmixture the fire will without external heat supply either spread or extinguish itself. The fire spreads only if the burning process generates enough heat for the pyrolysis of unaffected fibre material. If not enough heat is generated, the fire extinguishes itself. Textile materials will only ignite with enough heat supply.

The heating and ignition of a fabric can take place via different heat transfer mechanisms:

- convection by contact with hot air or combustion gases (e.g. by a match, a candle, an outdoor fire, an open fire, a cooking stove);
- conduction by contact with a surface of high temperature (e.g. by the surface of a burning stove or the contact with smouldering solids such as smouldering tobacco);
- thermal radiation from a hot, radiating surface or an amount of hot gases at a distance (e.g. in a burning room).

Usually several heat transfer mechanisms are involved in the process of ignition by a particular ignition source; for instance from a smouldering cigarette heat is transfered by both convection and conduction to a fabric (Zorgman, 1986). If a fabric is hanging freely, like the fabric of a night-dress or the legs of a pair of trousers or a curtain, the fabric can ignite at both sides. Thus the combustion process is stimulated. The fabric surface being heated is doubled and the air is sucked in from two sides to sustain the combustion process ("chimney-effect").

2.1.1.2 Fire performance characteristics

As fire performance characteristics of textile materials can be distinguished (Faasen in: Rogmans and Klasen, 1984):
- the ignitability;
- the fire spread;
- the flame temperature and flame length;
- the heat release;
- the smoke production;
- the development of toxic or corrosive gases;
- the falling of burning fragments or molten droplets.

The spread of the fire in textile material, that continues burning after contact with an ignition source, is expressed as the length of the flame, on the basis of empirical reasons. The flame length is determined by the speed of the pyrolysis, the volatility of the formed pyrolysis compounds and the amount of oxygen necessary for the burning of these compounds. The flame temperature is also an important factor in the spread of the fire. With increasing heat release during the combustion process the flame temperature rises. Every combustion process generates both heat and smoke. Fire gases from combustion with sufficient oxygen available contain mainly carbon dioxide (CO_2). In closed rooms fire gases will also contain carbon monoxide (CO) because of the limited oxygen availability. In the combustion of nitrogenous fibres small amounts of gaseous hydrogen cyanide (HCN) may be present in the combustion gases. Heated chlorinated fibres decompose with the generating of gaseous hydrogen chloride (HCl). For some synthetic fibres the temperatures of melting and decomposing differ considerably. If such a textile material comes into contact with an ignition source, a hole will develop by melting. The molten material usually drops

out of the reach of the flame, not supplying sufficient heat to reach the temperature of pyrolysis. Thus the material does not ignite. In the melting zone the heated material shrinks, thus inhibiting contact between the material and the ignition source. If the molten material cannot drip away from the ignition source and can be heated up to the pyrolysis temperature ignition will take place. This will happen if other components form a network, keeping the molten material in the ignition source like certain blended fabrics do, as shall be indicated in the next section (see also Ames and Pakkala in: Rogmans and Jackson, 1987).

2.1.1.3 Factors influencing the fire behaviour of textile products

The fire behaviour of textile products is not only determined by the burning characteristics of the fibre materials. Other factors influence the fire behaviour as well (Faasen in: Rogmans and Klasen, 1984; Pakkala in: Rogmans and Jackson, 1987; Schukking and Zorgman, 1984). The physical construction of a fabric (such as the areal mass and the type of pattern design) has its influence on the air contents. Loosely woven, light fabrics will ignite faster than tight and heavy fabrics. If small diameter fibres protrude from the fabric they can be ignited very quickly and can spread the flame very rapidly across a surface ("surface flash") compared with smooth surface fabrics. Blended fabrics can be less safe than the individual components. Blended fabrics of polyester and cotton or nylon and wool are much more flammable than comparable fabrics of pure polyester or wool. Cotton and wool form a network in the combustion process which holds the molten synthetic fibre material. This molten material can be heated until the ignition temperature is reached and ignition occurs.

The presence of finishes and residues of detergents and cleaning agents can increase the flammability, particularly of synthetic fabrics (Pakkala in: Rogmans and Jackson, 1987). Such products inhibit the dripping away of molten material, thus causing ignition when the fabric is heated continuously. In general dyes seem to have no demonstrable influence on the flammability of textiles, with certain exceptions (such as nylon coloured with chrome pigments, see Faasen in: Rogmans and Klasen, 1984).

The influence of artificial ageing by light on the flammability of fabrics was tested by Schukking and Zorgman (1984). In general the flammability of textiles does not or hardly change under the influence of artificial ageing by light.

The design of clothing influences the flammability. Loose clothing will ignite faster than tight fitting clothing and will also burn faster because of a so called "chimney

effect". Beltless dresses have been reported to cause more extensive injuries than dresses with a belt (Pakkala in: Rogmans and Jackson, 1987).

The flammability of clothing may be drastically increased by the presence of flammable liquids like oil on the clothing. The humidity of textiles can also influence their flammability (Schukking and Zorgman, 1984). Curtains hanging above a central heating appliance can become very dry, e.g. in wintertime.

2.1.1.4 Flame retardant additives

To diminish the flammability of textiles, fibres or complete fabrics can be treated with flame retardant additives. The way flame retardant additives work is not exactly known. In principle they bring about the release of hydrogen and oxygen atoms from the fibre molecules at pyrolysis temperature without ignition, often in combination with elements from the additive. A framework of mainly carbon remains, containing sometimes elements from the additive or the fibre itself. Further heating will burn this framework, producing carbonmonoxide, carbondioxide and compounds created out of the remaining elements (De Boer et al., 1988).
So called "reactive" additives bind themselves by a chemical reaction to the fibres and have a permanent effect. So called "non-reactive" additives attach only more or less to the fabric and disappear after a shorter or longer time by washing, rinsing etc. (De Boer et al., 1988; Loader, 1979).

Flame retardant additives can also have disadvantages. Flame retardant additives can increase the toxicity of combustion gases (e.g. Pohl et al., 1986). They can have serious health effects (King, 1979). Fabrics treated with such additives can cause environmental damage after the textile products they are used in have been disposed of (Klingenberg, 1988; Meckel, 1984). The comfort in use and the appearance of textile products can be influenced in a negative way by these additives (Faasen in: Rogmans and Klasen, 1984) as well as other performance characteristics like the durability (King, 1979).

2.1.1.5 Fire development in rooms

In the ISO Draft Technical Report-DP 9122 (1987) a general pattern for the fire development in a room is described as follows, see figure 1.

After ignition fire development may occur in different ways, depending on environmental conditions as well as on the arrangement of fuel. In the case of a compartment fire, the general temperature-time curve shows three stages.

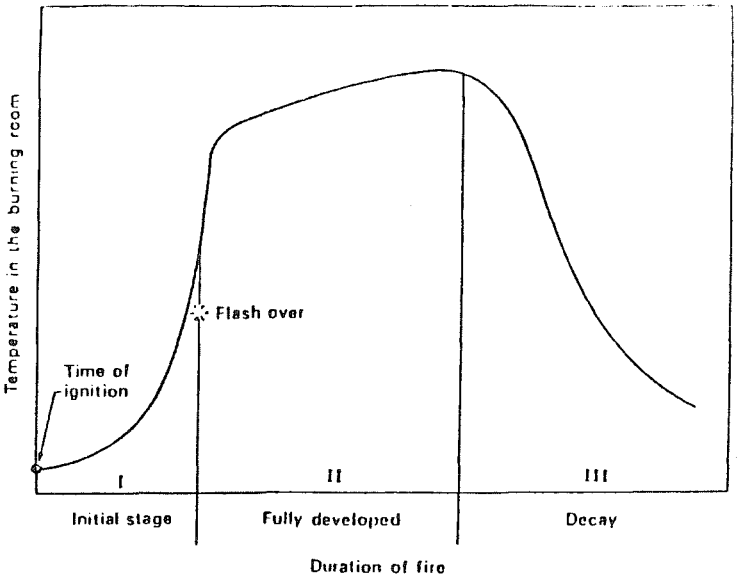

Figure 1: General temperature-time curve of fire development in rooms (from: ISO-DP 9122, 1987)

Stage 1 represents an exponential rise of the room temperature, when there is enough oxygen present (developing fire). A second stage is reached when the surfaces of all combustible contents of the room will be decomposed to such an extent that sudden ignition occurs all over the room (flash over); this characterises the stage of the fully developed fire. In this stage 2 (fully developed) the rapid temperature rise of flash over is subsequently moderated by oxygen depletion to a steady state (often termed ventilation controlled).
In stage 3 the combustibles in the room are depleted and the temperature decreases depending on the ventilation and the heat-and mass-transfer relations.

In each of these phases a different mixture of decomposition products will be obtained.

2.1.2 Product groups

2.1.2.1 Involved textile products

Different textile products appear to be involved in domestic fire accidents. They can be classified as soft furnishings and clothing textiles; soft furnishings including upholstered furniture, mattresses and bedding materials, curtains, textile floor coverings and textile wall coverings; clothing textiles including both day and night clothing, for adults and children. The mechanisms of domestic fire accidents will be discussed later in this chapter. First the general aspects of the progress of a fire involving each of the above specified textile products will be outlined.

2.1.2.2 Upholstered furniture

The materials used in upholstered furniture nowadays show large differences in flammability and fire spread. In the last decades new types of cover fabrics, fillings and other furniture constructions were brought on the market. Rubber latex foams and especially polyurethane foams are used as filling materials. These foams burn readily if ignited (although there are variations in burning behaviour) and furniture in which they are present burns rapidly with localised high temperatures and with the generation of large quantities of smoke (OECD, 1977). According to De Boer et al. (1988) the flammability of upholstered furniture depends on the fire behaviour of the cover materials in combination with the filling materials (see also Fittig, 1983 and OECD, 1977); the overall performance of an assembly cannot be predicted from the fire behaviour of the individual components (Benisek and Phillips, 1978).

Upholstered furniture can be ignited by flaming or by smouldering fire sources. The fire behaviour of furniture materials is uncorrelated for these two modes of exposure: a specimen performing very well under a flaming source may smoulder badly, and conversely (Babrauskas, 1988a). A smouldering source usually brings about local smouldering of an item of furniture and this can continue for a long period before there is a spontaneous transition to flaming. If this happens, the subsequent fire growth can be extremely rapid, due to the "preheating" of the materials during the smouldering phase. The growth of the flaming fire, whether from a smouldering source or an actual flame, depends very much on ventilation conditions (Fire Research Station, 1984). Fire accidents and fire tests with flash over occurring within a few minutes after ignition are mentioned frequently in literature (e.g. in Urethanes Technology, 1988; Zorgman, 1981). The type of the room (size, geometry) containing the upholstered furniture, as well as the composition of the

cover materials of walls and ceiling and of other interior goods present, such as curtains, floor covering, other furniture etc. will determine the flash over moment. If a smaller piece of furniture with a high, fast rate of heat release is put in a room containing many other flammable goods, a rapid flash over may be due to the combined burning behaviour of all these objects, initiated by the smaller piece of furniture (Zorgman, 1988 a). Ames (in: Rogmans and Jackson, 1987) describes the process of flash over with regard to furniture as follows.

> "The fire behaviour of a piece of furniture inside a room is quite different to its fire behaviour outside in the atmosphere. When an item of furniture burns inside a room, the smoke and hot gases evolved are trapped and form a layer under the ceiling. As the burning continues the layer becomes thicker and hotter and begins to emit thermal radiation which falls on all other items of furniture (and people) in the room. If the level of radiation increases sufficiently, all of the items in the room are heated to a point where they ignite almost simultaneously. This point is sometimes referred to as "Flash over"".

In a rapid fire development large amounts of smoke and toxic gases will be released within a short time, thus reducing the ability of people to see and escape and intoxicating them (ISO-DP 9122, 1987; Zorgman, 1988 a). In ISO-DP 9122 (1987) such fire accidents are described in detail as follows.

> "There are two different circumstances in which casualties due to toxic combustion products occur, those in the compartment of origin of the fire and those remote from it, and in each case the hazards may arise from non-flaming or flaming combustion.
>
> Statistics in the UK indicate that, with fires in domestic premises and in transport fires, most of the casualties occur in the compartment of origin of the fire. For fires in dwellings in the UK this class of fire is responsible for the highest incidence of deaths (60%) and a high incidence of injuries (39%), and these fires occur mostly in living rooms or bedrooms, and in upholstery or bedding. In these cases the material first ignited may be responsible for the toxic environment, the fire not yet having spread to other materials, there is no thermal flux external to the burning material and the burning or smouldering is sustained by its exothermic nature.
>
> In the USA statistics for the years 1980 through 1983 indicate that most of the fatalities from smoke only occur outside the room of fire origin (21% in the room of fire origin and 77% outside the room). The reason for this may be linked to differences in the reporting procedures between the UK and USA, due to the inclusion of 'joint burn and smoke' victims with 'smoke' victims in the UK.

The toxic hazard in such fires depends upon whether there is a long period of smouldering, or whether there is a rapidly growing flaming fire.

With smouldering fires there may be ample time for escape if alerted sufficiently early but persons may be overcome by fumes, particularly carbon monoxide, after a long period of time, if unaware of the danger. It is not possible from fire statistics to determine how common this type of fire is, since in many cases smouldering fires become flaming fires before they are detected. However it is likely that fires which are estimated to have burnt for 30 minutes or more before discovery have involved long term smouldering and it may be significant that deaths are much more likely in this class of fire.

For flaming fires where the person is in the compartment of origin the hazard relates to the early stages of fire growth. The most rapidly developing experimental fire takes only a few minutes to reach levels of heat and gases hazardous to life (Babrauskas, 1979; Woolley and Fardell, 1977).

The inability of persons to escape from such fires seems to depend upon a number of factors. Casualties include a higher proportion of children and old people than does the general population, and people who are incapacitated by a previous period of smouldering (see above) or by some other infirmity are obviously more at risk. However there seem to be two other factors of importance, the behaviour of the victim and the exponential rate of fire development.

In many cases there is only a short period during which to carry out the correct actions enabling escape, after which a person may be rapidly trapped. Some persons may be asleep during this critical escape 'window' but there are also reports of situations where the victim was aware of the fire from ignition, but remained to attempt to extinguish the fire or for some other reason failed to attempt to leave before the phase of very rapid fire growth, when heat and CO very quickly reach life threatening levels.

The second scenario is where casualties occur remote from the source of the fire. Apart from being a common occurrence in domestic dwellings such situations often occur in public buildings where the situation involves a developed fire which has spread from the first ignited material to others. Materials in such fires are subject to substantial external thermal flux and in some cases to oxygen deficient environments. In these cases large quantities of material may be involved in flaming combustion or pyrolysis producing large quantities of toxic smoke and gases.

Fires where the victim is remote from the compartment of origin are responsible for the highest incidence of non-fatal casualties (48%) in the UK and a large proportion of deaths (37%). Here the victim is five times more likely to be killed by smoke than by burns, and is often unaware of the fire during the crucial early phase, so that the gases may not penetrate to the victim until the fire has reached its rapid growth phase and the victim is already trapped. The major causes of incapacitation and death in this type of fire are almost certainly fumes, particularly carbon monoxide, which can build up rapidly to high concentrations, and the role of irritants in causing incapacitation and impeding escape attempts may be crucial" (ISO-DP 9122, 1987).

2.1.2.3 Mattresses and bedding materials

Many aspects of the fire hazard of mattresses are comparable to those of upholstered furniture containing combinations of foam (mostly polyurethane) and textile fibres as cover materials. In practice a large amount of different combinations of mattresses and bedding materials are found. Concerning foam mattresses the ignitability is mainly dependent on the cover materials. The flame spread is determined by both the cover materials and the filling materials; the latter playing a very important part (OECD, 1977). Bedding materials, such as sheets, blankets, pillows, quilts etc. always play an important part in the fire ignition and the growth of the fire (Woolley et al., 1976; Babrauskas and Krasny, 1985; De Boer et al., 1988). The development of a fire started in a mattress with bedding materials shares many characteristics with a fire started in upholstered furniture. Likewise the fire can spread very rapidly and can produce smoke and toxic gases in large amounts (Woolley et al., 1976).

2.1.2.4 Curtains

Many fabrics used in curtains and sunblinds can be ignited with a match, a candle etc. and can burn very quickly after ignition (Meckel, 1984; Zorgman, 1981). Hanging freely from the ceiling curtains burn faster because of the "chimney effect". Many of the frequently used curtain fabrics cause flames reaching the ceiling within one minute, possibly igniting other flammable materials in the room as indicated before, resulting in a rapid fire growth. Curtain fabrics consisting of thermoplastic fibres can also generate molten droplets in a fire, falling down and causing ignition of upholstered furniture, floor coverings etc. (De Boer et al., 1988).

2.1.2.5 Textile floor coverings

Floor coverings can catch fire by, for instance, children playing with fire or by sparks originating from an open fire. According to Meckel (1984) a carpet will not easily catch fire and will not sustain the fire. Floor coverings are usually oriented in a horizontal position and will therefore contribute less to the spread of a fire than for instance vertically oriented curtains. The main hazard lays in the back of a carpet catching fire during the development of a fire especially if the back of the carpet consists of rubber, which ignites rapidly and emits large quantities of smoke and toxic gases (De Boer et al., 1988; Meckel, 1984). A carpet covering the floor will have a relatively low temperature in a developed fire because of the circulation of air (Meckel, 1984). The floor surface will even be cooled down by the -cold- air, sucked in by the fire across the floor surface (Zorgman, 1981). Textile floor coverings on walls may therefore be considered more flammable (Meckel, 1984). The rising heat of combustion will in particular heat the walls and ceilings in a fire (Zorgman, 1981).

2.1.2.6 Textile wall coverings

Meckel (1984) indicates that textile wall coverings usually will not catch fire easily if they are glued to the walls. If a fire develops and the wall covering comes loose the wall covering will show a burning behaviour more or less comparable with the burning behaviour of wall paper. Via the back of wall covering materials in general thermal conduction may occur. Concerning the burning behaviour of textile wall coverings no other information was found.

2.1.2.7 Clothing

A clothing fire may be defined as a fire in a worn piece of clothing, with the article of clothing igniting first (Zorgman, 1986). The general development of a combustion process in textile fibres is already discussed. When the ignition source is taken away, there is a chance that the heat released by the burning of the textile is too little to sustain the flame. The combustion process stops, the fire extinguishes itself. On the other hand the released heat may be enough to heat an increasing part of the fabric until ignition takes place: the clothing fire thus escalating (Zorgman, 1986).
The distance to the underlaying clothing or the skin is important to the fire development. By contact with the body heat can be transferred to the body, delaying the combustion process. A flammable fabric present under the burning fabric can produce flammable gases itself, accelerating the burning process or igniting itself (Zorgman, 1986; see also Pakkala in: Rogmans and Jackson, 1987; Ryan, 1987).

From thermoplastic fibres the burning part can drop down by softening, protecting the remaining fabric from igniting or delaying the combustion process when the fabric keeps burning. The burning or hot molten droplets of softened material possibly produced by thermoplastic fibres can cause severe skin damage (Pakkala in: Rogmans and Jackson 1987; Ryan, 1987; Zorgman, 1986). When these droplets fall on other parts of pieces of clothing these can ignite, thus accelerating the combustion process (Pakkala in: Rogmans and Jackson 1987; Zorgman, 1986).

The hazard of asphyxiation by smoke and toxic gases from clothing fires is relatively small because of the relatively small quantities of burning materials (Faasen in: Rogmans and Klasen, 1984).

2.2 Accident mechanisms

In domestic fire accidents involving textile products different accident mechanisms occur. Two main textile product groups can be distinguished: soft furnishings and clothing textiles. Soft furnishings include upholstered furniture, mattresses and bedding materials, curtains, textile floor coverings and textile wall coverings. The mechanisms of residential fire accidents involving textile products and clothing fire accidents will be analyzed in this section. To give an indication of the size of the problem of domestic fire accidents in Western countries some fire data are presented.

2.2.1 Soft furnishings

In the United Kingdom 160 people died in 1983 in fires involving upholstered furniture and in the Federal Republic of Germany the Berlin Fire Service Statistics report 485 fires which started in furniture in 1982 (Meckel, 1984). In the Netherlands at least 460 fires occur each year in which furniture and mattresses and bedding materials were the first items ignited (Dees, 1988). According to Hoebel (in: Rogmans and Jackson, 1987) 622 000 residential fires were reported to the fire service in the United States of America during 1985, in which approximately 5000 people died (whether or not all these fires started in textile products is not reported).

Smoking materials are the main ignition sources to fires in upholstered furniture and mattresses and bedding materials (Ames in: Rogmans and Jackson, 1987; De Boer et al., 1988). Burning tobacco, smouldering cigarettes, cigarette ends, ashes, matches and lighters are the most frequent ignition sources to upholstered furniture, mattresses and bedding materials. According to De Boer et al. (1988), who made a comparative analysis of risks by means of

the fire and accident statistics available in the Netherlands and several other Western countries, more than 48% of the fires involving upholstered furniture in the United Kingdom in 1979 were ignited by smoking materials including matches and lighters. More than 28% of the fires involving mattresses and bedding materials in the UK in 1979 were ignited by these ignition sources. In the United States in 1983 more than 79% of the fires involving upholstered furniture were ignited by smoking materials including matches and lighters; more than 72% of the fires involving mattresses and bedding materials were ignited by these ignition sources. In the Netherlands in 1983 more than 48% of the fires involving upholstered furniture and more than 42% of the fires involving mattresses and bedding materials were ignited by smoking materials including matches and lighters.

Different countries have different ways of registering fire statistics and therefore the data are not directly comparable. Nevertheless they all indicate that smoking materials including matches and lighters are the most frequent ignition sources of fires involving upholstered furniture, mattresses and bedding materials. Carelessness with smoking materials, as well as playing with matches and lighters arise as the main causes of fires with soft furnishings in general. Other ignition sources found in fire statistics are candles, roomheating (e.g. gasstoves) and open fires, cooking stoves, electrical equipment like illumination and electric blankets (De Boer et al., 1988; Hoebel in: Rogmans and Jackson, 1987; Meckel, 1984). Fires start either by carelessness and inexpertness in handling these ignition sources, or by people coming into contact with them without noticing. Arson can also be the cause of a fire.

As many fires in upholstered furniture and mattresses and bedding materials start by smoking, it is relevant to look at the accident mechanism of these kinds of fire accidents.

2.2.1.1 The scenario "smoking"

It is assumed that many fires in soft furnishings start by persons falling asleep, while smoking in bed or on a settee, possibly under the influence of alcohol and/or narcotics (Day, 1985; De Boer et al., 1988; Meckel, 1984). Levin et al. (1985) sketch the following situation:

> "A person falls asleep with a lit cigarette which drops into the crevice of a chair, where it smoulders for an undetermined length of time. The person may wake during this time and go to bed in another room, not realizing that the cigarette is still smouldering in the chair crevice. The unsuspecting family may be asleep when the chair undergoes the transition from smouldering to flaming, which may soon produce flash over conditions in the room. In many of these cases, the family members die from smoke

inhalation (not burns) in rooms other than the room of fire origin either in their beds or close to their beds, an indication of little or no effort to escape. Whether the occupants are incapacitated or killed by the toxic combustion products which are generated by the early smouldering conditions or those generated when the chair bursts into flames or when the room experiences flashover is unknown, since the arrival of help on the scene usually occurs after flash over, when large quantities of smoke become evident outside the residence".

Such a story is also imaginable in a situation where somebody has fallen asleep while smoking in bed (Hoebel in: Rogmans and Jackson, 1987; OECD, 1977; Woolley et al., 1976). The cigarette continues smouldering in the bed, after which a fire can start in the bedroom in a similar way as a fire in a living-room starts. The scenario above illustrates a specific problem that often occurs with fire accidents involving upholstered furniture and mattresses and bedding materials. Many victims find their death due to the inhalation of smoke and toxic gases during the fire as is already indicated in section 2.1.2.2.

2.2.1.2 Other scenarios

Another important fire accident scenario regards children playing with fire; playing with matches and lighters without parental supervision (Hoebel in: Rogmans and Jackson, 1987; Ryan, 1987). Hoebel reports that one of the major causes of children's fire deaths in the United States is children playing with cigarette lighters. An estimated 125 children under 5 years of age die each year in the United States in fires started by children playing with lighters. Information about the kind of lighter involved, the age of the child who operated it and the exact method of operation is lacking. Neither were more details of this kind of accident mechanism found with other authors. The scenario concerning arson is not worked out here. Neither will the scenarios on candles, roomheating and open fires, cooking stoves and electrical equipment be worked out in this report. In the consulted literature no detailed information was found on the ins and outs of fire accidents with such ignition sources. As with the other ignition sources the first ignited textile product and the presence of other textile products and objects in a room are important to the development of a fire.

In general it can be said that people die more often from asphyxiation than from burns (Hoebel in: Rogmans and Jackson, 1987; Mahon and Hills, 1983). According to Malhotra (in: Rogmans and Jackson, 1987) general conclusions may be drawn from detailed fire statistics in the United Kingdom that over 80% of deaths and injuries are suffered in dwellings and that

there are roughly 10 times as many injuries as deaths. Nearly 70% of deaths are due to the inhalation of fire gases and burns are responsible for just 25% of deaths and injuries. In the United Kingdom 4768 fires in dwellings were reported in 1982 where furniture (including beds and textiles but not clothing) was the first item ignited or the contributor to the development of the fire, and where smokers' materials and matches were the ignition sources, causing 219 deaths. Many of the deaths were caused by the inhalation of smoke and toxic gases (Fire Research Station, 1984). Hoebel and Orzel (1983) indicate that about 5000 people are killed each year in the United States of America as a result of residential fires; most of these deaths are caused by smoke inhalation. It should be kept in mind that these data, illustrating the size and nature of the Western residential fire accident problem, are not directly comparable.

2.2.2 Clothing textiles

The most important ignition sources of fires in clothing textiles in Western countries are (Zorgman, 1986; see also Ryan, 1987; Warne, 1979):
- matches, lighters, candles;
- cooking stoves, paraffin stoves;
- open fires, outdoor fires;
- hot surfaces, especially of stoves;
- flammable liquids;
- burning tobacco;
- fireworks.

Clothing catches fire in contact with an ignition source. Clothing burn incidents are caused by very common ignition sources and activities according to Ryan (1987); such as children playing with matches and lighters, adults' carelessness with cigarettes, flimsy nightgowns near gas range burners, improperly handled flammable liquids and others. A piece of clothing can also come into contact with the flame of a candle or a gas cooking stove without people noticing this; the piece of clothing catching fire in this way (Rogmans, 1985; see also Belshaw and Jerram, 1986).

Zorgman (1986) has studied statistical information about clothing fires available in the Netherlands and several other Western countries. Zorgman reports 29 fatal fire accidents in the Netherlands within the years 1977-1981, resulting from the ignition of clothing. During 1980 and 1981 154 people with burn injuries from clothing fires were treated in hospitals in the Netherlands. Zorgman mentions data from the Consumer Product Safety Commission in the United States of America: 96.000 fires which started in items of clothing were reported in the USA in 1978. The most important ignition sources were, among others, heating and cooking stoves (45%), as well as smoking materials including matches and lighters

(12%). Warne reports in 1979 some 115 fatalities in the United Kingdom resulting from the ignition of clothing and many serious accidents each year. Zorgman mentions data from fire statistics in the United Kingdom concerning ignition sources. In 1978 75% of the clothing fires in the United Kingdom were ignited by cooking stoves and heating stoves, at least 15% were ignited by smoking materials including matches. Apart from flammable liquids, stoves and smoking materials are also relatively frequently mentioned as ignition sources of clothing fires in the Netherlands (Zorgman, 1986). It should be kept in mind that these data are not directly comparable, they should be considered indicative. According to the OECD (1977) smoking materials, matches and cooking stoves are frequent sources of ignition which will be common to all Western countries.

The first ignited piece of clothing has an important influence on the development of the clothing fire (Pakkala in: Rogmans and Jackson, 1987). The design of the clothing also influences the fire progress (King, 1979; Pakkala in: Rogmans and Jackson, 1987; Tovey, 1976). Fire accidents involve all kinds of clothing articles. According to Warne (1979) the following articles were involved in fire accidents in the United Kingdom: trousers/jeans; shirts/blouses/tee-shirts; cardigan/jumpers; dresses/skirts/smocks; overalls/ pinafores/ aprons; tights/socks; jackets; nightdresses; pyjamas; dressing gowns; bedjackets. Both night and "day" clothing are involved in fire accidents for children as well as adults. Other authors (e.g. Belshaw and Jerram, 1986; Zorgman, 1986) do not specify garments involved in fire accidents as extensively as Warne; those specified correspond with those mentioned by Warne.

Fires involving clothing textiles often result in very serious burns, as people cannot escape from burning clothing. In clothing fires relatively few victims die from asphyxiation (De Boer et al., 1988). Burn injuries can also result from molten or burning droplets, originating from clothing textiles (Pakkala in: Rogmans and Jackson, 1987).

2.3.3 Brief characterization of victims and injuries

The segments of the population at greatest risk concerning fire accidents involving textile products are the very young and the elderly, especially children under five and adults over 65 years (Belshaw and Jerram, 1986; Hoebel in: Rogmans and Jackson, 1987; ISO-DP 9122, 1987; Ryan, 1987). This holds for both residential and clothing fires. These groups are more prone to a lack of coordination caused either by their undeveloped or failing senses. Thereby their reaction time when the injury occurs is slower. In the case of the elderly, this may be due to physical limitations. Very young children are extremely vulnerable, especially if they are without parental supervision (Ryan, 1987).

Day (1985), De Boer et al. (1988) and Meckel (1984) observe that especially the victims of mattress fires and bedding material fires may be under the influence of alcohol and/or narcotics. Meckel suggests that the fact that (older) people live more and more isolated than they used to, e.g. in small houses, contributes to fire risks.

The injuries and causes of death in fires involving textile products were discussed already in the previous sections. Burns and asphyxiations form the causes of death and injuries. In residential fires victims die more often from asphyxiation by smoke and toxic gases than from burns. In clothing fires relatively few victims die from asphyxiation.

2.3 Summary of accident mechanisms and fire hazards

To arrive at a consistent framework of principles and essential requirements in the chapters 3 and 4 it is important to summarize the accident mechanisms and the specific fire hazards of the involved textile products discussed in this chapter.

1. In residential fires involving soft furnishings the main ignition sources are smoking materials including matches and lighters.

2. The main activities leading to residential fires involving soft furnishings are:
   - carelessness with smoking materials
   - playing with fire, especially matches and lighters.

3. Apart from flammable liquids the main ignition sources of clothing fires are stoves and smoking materials including matches and lighters.

4. The most common activities leading to clothing fires are:
   - wearing clothing closely to stoves etc.
   - carelessness with smoking materials
   - playing with fire.

5. The first ignited piece of furniture, clothing etc. is very important to the fire development.

6. Some fabrics can produce molten droplets while being heated. These droplets may influence the fire development in both residential and clothing fires and may cause burn injuries.

7. The orientation of a textile product (vertically, horizontally etc.) is important to its fire behaviour.

8. Fires which started in upholstered furniture and mattresses and bedding materials can grow very rapidly; the presence of other textile products in a room is important to the fire development.

9. The combination of filling and cover materials etc. in a certain design of upholstered furniture determines the fire behaviour of the upholstered furniture.

10. The combination of filling, cover materials etc. in a particular assembly of mattresses and bedding materials determines the fire behaviour of the assembly.

11. During residential fires involving upholstered furniture or mattresses and bedding materials many victims die due to the inhalation of smoke and toxic gases and the limitation of sight.

12. In loose garments and curtains a "chimney effect" can occur.

13. Both "day" and night clothing are involved in fire accidents.

14. The design of the clothing is important to the fire behaviour of the clothing.

15. Loose garments can easily ignite by touching hot surfaces and candle flames etc.

16. Some fabric types, usually intended for clothing, like napped fabrics and simulated furs etc. constitute the fire hazard of "surface flash".

17. Victims of residential fires involving soft furnishings and clothing fires are relatively often found among children and the elderly.

3 PRINCIPLES OF FIRE SAFETY

In this chapter a set of principles for the fire safety of both soft furnishings and clothing textiles will be proposed. In order to arrive at these principles some fundamental aspects of injury prevention measures in general will be discussed, as well as some fundamental aspects of fire safety closely related to the accident mechanisms involved, first for textile products in general and then for both soft furnishings and clothing textiles. Elements from this chapter may be used in a European Directive on the fire safety of textile products for consumers, once it were decided to issue such a directive.

3.1 Injury prevention measures

In this section some fundamentals of the effectiveness of injury prevention measures in general will be discussed. Baker (in: Pearn, 1983) discusses the effectiveness of measures that are designed to prevent injuries in general, including measures in the field of both individual activities, and products and designs. According to Baker one important factor is the frequency with which action is required of individuals or families in order to be protected. The measures that have proved to be most likely to work are those that never require any action by the users. Many forms of automatic protection ("passive" protection) have been designed into products and environments with notable results. Protection by such products and environments not only requires no action by the users, but also is totally independent of their wisdom, caution, skill and psychological makeup. Baker reports a likelihood of success decreasing as the frequency of required action increases.

Another factor influencing the likelihood that a preventive measure will be successful, according to Baker, is the amount of effort involved each time someone is protected. The most effective measures are the automatic, "passive" measures that require no additional effort beyond that which would be otherwise involved; in other words when (more) safety is reached without extra effort. The least successful measures are those that require substantial effort each time someone is protected.

In addition to the frequency of required action and the amount of effort, there are other deterrents or disincentives that can keep a measure from widely being applied. These include cost, delay, discomfort and the sacrifice of pleasures. On the other hand there are incentives which, if strong enough, support the individual or family cooperation in prevention activities. These incentives may include various rewards, an instinct for self-preservation and desire to avoid pain, loss, embarrassment or punishment. Wherever

injury prevention requires individual cooperation, success will depend on the balance between incentives and deterrents, which varies with the individual.

One of Baker's conclusions is therefore that a mixture of approaches will be needed in the attack on any major group of injuries.

3.2 Textile products in general

Several strategies to prevent domestic fire accidents involving textile products are summarized in this section. The attention will be focused on the strategies that are likely to be the most effective.

Baker (in Pearn, 1983) provides an illustrative example with regard to fire prevention:

"We depend on parents to keep matches away from children and to properly dispose of cigarettes. But if the child does find and play with matches, or if a careless smoker does leave a smouldering cigarette when he goes to bed, injury or death could be prevented by anyone of the following: matches or cigarettes designed to self-extinguish, furnishings that are fire-retardant, homes designed to prevent the spread of fire, automatic detection and extinguishment systems, or alternate escape routes".

Hoebel (in: Rogmans and Jackson, 1987) distinguishes at least five strategies to attempt to reduce the frequency and severity of (residential) fires. These include:

1. Ignition Prevention: if ignition does not occur, there is no fire and no toxic hazard.
2. Early Warning: warning potential victims as early as possible to ensure maximum escape or rescue time and to facilitate fire suppression.
3. Reduce Contribution of Products to the Fire: development of fire may be slowed and production of toxic smoke reduced by the judicious choice of materials used in the product.
4. Fire Control/Confinement/Suppression: this includes efforts to prevent a fire from spreading and to extinguish the fire.
5. Information and Education: an informed citizen is more likely to avoid a hazardous situation, and is better prepared to escape.

With regard to Baker's "passive" protection (see 3.1), the strategies of ignition prevention and of reducing the contribution of products to a fire are most closely related to the textile products themselves.

With regard to the main activities leading to residential fires involving soft furnishings (see 2.3) and to ignition prevention Hoebel (in: Rogmans and Jackson, 1987) mentions the suggestion of cigarettes and little cigars with reduced propensity to ignite upholstered furniture and mattresses and of child-resistant lighters. In the United States such product changes are under consideration. As this study concentrates on the fire safety of textile products this aspect of ignition prevention is not further discussed here.

The strategy of information and education is undoubtedly very important to protect people from fire accidents. People should become aware of the fire hazards of textile products, of potential ignition sources and of proper use and maintenance of textile products with regard to optimum fire safety etc. They should learn to handle ignition sources with care and they should supervise the behaviour of their children. However, how much publicity and consumer information there may be, it is unlikely to be more than partially effective (OECD, 1977).

From both Baker's and Hoebel's opinions it becomes clear that in an effective fire prevention programme a well balanced mixture of strategies will be needed. The textile products involved in domestic fire accidents have their function in the individual's and family's daily life. The fire hazards of those textile products belong to daily life, too. If a piece of furniture or clothing catches fire -as it will not always be possible to prevent ignition-, a person should have enough time to undertake appropriate action to deal with the fire situation. The amount of time necessary to do so also depends on the capacities of the victims. Victims of domestic fire accidents are relatively often found among children and the elderly, probably owing to their undeveloped or failing senses or abilities. Children without parental supervision are very vulnerable. Information and education can help people to learn how to handle fire situations properly, if they occur. Such protection measures alone will nevertheless be insufficient, not only because especially children and the elderly are at risk, but also because people may be asleep or become panicky when a fire accident occurs, which prevents them from taking appropriate measures to extinguish the fire before the conflagration is out of control. Therefore, labelling of textile products with appropriate and adequate warnings drawing attention to their flammability will be insufficient. If such labelling is to be considered, it should always be combined with product related prevention measures other than information, to establish at least a minimum of product fire safety. The aim of this study is to provide the basis for a conceptual framework for fire safety regulations concerning textile products involved in domestic fire accidents, taking into account the accident mechanisms of such fire accidents and the products themselves.

A European Directive on the fire safety of textile products for consumers should take into account all fire accident scenarios that relatively frequently occur in the different Member States of the EEC, including specific local fire conditions and hazards. All textile products circulating in the EEC should provide a certain amount of fire safety protection to the common and specific fire hazards existing in the Member States.

From the specific accident mechanisms of domestic fire accidents involving soft furnishings and clothing textiles respectively, principles for the fire safety of these two product groups will be derived in the next sections.

3.3 Soft furnishings

The merits of "passive" protection measures in general have been discussed in the previous section. In this section the fundamental aspects of the fire safety of soft furnishings will be discussed. The general and specific fire hazards of residential fires will be discussed, as well as the importance of the time factor in escape scenarios and the scope and side-effects of product related prevention measures. Principles for the fire safety of soft furnishings in general, derived from the fundamentals indicated above, will be proposed at the end of this section. These principles provide a basis for product related fire prevention regulations for soft furnishings.

3.3.1 Fire load and hazard assessment

The entire fire load of a room consists of the combination of several types of soft furnishings in a room (like upholstered furniture, curtains, carpets, mattresses and bedding materials etc.), together with the walls, ceiling, floor and other building materials in certain constructions, as well as other non-textile interior goods present in a room. Ames (in: Rogmans and Jackson, 1987) suggests that people are not able to assess fire hazards of soft furnishings in their houses. Their experience of fire is limited to occurrences outside buildings and this experience may lead them to badly underestimate the hazards that arise when, for instance, furniture fires occur inside a room. Some types of soft furnishings may exhibit fire characteristics which represent a rapid hazard to life, but users of the furniture may not be aware of the hazard.

3.3.2 The hazard of ignition

In countries that keep a record of fire statistics most of the reported residential fires are ignited by smouldering cigarettes, matches and lighters. Other common frequent

ignition sources are candles and heating equipment. The relative frequency of certain ignition sources involved in domestic fire accidents may differ in different countries. Open fire places, for instance, may be common in some countries, but not in others (OECD, 1977). However, there is a large similarity in the main ignition sources of domestic fire accidents involving soft furnishings in different Western countries, which are smokers' materials, including matches and lighters. The main activities leading to such fire accidents will be common to all countries: carelessness with smoking materials and playing with fire. Sometimes alcohol or narcotics appear to be involved.

3.3.3 The hazards of fire growth, smoke and toxic gases

A lot of fires involving soft furnishings start in items of upholstered furniture or mattresses and bedding materials (Ames and Hoebel in: Rogmans and Jackson, 1987). Once ignition has occurred a period of fire growth will need to follow before the severity of the fire produces a risk of injury or death. Where the ignition is caused by a cigarette it is likely that a period of 30 minutes to several hours of smouldering may follow before flaming combustion begins. During the period of smouldering only small amounts of heat, smoke and toxic gas are released, compared with the rapid rates of generation that may occur when the reaction converts to flaming combustion (Ames in: Rogmans and Jackson,1986). If the local smouldering converts to flaming combustion, the subsequent fire growth can be extremely rapid. Fire accidents that have shown flash over occurring within a few minutes after ignition, setting a complete room on fire, have been frequently reported.

The generation of smoke accompanies the burning process and the volume of smoke released may be very high involving many hundreds of cubic metres with a visibility of 1 metre or less. This aspect of fire performance is important because it can affect people remote from the fire and interfere with their attempts to escape (Ames in: Rogmans and Jackson, 1987).

Toxic gases are released from all materials when they burn. Carbon dioxide is always present in high concentrations in fire gases, but carbon monoxide, although present in lower concentrations, is recognized as the most important of all fire gases in terms of life risk. Hydrogen cyanide is also found in the fire gases from some common furniture materials and has been shown to contribute in a small proportion of fire deaths (Ames in: Rogmans and Jackson, 1987). According to ISO-DP 9122 (1987) the most rapidly developing experimental fire in a laboratory takes only a few minutes to reach levels of heat and gases hazardous to life.

As the hazard of smoke and toxic gases is nowadays very important in residential fires, it is relevant to focus on this problem. Two different opinions on the problem of smoke and toxic gases generated by residential fires involving furnishings are described in ISO-DP 9122 (1987). One view says that the composition of fire products has changed so that the smoke from "modern" fires is more toxic (on a mass/mass basis) than the smoke produced by "traditional" materials (e.g. wood, wool, cotton etc.), and that the presence of unknown toxicants may account for the fact that persons are now more likely to be overcome and fail to escape from a fire. The other view says that the composition and toxicity of fire products has changed little, if at all, but that the rate of fire growth is much more rapid and the rate of evolution of fire products is much greater than previously. It is suggested that fire loads may have increased in typical residential living spaces, especially since in the last decades new types of furniture materials etc. were brought on the market. Other suggestions are given in the direction of fire statistics: the statistics may be influenced by changes in the reporting of fires, and actual fires may not have changed as much as it appears.
In the ISO-DP 9122 (1987) report, a study on fire fatalities is referred to that says that no significant group of fatal victims was found for which death could not be attributed to either CO or burns, so that there was no evidence that substances of unusual specific toxicity are important in fires, although their existence cannot be ruled out. Although most fatal victims had burns or high blood carboxyhaemoglobin concentrations (because of high CO concentrations), this does not prove that either agent was responsible for the initial incapacitation. The ISO-DP 9122 (1987) report states that evidence from real fires and fire casualties when taken with data from experimental fire and combustion toxicity studies suggests that substances of unusual specific toxicity are not important and that the major toxic product formed in fires causing incapacitation and subsequent death is CO, with a possible contribution from HCN in some cases. In addition, irritants are likely to play an important part in delaying escape by effects on the eyes and upper respiratory tract and possibly also on the lungs. It is suggested that there has been no significant change in the toxicity of combustion products that could account for the increased incidence of incapacitations and deaths, so that the problem most probably lies in the way in which the basic combustion products (including carbon monoxide) are evolved in modern fires. This opinion is shared by Babrauskas (private communication).

According to Hoebel and Orzel (1988) toxicity alone cannot be used to predict the fire hazard of materials. As an example, a material that produces unusually toxic combustion products but thermally decomposes at a high temperature can be a lesser fire hazard than a less toxic material that degrades at a lower temperature. Therefore, other performance

characteristics which influence the generation of heat and toxic gases and affect the time to development of hazardous conditions must be considered. Hoebel and Orzel note that there is no simple laboratory test to determine the fire hazard of materials. They consider hazard evaluation as a complex problem that involves the integration of large amounts of thermophysical and toxicological data and information on the building and on the behaviour of the occupants as well.

According to Ames (in: Rogmans and Jackson, 1987) smoke and toxic hazards, although often shown as the cause of death, may be considered as secondary hazards to heat release and fire growth which themselves help generate and drive the movement of the smoke and toxic gas towards the potential victim.
Ames has the opinion that the rapidity of fire growth is probably the most important factor related to personal injuries and death arising from furniture fires. Babrauskas (1988 a,b) considers the rate of heat release as the single most important fire hazard variable.

3.3.4 The hazards of melting

Some materials applied in soft furnishings, like thermoplastic materials, supply specific fire hazards. If these materials melt away after contact with an ignition source, the remaining material will usually not ignite. Nevertheless the molten material can start a fire elsewhere. If the molten material cannot drip away from an ignition source, the fire might be supported. In upholstered furniture, for instance, another fire hazard is present: after the melting away of a synthetic cover material other (filling) materials might be exposed, possibly easily ignitable and burning rapidly (OECD, 1977).

3.3.5 Escape time

According to Malhotra (in: Rogmans and Jackson, 1987) the possibilities of escape from a building are time dependent and therefore escape design should be time based. The time at which conditions become hazardous for occupants in the fire zone and in other parts is closely linked to a time-related escape scenario. Malhotra indicates various components of time based escape systems: time of ignition, time of the fire awareness, reaction time for occupants, time when conditions become critical, time available for moving to a safer zone and time needed to travel to a safer zone.

Malhotra reports that in most incidents the time of ignition is not known and the time of awareness will depend upon the detection of the fire. People in the vicinity will detect a

fire by seeing smoke or flames, by smelling smoke and/or by the noise of burning materials. People in other areas will rely by and large on seeing smoke emission from a room or smoke travelling along the ceiling or up unprotected stairs. Hence the time of detection is difficult to specify unless an automatic detection and alarm system is provided.

Malhotra's arguments in favour of alarm systems and Ames' suggestions about people's unawareness of the fire hazards of soft furnishings, discussed in subsection 3.3.1, support the need of a well balanced mixture of strategies to provide an effective fire prevention programme, as is already indicated before. In this study the attention will be focused on product related prevention measures.

3.3.6 Scope and side-effects of product related prevention measures

Product related prevention measures with regard to fire safety should regard complete items of soft furnishings. (Cover) fabrics, filling materials, interliners, accessories, decorations etc. should be regarded as complete assemblies in certain designs, as they are likely to be used in the households. Mattresses should be considered in combination with bedding materials, as they are likely to be used by consumers in a domestic environment. It is important to realize that, for instance, the overall fire performance of an upholstery assembly cannot be predicted from the fire behaviour of the individual components.

Product related prevention measures, such as the addition of flame retardant substances to soft furnishings, should not have significant adverse effects on the users' health, the environment and other essential product properties. Neither should they have significant adverse effects on other flammability parameters than those they are intended to affect. For example, flame retardant substances should not increase the toxicity of combustion products, while diminishing the flammability of soft furnishings.

3.3.7 Principles

From the fundamental aspects of the fire safety of soft furnishings discussed in the previous subsections, two important principles for the fire safety of soft furnishings in general can be derived:

1. For any item of soft furnishing the likelihood of ignition should be limited.

As it will not always be possible to prevent ignition, the following principle is proposed:

2. If an item of soft furnishing has caught fire, people should have sufficient time to react: to escape to a safe place, or to prevent flame spread and extinguish the fire. People should not be overcome by smoke, toxic gases, heat or flame spread, creating conditions hazardous to life.

3.4 Clothing textiles

In this section the fundamental aspects of the fire safety of clothing textiles will be discussed. The general and specific fire hazards of clothing fires will be dealt with, as well as the scope and side-effects of concerned product related prevention measures. Principles for the fire safety of clothing textiles, derived from the fundamentals indicated above, will be proposed at the end of this section. These principles provide a basis for product related fire prevention regulations for clothing textiles.

3.4.1 The hazards of ignition, burn rate and heat

According to fire statistics different kinds of ignition sources appear to be involved in clothing fires. The relative frequency of certain ignition sources involved may differ in different countries. For instance, open fire places, which present an obvious danger, may be common in some countries but not in others. This may also be the case with certain radiant heat sources - electric, gas and oil heaters - which are well able to ignite clothing coming into contact with them. However, certain ignition sources will be common to all Western countries: smoking materials, matches, and heating and cooking stoves. The activities leading to clothing fires by means of these ignition sources will also be common to all Western countries, such as playing with matches and lighters, carelessness with cigarettes and the wearing of flammable clothing closely to stoves etc.

The degree of hazard which any item of clothing represents depends, among others, on its likelihood of coming into contact with a source of ignition (OECD, 1977). To this event, the outer garment is in the "key position". Materials with short ignition times are more likely to ignite during inadvertent exposure to small ignition sources: ignition time can thus be considered a major component of the hazard of various fabrics that release enough heat to cause burn injury (Krasny, 1986). Therefore it is logical, according to Krasny, to stipulate that long ignition times are beneficial because they reduce the probability of inadvertent garment ignition. Not only the fabric material, structure etc. but also the design of a garment influences its fire behaviour. In a simply cut garment of minimal yardage there is far less chance of fabric billowing into a flame source or concealing dropped ashes (King, 1979).

The degree of hazard also depends on the burn rate, which is also influenced by the garment design. In loose garments a "chimney effect" can occur. Loose garments have been shown to be more likely to cause extensive burns in manikin experiments. More extensive burns are generally associated with garments which cover most of the body (e.g. nightgowns, dresses) than with half-cover garments (e.g. shirts, trousers). Manikin experiments indicate that beltless dresses cause more extensive injuries than dresses with a belt (Pakkala in: Rogmans and Jackson, 1987), although other experiments indicate that belts of robes (made from the same fabric as the garment) had little effect on the overall burning character (Krasny, 1986). Krasny (1986) reports a radical slowing in burn rate, usually leading to extinguishment, in manikin burns when the flame progresses into a garment area that is in contact with the manikin surface. Tight-fitting garments are in close contact with the body, the body prevents air access to one side of the flaming fabric and acts as a heat sink if a clothing fire occurs. It should be noted that during real life accidents the distance between the garment and the skin is changed by the victim's movements (Krasny, 1986). Loose garments can also be expected to come into contact with the skin during clothing fire accidents. Fabrics that continue burning rapidly while in contact with a body could be expected, according to Krasny, to have higher injury potential than those that are extinguished by such contact.

Many commonly used clothing materials produce heat of burning that is several times higher than the level of human skin tolerance. Thus, injury from flammable fabrics is produced by transfer of heat to the skin in excess of human tolerance (Pakkala in: Rogmans and Jackson, 1987). Krasny (1986) discusses findings which indicate that the heat release rate tests are better predictors of injury potential of fabrics than other tests, for instance flame spread rates measurements.

Not only the outer garment, but also the undergarment affects clothing burns. Especially when a fire spreads the type of garment in combination with the type of undergarment becomes essential (Pakkala in: Rogmans and Jackson, 1987).

3.4.2 The hazards of melting

An important aspect in accident mechanisms is the melting of synthetic fibres. In many cases the material does not ignite at all if it shrinks away from the ignition source. Dripping of the molten material can stop the burning, but can also cause severe burns or start burning elsewhere (Pakkala in: Rogmans and Jackson, 1987). Garments made from thermoplastic materials - although they may qualify as flame resistant - are likely to burn fairly rapidly if worn in combination with

garments made from non-melting fabrics and ignited (OECD, 1977; Stacey, 1985).

3.4.3 The hazard of "surface flash"

Some fabric types, like napped fabrics and simulated furs etc., constitute the fire risk of "surface flash". The surface flash can, during its brief duration, cause burns to the face and head of the wearer of the garment (OECD, 1977; Pakkala in: Rogmans and Jackson, 1987).

3.4.4 Scope and side-effects of product related prevention measures

Protection measures with regard to fire safety should not only cover complete garments of "day" and night wear, for children and adults, but also fabrics and accessories and decorations of textile materials intended for use in apparel.

Product related prevention measures, such as the addition of flame retardant substances to clothing textiles, should not have significant adverse effects to the users' health, the environment and other essential product properties. Neither should they have significant adverse effects to other flammability parameters than those they are intended to affect.

3.4.5 Principles

From the fundamental aspects of the fire safety of clothing textiles discussed in the previous subsections, three important principles for the fire safety of clothing textiles can be derived:

1. For clothing fabrics, accessories etc. the likelihood of ignition should be limited. The ignitability characteristics of materials applied in loose garments, coming relatively easy into contact with potential ignition sources, should compensate the hazardous effects of the design of such garments.

As it will not always be possible to prevent ignition, the following principle is proposed:

2. If a piece of clothing has caught fire, the wearer should have sufficient time to undertake appropriate action to prevent flame spread and injury and to extinguish the fire. The burning characteristics of materials applied in loose garments should compensate the hazardous effects of the design of such garments.

As victims of clothing fires are relatively often found among children and the elderly, probably owing to their underdeveloped or failing senses or abilities, the following principle is proposed:

3. Clothing (textiles) intended for children and disabled persons should provide a higher fire safety level than the fire safety level required for other clothing (textiles) because children and disabled persons cannot handle fire situations properly.

4 ESSENTIAL FIRE SAFETY REQUIREMENTS

In this chapter a consistent framework of essential fire safety requirements for textile products for consumers will be worked out. The fire safety principles proposed in the previous chapter will be used as a guideline to formulate the essential requirements. The essential requirements will be distinguished for both soft furnishings and clothing textiles.

These requirements may be implemented in a future European Directive on the fire safety of textile products for consumers; then they have to be worked out by means of European standards.

4.1 Soft furnishings

From the fundamental aspects and the principles of the fire safety of soft furnishings in general discussed in chapter 3, essential fire safety requirements for soft furnishings - including upholstered furniture, mattresses and bedding materials, curtains, textile floor coverings and textile wall coverings - will be derived. These essential requirements will be related to the most relevant flammability parameters in residential fires and to the main specific fire hazards occurring in residential fires.

The essential requirements apply to complete items of soft furnishings and to combinations of mattresses and bedding materials, likely to occur in the households. They do not apply to separate soft furnishing components, such as cover materials, fillings, curtain cloth etc., intended to be used in soft furnishings, for re-upholstery etc. To regulate their flammability, the application of these soft furnishing components should be simulated in the most likely combinations and designs that can be expected to occur in the households, which models should then meet the essential requirements designed for complete items of soft furnishings.

The essential requirements should not only regard new soft furnishings, but also soft furnishings aged by use, cleaning, washing etc.

Fire safety requirements for soft furnishings should be consistent with fire safety requirements for buildings and other interior goods (if adequate), in order to arrive at a fire safety level of the domestic environment which offers a sufficient amount of protection to consumers.

As far as ignition sources are concerned, the essential requirements will be based upon the most common frequent ignition sources involved in residential fires: smokers' materials including matches and lighters. A detailed study of

the fire statistics of the different Member States of the EEC for the purpose of a European Directive on the fire safety of textile products for consumers might add other ignition sources. Such a study is beyond the scope of this report. If future fire statistics indicate that other ignition sources are frequently involved in residential fires, the scope of the following essential requirements should be extended to these ignition sources as well.

Ignitability

The first principle for the fire safety of soft furnishings regards the likelihood of ignition. From this principle the first essential requirement arises:

1. Soft furnishings should resist ignition by the most common ignition sources in residential fires, which are smouldering cigarettes and small flames, under foreseeable domestic conditions, paying attention to the possibility of longterm smouldering.

As it will not always be possible to prevent ignition, the following set of essential requirements can be formulated in the context of the second principle for the fire safety of soft furnishings. This second principle regards the time necessary for a person, if an item of soft furnishing has caught fire, to undertake appropriate action to escape or to prevent flame spread and extinguish the fire. This principle leads to several essential requirements concerning the rate of heat release as an overall expression for fire growth in a room, which includes the local individual flame spread contributions in a room fire (Babrauskas, 1988b) and the production of smoke and toxic gases.

Rate of heat release

2. Soft furnishings should have a limited rate of heat release during the process of burning, paying attention to the possibility of longterm smouldering and its conversion to flaming combustion, in order to give people sufficient time to react, that is to escape or to extinguish the fire.

Smoke production

3. Soft furnishings should have a limited emission of smoke during the process of burning, paying attention to the possibility of longterm smouldering and its conversion to flaming combustion, in order to give people sufficient visibility and time to react, that is to escape or to extinguish the fire.

Toxic gases

4. Soft furnishings should have a limited emission of toxic gases (among others CO, HCN and CO_2) during the process of burning, paying attention to the possibility of longterm smouldering and its conversion to flaming combustion, in order to give people sufficient time to react, that is to escape or to extinguish the fire.

Melting

Certain components of soft furnishings can supply specific fire hazards because of melting characteristics. The following essential requirement regards these hazards:

5. Soft furnishings should not provide specific fire hazards accompanying the process of melting by starting a fire elsewhere.

Side-effects of flame retardant substances

The addition of flame retardant substances to soft furnishings should be handled with care. To prevent the occurring of significant adverse effects, the following essential requirements are proposed:

6. Flame retardant substances, added to soft furnishings, should not be dangerous to the users' health: they should neither be irritant, toxic, mutagenic, carcinogenic nor teratogenic.

7. Flame retardant substances, added to soft furnishings, should not significantly adversely affect other essential product characteristics such as comfort, durability etc.

8. Flame retardant substances, added to soft furnishings, should not cause environmental damage, especially after these soft furnishings are being disposed of.

9. Soft furnishings treated with flame retardant substances should not require much extra caution or effort in maintenance, cleaning etc. Users should be informed about the proper ways of maintenance, cleaning etc. of soft furnishings treated with flame retardant additives, in order to secure the permanence of the flame retardant treatment.

4.2 Clothing textiles

From the fundamental aspects and the principles of the fire safety of clothing textiles discussed in chapter 3, essential fire safety requirements for clothing, clothing textiles and accessories etc. of textile materials intended for clothing

will be derived. These essential requirements will be related to the most relevant flammability parameters in clothing fires and to the main specific fire hazards occurring in clothing fires. Because a lot of consumers make their own clothes with the help of paper patterns, essential requirements are included that concern clothing textiles for consumer sale and paper patterns for garments with a high fire hazard because of their design.

The essential requirements should concern both "day" and night clothing (textiles) as far as such clothing (textiles) can be expected to be involved in domestic clothing fire accidents. The essential requirements need not be applied to clothing that is exclusively intended for outdoor purposes like outdoor sportswear, rainwear etc. Neither need the essential requirements be applied to non-textile clothing materials like leather, suede, (natural) fur etc. It should be noted that textile linings applied in garments of such non-textile materials should meet the essential requirements.

It appears that most garments could be made from relatively low flammability hazard fabrics if customer preference and manufacturing considerations are subordinated to fire safety (Krasny, 1986). In order to determine which clothing (textiles) should meet the essential requirements outlined in this section and which types of clothing (textiles) should be excluded, a balanced overall weighting, including all relevant product characteristics, economic effects and the severity of the involved clothing fire accidents should be carried out. The philosophy and priorities that should direct such a weighting are beyond the scope of this study.

The essential requirements should not only regard new clothing (textiles), but also clothing (textiles) aged by wearing, washing etc.

The essential requirements for children's apparel should also be applied to garments that are exclusively intended for the disabled, who are reacting slower to fire situations.

As far as ignition sources are concerned, the essential requirements will be based upon the most common frequent ignition sources in clothing fires: smokers' materials including matches and lighters, and heating and cooking stoves. A detailed study of the fire statistics of the different Member States of the EEC for the purpose of a European Directive on the fire safety of textile products for consumers might add other ignition sources. Such a study is beyond the scope of this report. If future fire statistics indicate that other ignition sources are frequently involved in clothing fires, the scope of the following essential requirements should be extended to these ignition sources as well.

Ignitability

The first principle for the fire safety of clothing (textiles) regards the likelihood of ignition. From this principle the following essential requirements emerge:

1. Apparel, clothing fabrics and accessories etc. should resist ignition by the most common ignition sources in clothing fires, which are smouldering cigarettes and small flames, under foreseeable conditions.

2. Garments that because of their style and design are likely to come relatively easy into contact with potential ignition sources should also resist ignition by the most common ignition sources in clothing fires, which are smouldering cigarettes and small flames; the ignitability characteristics of the materials applied in such garments should compensate the hazardous effects of the garment designs.

3. Garments intended for children and clothing fabrics and accessories etc. intended for use in children's clothing should have a higher resistance to the most common ignition sources, that is to smouldering cigarettes and small flames, than the required basic resistance for all clothing (textiles). The fire safety level for children should be higher because they cannot handle fire situations properly.

As it will not always be possible to prevent ignition, the following set of essential requirements can be formulated in the context of the second principle for the fire safety of clothing textiles.

Rate of heat release

The second principle for the fire safety of clothing (textiles) regards the time necessary for the wearer, if his clothing has caught fire, to undertake appropriate action to prevent flame spread and injury and to extinguish the fire. This principle leads to the following essential requirements:

4. Apparel, clothing fabrics and accessories etc. should have a limited rate of heat release in order to give people sufficient time to react. There should be no tendency to continue burning rapidly upon skin contact.

5. Loose garments that because of their style and design represent relatively high injury hazards should also have this limited rate of heat release; there should also be no tendency to continue burning rapidly upon skin contact. People should have sufficient time to react; the burning characteristics of the materials applied in such

garments should compensate the hazardous effects of the garment designs.

6. Garments intended for children and clothing fabrics and accessories etc. intended for use in children's apparel, should have a lower rate of heat release than the required rate of heat release for other clothing (textiles). There should -of course- also be no tendency to continue burning rapidly upon skin contact. The fire safety level for children should be higher because they cannot handle fire situations properly.

"Surface flash"

The following essential requirement emerges from the specific fire hazard of "surface flash".

7. The outside surface of apparel, clothing fabrics and accessories etc. should not display the phenomenon of "surface flash" in contact with the most common ignition sources in clothing fires, which are smouldering cigarettes and small flames.

Melting

Certain clothing textiles can supply specific fire hazards because of melting characteristics. The following essential requirement regards these hazards:

8. Apparel, clothing fabrics and accessories etc. should not provide specific hazards accompanying the process of melting, like causing severe burns or starting a fire in another piece of clothing.

Side-effects of flame retardant substances

The addition of certain flame retardant substances to clothing textiles should be handled with care. To prevent the occurring of significant adverse effects, the following essential requirements are proposed:

9. Flame retardant substances, added to clothing textiles, should not be dangerous to the users' health: they should neither be irritant, toxic, mutagenic, carcinogenic nor teratogenic.

10. Flame retardant substances, added to clothing textiles, should not significantly adversely affect other essential product characteristics such as comfort, durability etc.

11. Flame retardant substances, added to clothing textiles, should not cause environmental damage, especially after these clothing textiles are being disposed of.

12. Clothing textiles treated with flame retardant substances should not require much extra caution or effort in maintenance, washing etc. Users should be informed about the proper ways of maintenance, washing etc. of clothing textiles treated with flame retardant additives, in order to secure the permanence of the flame retardant treatment.

Clothing textiles for consumer sale

The following essential requirement relates to clothing textiles for consumer sale, suitable to be applied in apparel.

13. Clothing textiles for consumer sale, suitable to be applied in apparel, should bear a fire warning on a label whether they are suitable to be applied in loose-fitting garments, with a relatively high fire hazard because of their design, or not. This warning should comply with the fire performance characteristics of the clothing textiles concerned.

Paper patterns

The following essential requirement relates to paper patterns for garments with a relatively high fire hazard because of their design.

14. Paper patterns of garments that because of their style and design are
    a. likely to come easily into contact with potential ignition sources and/or
    b. likely to contain a considerable amount of air entrapped between the garment and the wearer,

    should bear a fire warning paragraph visible and readable when buying and using them, drawing attention to the relatively hazardous design of the paper pattern concerned and to the need of the application of suitable clothing textiles with a relatively high level of fire safety, referring to the fire warning on the labels attached to clothing textiles for consumer sale.

5 SUGGESTIONS FOR STANDARDIZATION

In this chapter a set of statements will be developed that can give guidance to the work of standardization groups once it were decided to give a mandate to CEN on the basis of a European Directive on the fire safety of textile products for consumers. The essential requirements of chapter 4 would then have to be worked out by means of European standards. More or less detailed suggestions for the development of fire safety standards will be presented in order to give the first impulse to the translation of the essential requirements of chapter 4 into fire safety standards. The suggestions will be distinguished for soft furnishings, including upholstered furniture, mattresses and bedding materials, curtains and textile floor coverings, and for clothing textiles.

The first section regards soft furnishings, which is detailed into subsections concerning the general aspects and the separate product groups of soft furnishings. These subsections contain suggestions for standardization that have arisen from the screening of the principles and scopes of the relevant standards regarding these product groups summarized in Annex 1, with the essential requirements of chapter 4 in mind and from relevant literature. The second section concerns clothing textiles and contains both global suggestions for standardization and suggestions for standardization that have arisen from the screening of the principles and scopes of the relevant standards regarding clothing textiles and apparel etc. summarized in Annex 1, with the essential requirements of chapter 4 in mind.

It should be noted that, with regard to the determination of the criteria concerning the fire safety of textile products for consumers, a balanced overall weighting, including all relevant product characteristics, economic effects and the severity of the involved domestic fire accidents etc., should be carried out. The philosophy and priorities that should direct such a weighting are beyond the scope of this study.

5.1 Soft furnishings

5.1.1 General aspects

In this section some suggestions for standardization will be proposed for soft furnishings in general.

1. Only full-scale room fire tests can serve as a "primary" reference for fire hazard performance. A sound full-scale test requires that a well-justified fire scenario be established (Babrauskas, 1988a). Test methods should thus concern complete items of soft furnishings, the test specimens simulating real life soft furnishings as far as possible. According to Babrauskas (1988a) all

bench-scale methods and those full-scale methods which do not use an actual test room receive validity only by means of validation or correlation against full-scale room fire results. Test methods based upon components should therefore only be allowed if they have proved to predict the fire behaviour of a complete item of soft furnishing.

2. If separate soft furnishing components are tested, the application of these components should be simulated in the most likely combinations and designs that can be expected to occur in the households. Babrauskas (1988a) mentions that bench-scale tests have the limitation that fire behaviour which is influenced by full-scale geometry or configuration may be difficult to represent.

3. Test methods should regard new soft furnishings, as well as soft furnishings aged by (simulated) real life conditions like foreseeable use, cleaning etc.

4. The purpose of the standardization of the fire safety of soft furnishings should be the providing of a level of domestic fire safety consistent with the fire safety level of other interior goods and buildings.

5. Test methods should be based upon the most common ignition sources in residential fires: smouldering cigarettes and small flames.

6. The most common ignition sources should be simulated as realistically as possible; attention should be paid to the specific characteristics of ignition sources like the calorific output, temperature, flaming or smouldering performance etc.

7. The phenomenon of ignition, involved in the accident mechanisms, should be simulated as realistically as possible; attention should be paid, among others, to the involved heat transfer mechanisms in the contact of a test specimen with an ignition source, the contact time during which contact is established between the test specimens and the ignition sources - nota bene: long term smouldering! - as well as the position of the ignition source and the orientation of the test specimen during contact.

8. The orientation of a test specimen should be as realistically as possible in any test method; the most hazardous orientation during the foreseeable use of soft furnishings should be simulated; for instance, curtains should be tested taking into account the folds, providing the "chimney-effect" hazard.

9. The phenomenon of longterm smouldering, converting to flaming combustion should be simulated in test methods for

the determination of the ignitability, the rate of heat release and the production of smoke and toxic gases.

10. From Annex 1 it has become clear that few standards are available concerning the measurements of the rate of heat release, smoke production and the production of toxic gases. Those that are available or under development are usually intended for high-risk occupancies, public occupancies etc. and not for residential applications. In the previous chapters it is shown that hazard assessment and the formulation of criteria regarding these fire performance characteristics are very complex matters. These fire performance characteristics are responsible for many fire deaths and therefore much attention should be paid to the standardization of the measurements of the rate of heat release, smoke production and toxic gases. The measurement of oxygen levels in the combustion products which are collected and passed through a duct might provide a basis for the calculations of the heat released by burning specimens and of the amounts of smoke and certain toxic gases (e.g. carbon monoxide) produced (after Ames in: Rogmans and Jackson, 1987).

11. Attention should be paid to items of soft furnishings that are the second to ignite (Babrauskas, 1988a). None of the existing full-scale tests provide for external specimen heating and the presence of external heating may change the real fire performance of soft furnishings (Babrauskas, 1988a, with regard to upholstered furniture).

12. The test programme for the health effects of flame retardant substances used in certain soft furnishings should be based upon the use of these soft furnishings in practice. Bed linen, for instance, often in close body contact with the user, may need an approach different from curtains.

13. A realistic simulation of the use of the soft furnishings concerned should provide the basis for the testing of the permanence and the influence on other essential product characteristics of flame retardant substances applied in soft furnishings. Bed linen, for instance, which should provide comfort and is often washed, may need an approach different from upholstered furniture.

14. All phases of the life cycle of soft furnishings, treated with flame retardant substances, should be considered in the design of a test programme for the environmental effects of flame retardant substances.

In the following sections suggestions for standardization will be proposed for upholstered furniture, mattresses and bedding materials, curtains and textile floor coverings.

These suggestions have arisen from the principles and scopes of the standards regarding these product groups as described in Annex 1, which were screened with the essential requirements of chapter 4 in mind and from relevant literature.

From the brief summary of the standards presented in Annex 1 no profound judgements can be derived concerning these standards. The suggestions that have arisen from the standards are intended to give guidance to the process of standardization. Within the scope of this study, neither can judgements be derived concerning test methods based upon specimens of textile components separately, in order to determine whether they are able to predict the fire behaviour of complete items of soft furnishings or not. Nevertheless useful suggestions for standardization might be obtained from such standards, for instance the idea of simulating curtain folds is brought up in such a standard. A more detailed discussion concerning test methods for measuring flammability properties of upholstered furniture and mattresses and bedding materials is presented by Babrauskas and Krasny (1985). More detailed suggestions for standardization may be derived from this discussion, which are beyond the scope of this report.

Standards regarding the determination of possible adverse effects of flame retardant substances are beyond the scope of this study. Concrete suggestions in this field are therefore absent here.

5.1.2 Upholstered furniture

1. A test concerning the ignitability of upholstered furniture assemblies is provided by BS 5852: Part 1 (1979). The test includes the simulation of two relevant ignition sources, representing smokers' materials: a smouldering cigarette and a burning match. The position at which accidentally dropped cigarettes or lighted matches are most likely to cause ignition is simulated in the test. The phenomenon of "longterm progressive smouldering" receives attention in the standard. Design of upholstered furniture is not taken into consideration and should receive attention, as design features can greatly affect the fire properties of upholstered furniture.

2. A finished product ready for sale to the consumer or a prototype mock-up of actual components which duplicates the design and structure of the finished product is tested in the Californian Technical Bulletin 116 (1980). Burning cigarettes are the only ignition sources involved. Sheeting material covers the burning cigarettes during the test, which does not come close to reality. According to Babrauskas and Krasny (1985) the use of a cover fabric

over the cigarette makes the test slightly more severe and more reproducible. It may compensate for the effect of aging and dirt accumulation which has been reported to decrease cigarette ignition resistance. The sheeting should fit tightly over the cigarette to be effective.

3. The most important specimen variable to be determined is the full-scale peak rate of heat release, since that is the quantity which most closely describes the actual fire hazard expected from the item (after Babrauskas, 1988b). Most of the standards concerning the fire behaviour of upholstered furniture discussed in section 2.1 of Annex 2, regard components separately, e.g. filling materials and cover fabrics. The standards for residential applications are only concerned with the ignitability of upholstered furniture; other fire performance characteristics such as the rate of heat release, smoke production, the production of toxic gases and the specific phenomenon of melting are not considered. Standards should be developed for domestic applications also with regard to these fire performance characteristics.
Babrauskas has the opinion that the Nordtest NT FIRE 032 (1988) provides possibilities for the testing of these fire performance characteristics with regard to domestic applications (private communication). Sundström (1988) summarizes the Nordtest -intended to be used for high-risk occupancies etc.- as follows:

"The tested item, a full size sofa or full size mock-up, is ignited with a wooden crib and allowed to burn freely without restrictions on air supply. Rate of heat release, mass burning rate, production of light obscuring smoke and production of carbon-monoxide are measured.

Measured peak heat release rates can be used to estimate risk for compartment flash over and ignition of a second item as well as time for a safe escape or attack of the fire.

The measured production rates of smoke and carbon-monoxide can be used to demonstrate visibility and toxicity."

5.1.3 Mattresses and bedding materials

1. The ignitability of mattresses in combination with bedding materials is tested in BS 6807 (1986), with both primary and secondary ignition sources; secondary sources simulating the effects of varying amounts and types of bedcovers in combination with primary sources. Smouldering and flaming ignition sources are placed on top of and/or below the test specimen. The flaming behaviour of larger amounts of added bedcovers is intended to be modelled by burning wood cribs in a BSI-test method that is at present

under development. The range from which a consumer can choose his bedding products should be imitated in a test method; this is achieved in this standard by using smoulderable or non-smoulderable insulation pads.

2. The American standard 16 CFR 1632 (FF4-72), 1986 concerns the ignition resistance of a mattress or mattress pad (prototype designs) when exposed to a lighted cigarette. A two-sheet test, wherein the burning cigarettes are placed between the sheets, is also included. The sheeting material has to be laundered and dried before use. Other bedding materials are not simulated in this standard.

3. In Norway combinations of bedding materials are tested in the "Provisional rules for testing" method (1983) to the ignition sources of glowing cigarettes and/or methenamine tablets. Unlaundered as well as laundered specimens are tested. Because this standard considers many different combinations of several bedding materials it might be useful in the design of a test programme concerning mattresses and bedding materials.

4. In the Federal Republic of Germany different kinds of ignition sources are used in the Hoechst Werkrichtlinie 93-0666 (1981); glowing cigarettes, matches, methenamine tablets and newspapers. The tests are carried out on a small-scale bed including all kinds of bedding materials. Elements of these tests might be useful to the design of a test programme concerning mattresses and bedding materials.

5. In Japan the 1983-regulations give special attention to the phenomenon of melting. These regulations might assist in the design of a test programme concerning mattresses and bedding materials, regarding this characteristic.

Realistic standards concerning mattresses in combination with bedding materials including blankets were not found in literature and should be developed. All summarized standards are only concerned with the ignitability of mattresses and bedding materials; other fire performance characteristics such as the rate of heat release, smoke production and the production of toxic gases are not considered. Standards should be developed for domestic applications with regard to these fire performance characteristics.

5.1.4 Curtains

1. Test specimens of curtains should be vertically oriented. The standards of section 2.3 of Annex 1 do not relate to complete curtains, but vertically suspended specimens of curtain materials. Seams and linings and their effects on the fire behaviour of curtains should be considered as well.

2. NEN 1722 (1986) simulates folds in curtains by positioning three layers of cloth behind each other. Because of the "chimney effect" hazard this aspect should be taken into consideration.

3. Possible effects of ageing, soiling and cleaning are brought under attention in NEN 1722 (1986), but not worked out. Such effects on the fire behaviour of curtains should be considered. In the ÖNORM B 3820 (1986), reference is made to DIN standards for cleaning and washing procedures.

Several burning properties of curtain materials are tested and evaluated in the existing standards, e.g. the ease of ignition and flame spread properties. Other fire performance characteristics are not tested and evaluated in the standards summarized in section 2.3 of Annex 1, such as the rate of heat release, smoke production, the production of toxic gases and the specific phenomenon of melting. Such fire performance characteristics should also receive attention.

5.1.5 Textile floor coverings

1. Test specimens of textile floor coverings should be horizontally oriented and in finished condition as they will be used by consumers.

2. The test specimens of BS 4790 (1987) include any backing or underlay that forms part of the final installation of textile floor covering. The final installation of textile floor covering should be simulated.

3. Specimens with a pile on the surface should have their pile raised, in order to let the specimens contain the maximum amount of air (e.g. BS 4790).

4. NEN 1775 (1985) measures, among others, the contribution of a horizontally oriented test specimen to fire propagation by subjecting it to a defined radiant heat energy source. This aspect should be considered.

5. The American standards 16 CFR 1630 (FF 1-70), 1986 and 16 CFR 1631 (FF 2-70), 1986 make reference to excluding one of a kind carpets or rugs, like an antique, an Oriental or a hide. This seems a practical suggestion.

6. Both loose-laid and fully adhered carpets shuld be tested and evaluated (e.g. BS 4790; 16 CFR 1630).

7. The American standards 16 CFR 1630 and 16 CFR 1631 include 10 times washing, dry cleaning or shampooing of carpets or rugs which are flame retardant, depending on the manner that is normally used for such carpets or rugs in service. Normally used cleaning methods should be taken into consideration.

Other standards include the testing of vertically oriented specimens, whereas a vertical orientation of textile floor coverings is unrealistic unless it concerns coverings to be applied (also) to the wall. The standards do not regard the fire performance characteristics rate of heat release, smoke production, the production of toxic gases and the specific phenomenon of melting. These fire performance characteristics should also receive attention.

5.2 Clothing textiles

In this section some suggestions for standardization will be proposed with regard to clothing textiles. These suggestions have arisen from the screening of the principles and scopes of the relevant standards described in Annex 1, with the essential requirements of chapter 4 in mind and from relevant literature.

From the brief summary of the standards presented in Annex 1 no profound judgements can be derived concerning these standards. The suggestions which have arisen from the standards are intended to give guidance to the process of standardization.

Standards regarding the determination of the adverse effects of flame retardant substances are beyond the scope of this study. Suggestions in this field are therefore only global.

1. Test methods should simulate real life situations as far as possible. Manikin tests are recommended for apparel. Such tests support the observations made from actual burn injuries and are a much better indicator of hazards than small scale fabric burning tests, although they do not perfectly represent real life burn accidents and can be considered a worst case simulation of real life accidents, as the manikin "victim" does not react to the burn by moving (after Belshaw and Jerram, 1986 and Krasny, 1986). Many summarized standards (see Annex 1) concern the ignitability and rate of flame spread of clothing textiles. Flame spread rates are used widely as the criterion in many flammability tests. Krasny (1986) refers to studies in the United States and the United Kingdom in which flame spread rates measured on fabrics retrieved from garment burn accidents were compared with the size of injury suffered by the wearers. These studies showed no correlation between flame spread rate and injury size. While flame spread rate can identify some fabrics with inordinately high injury potential it does not seem to relate to injury potential of ordinary fabrics as effectively as heat release tests (Krasny, 1986). Furthermore, the behaviour of framed specimens is often not typical, according to Krasny, of that occurring in garments. Krasny also indicates that mass loss rate of burning fabrics is not an appropriate predictor of garment

burn injury hazard and he expresses the opinion that heat release rate tests are better predictors of injury potential of fabrics than other tests. Standardized full-scale heat release rate manikin tests are not available and should be developed.

2. The use of certain trims, accessories and sewing threads can have an adverse effect on the flammability of a garment: this should be incorporated in a test programme, as is for instance indicated in BS 5722 (1984), NEN 1722, Appendix B (1987), and the American standards 16 CFR 1615 (FF 3-71), 1986 and 16 CFR 1616 (5-74), 1986.

3. Test methods should have regard to new clothing (textiles), as well as clothing (textiles) aged by (simulated) wearing, washing etc. In BS 5651 (1978) cleansing and wetting procedures for use in the assessment of the effect of cleansing and wetting on the flammability of fabrics and fabrics assemblies are given. ISO 6330 (1984) and ISO 3175 (1979) also deal with cleansing procedures for apparel, as well as the American standards 16 CFR 1610 (CS 191-53), 1986, 16 CFR 1615 (FF 3-71), 1986 and 16 CFR 1616 (FF 5-74), 1986. No standards were found that include simulation procedures for the effect of wearing.

4. If body measurements are involved in the design of test methods and criteria, like in AS 1249 (1983), local differences in anthropometric data should be incorporated.

5. Test methods should be based upon the most common ignition sources in clothing fires: smouldering cigarettes and small flames.

6. The most common ignition sources should be simulated as realistically as possible; attention should be paid to the specific characeristics of ignition sources like the calorific output, temperature, flaming or smouldering performance etc.

7. The phenomenon of ignition, involved in the accident mechanisms, should be simulated as realistically as possible; attention should be paid, among others, to the involved heat transfer mechanisms in the contact of a test specimen with an ignition source, the contact time during which contact is established between the test specimens and the ignition sources, as well as to the position of the ignition source and the orientation of the test specimen during contact.

8. The orientation of a test specimen should be as realistically as possible in any test method, including test methods relating to the determination of the rate of flame spread; for instance, a pair of trousers or a dress

should be oriented vertically, in accordance with the way these garments are worn, thus providing the hazard of the "chimney-effect" in a realistic simulation. Fabrics should be tested in an orientation corresponding with the orientation of the fabric in the garment.

9. In test methods for the phenomenon of "surface flash", the contact with the most common ignition sources in clothing fires should be simulated as realistically as possible; the contact should be established at the outside surface of the apparel and the pile of the surface should be raised, to ensure that a maximum of air is entrapped. BS 4569 (1983) provides a test method for the phenomenon of "surface flash"; the pile of the fabric is raised before the test is carried out. NEN 1722 (1987) also provides a test method and criteria for "surface flash". Whether this standard identifies fabrics with a specific "surface flash" hazard is at the moment under discussion. In AS 1249 (1983) this phenomenon is also subjected to a test and criteria.

10. The phenomenon of melting should be considered in a test programme. BS 5438 (1976) and NEN 1722 (1987) pay attention to flaming debris behaviour. No specific test methods were found that focus on melting characteristics.

11. The test programme for the health effects of flame retardant substances used in clothing (textiles) should be based upon the use of these clothing (textiles) in practice, which often means close contact with the body during many hours at a stretch.

12. A realistic simulation of the use of the clothing (textiles) concerned should provide the basis for the testing of the permanence and the influence on other essential product characteristics of flame retardant substances applied in clothing (textiles).

13. All phases of the life cycle of clothing (textiles), treated with flame retardant substances, should be considered in the design of a test programme for the environmental effects of flame retardant substances.

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ANNEX 1

STANDARDS AND LEGISLATION

In this Annex a survey of the existing standards concerning the flammability of textiles in the Member States of the EEC and various other Western countries is presented. The survey consists of sections on textiles in general, soft furnishings including upholstered furniture, mattresses and bedding materials, curtains and textile floor coverings, and clothing textiles. Concerning textile wall coverings no standards were found.

Some countries have mandatory regulations on the flammability of textile products, some have voluntary regulations, some have both types of regulations and others have neither mandatory nor voluntary regulations.

Legislation concerning the flammability of textiles is usually based on standards involving suitable test methods. In this annex the attention will be focused on the existing flammability standards. The specific mandatory regulations incorporating these standards will be discussed briefly, as well as the most important voluntary regulations.

In the literature concerning the flammability of textiles many standards are referred to. The standards considered here were selected on the basis of the following criteria:
- the origin of a standard: special attention was given to the standards existing in the EEC Member States (e.g. although they were not often referred to, several French standards were taken into consideration);
- the scope of a standard (e.g. a standard on the fire safety of buildings in general was not taken into consideration; a standard on a particular aspect of textile flammability was studied);
- the quality of a standard as evaluated in the consulted literature (e.g. a severely criticized standard was not taken into consideration).

The principles and the scopes of the listed standards will be characterized briefly with regard to the accident mechanisms and fire hazards discussed in the previous chapter.

It should be noted that, according to Babrauskas (1988b)*, the existing national flammability standards concerning building products or contents, based on various small scale testing devices, have generally been developed on an ad hoc basis, to exclude some specific materials known to be poor performers, and not on a detailed understanding of fire

* References can be found in the general reference list.

behaviour. Babrauskas reports also that the relationship between the test results according to different small-scale flammability standards was found to be almost completely random.

1 Textiles in general

Standards regarding the flammability of textiles in general are available in many Member States of the EEC and various other Western countries. In some countries mandatory regulations are based on such standards. An inventory of such standards, selected on the basis of the criteria discussed before, is presented here. A brief characterization of the scope and principles of the standards is given. The standards are classified in separate sections according to the orientation of the test specimens, that is vertically oriented, horizontally oriented or 45° oriented. The last section contains standards concerning the flammability of textiles in general which cannot be classified according to the principle of the orientation of the test specimen. They concern specific fire hazards, introduce specific test equipment for flammability testing of textiles or have regard to flammable properties of toys, including groups of toys which contain textile materials.

1.1 Vertically oriented textile fabrics

United Kingdom

* BS 5438 - Flammability of vertically oriented textile fabrics and fabric assemblies subjected to a small igniting flame (1976)

This standard provides the basis for BS 5722, regarding the flammability performance of fabrics and fabric assemblies used in sleepwear and dressing gowns, discussed in section 3 of this Annex.
The scope of this standard is formulated as follows:

> "This British Standard specifies test methods for observing and measuring aspects of the flammability (when subjected to a small igniting flame) of vertically oriented fabrics, specimens being either a single layer or an assembly of two or more layers. These aspects are relevant to apparel fabrics and to those textile fabrics which will be held loosely in an essentially vertical position, for example curtains and drapes. The result may not apply to situations where there is restricted air supply or prolonged exposure to large sources of intense heat as in a conflagration."

Three test methods are distinguished. The principles of these test methods are:

principle test 1:
"A wide vertical strip of the fabric or assembly is taken, and a specified small butane flame is applied to the face of the strip for prescribed times. The minimum flame application time is found that causes ignition (that is: flaming of the specimen for a period of 1 s or more after extinguishing of the butane flame, unless otherwise specified in performance requirements) of the specimen."

principle test 2:
"A wide vertical strip of the fabric or assembly is taken and a specified small butane flame is applied to the face of the strip for a prescribed time. The extent of vertical and horizontal spread of flame is observed. Flaming debris behaviour may be described and the duration of flaming and afterglow and extent of hole formation may be measured."

principle test 3:
"A wide vertical strip of the fabric or assembly is taken and a specified small butane flame is applied to the face of the strip for a prescribed time. The rates of vertical and horizontal spread of flame are measured. Flaming debris behaviour may be described and the duration of flaming and afterglow may be measured."

It is suggested that, if possible, trimmings should be tested as part of the assembly in which they are or will be used.

Federal Republic of Germany

* DIN 54 336 - Testing of textiles; determination of burning behaviour; vertical method, ignition at the lower edge of the specimen (1986)

The principle and scope of this standard can be summarized as follows. A standardized flame is used to determine the burning behaviour of vertically oriented textiles, ignited at the lower edge of the test specimen. The standard can be used for the determination of the fire behaviour of all kinds of textile fabrics. The burning behaviour is observed under standardized test conditions, which are not identical to the circumstances in actual fire accidents. When evaluating the fire hazards of textile fabrics on the basis of test results originating from this test procedure, this should be kept in mind. The test method is not intended for the testing of textile floor coverings and textile wall coverings.

France

* NF G07-181 - Textile fabrics - Burning behaviour - Determination of ease of ignition of vertically oriented specimens (1985)

This standard is a complete reproduction of the ISO 6940 (1984) standard and will therefore not be discussed here. The ISO 6940 (1984) standard will receive attention at the end of section 1.1 of this Annex.

In the French standard NF G07-182, which will be summarized in section 1.3, is indicated that the French standard NF G07-183 is similar to ISO 6941 (1984). This ISO 6941 (1984) standard will be discussed later.

The Netherlands

* NEN 1722 - Burning behaviour of textile vertically oriented fabrics. Determination of the ease of ignition and flame spread properties (1986)

This test method is derived from ISO 6941 (1984), discussed later in this section. In the introduction to NEN 1722 some modifications of ISO 6941 are announced: e.g. an adaptation of the standard to test the fire behaviour of curtains (see section 2.3). A special appendix concerns textile fabrics intended to be used in nightwear; this appendix will be discussed in section 3 of this annex.

The scope of the standard can be translated as:
This standard describes a test method to determine the ease of ignition and the flame spread properties (in vertical direction) of vertically oriented textile fabrics, intended to be used in curtains, apparel etc. The fabrics may be single- or multi-component (that is coated, quilted, multilayered, sandwich construction and similar combinations) fabrics. The influence of folds on the flame spread properties of curtains can be tested with the help of three layers stretched behind each other (see section 2.3).

The principle can be translated as follows:
(see also ISO 6941, 1984):
A defined ignition flame from a specified burner is applied for a given period of time to textile specimens which are vertically oriented. During the test the fire properties afterflame time, afterglow time, ignitability and rate of flame spread (vertical direction) are determined.

International Standards

* ISO 6940 - Textile fabrics - Burning behaviour - Determination of ease of ignition of vertically oriented specimens (1984)

The scope and field of application of this international standard are formulated as follows:
- "This International Standard specifies a method for the measurement of ease of ignition of vertically oriented

textile fabrics intended for apparel, curtains and draperies in the form of single- or multicomponent (coated, quilted, multilayered, sandwich construction and similar combinations) fabrics.

This method should be used solely to assess the properties of materials or systems in response to heat and flame under controlled conditions. Results may not apply to situations where there is restricted air supply or prolonged exposure to large sources of intense heat as in a conflagration."

The principle is:
"A defined ignition flame from a specified burner is applied to textile specimens which are vertically oriented. The time necessary to achieve ignition is determined as the means of the measured times for ignition of the fabric."

* ISO 6941 - Textile fabrics - Burning behaviour - Measurement of flame spread properties of vertically oriented specimens (1984)

The scope and field of application of this international standard are closely related to those of ISO 6940 (1984):
"This International Standard specifies a method for the measurement of flame spread properties of vertically oriented textile fabrics, intended for apparel, curtains and draperies in the form of single - or multi - component (coated, quilted, multilayered, sandwich construction and similar combinations) fabrics.

This method should be used solely to assess the properties of materials or systems in response to heat flame under controlled laboratory conditions. The results may not apply to situations where there is restricted air supply or prolonged exposure to heat as in a conflagration."

The principle is formulated as follows:
"A defined ignition flame from a specified burner is applied for a defined period of time to textile specimens which are vertically oriented. The flame spread time is the time in seconds for a flame to travel between marker threads located at defined distances. Other properties relating to flame spread may also be observed, measured and recorded."

1.2 Horizontally oriented textile fabrics

Federal Republic of Germany

* DIN 54 333 - Testing of textiles; determination of burning behaviour; horizontal method - ignition at the edge of the specimen (1981)

The principle and scope of this standard can be summarized as follows: a standardized flame is used to determine the burning behaviour of horizontally oriented textiles, ignited at the edge of the test specimen. The standard can be used for the determination of the fire behaviour of all kinds of textile fabrics, possibly combined with other materials like foams or foils. The burning behaviour is observed under standardized test conditions, which are not identical to the circumstances in actual fire accidents. When evaluating the fire hazards of textile fabrics on the basis of test results, originating from this test procedure, this should be kept in mind.

* DIN 54 334 - Testing of textiles; determination of the burning behaviour; minimum ignition time; edge ignition (1975)

In this standard the minimum ignition time of horizontally oriented textiles is determined, under the influence of a standardized flame at the edge of the test specimen. The phenomenon of melting also receives attention in the standard, as well as possible additional effects.

1.3 45° oriented textile fabrics

Federal Republic of Germany

* DIN 54 335 - Testing of textiles; determination of burning behaviour, 45°-method, ignition on the edge (1977)

In this standard a standardized flame is used to determine the burning behaviour of textile fabrics, oriented at a 45° angle, ignited at the edge of the specimen. The standard can be used for the determination of the fire behaviour of all kinds of textile fabrics.

France

* NF G07-182 - Textiles - Fire behaviour - Measurement of flame spread properties of 45° oriented specimens - Determination of flame spread rate (1985)

This standard provides larger possibilities to measure flame propagation in textiles than standards with vertically oriented test specimens, because the determination of flame spread properties is easier, experimentally, in a 45° oriented test specimen, according to the introduction to this standard. The scope of this standard can be summarized as follows. The standard specifies a test method to determine flame spread properties of textile fabrics, oriented at a 45° angle, intended for use in apparel, soft furnishings and technical applications. All kinds of textiles, single- or multicomponent fabrics, can be tested.

The principle regards the application of a flame under specified conditions to the edge of a test specimen, oriented at a 45^{o} angle. The flame spread properties of the specimen are measured. The standard contains an Annex (c), in which a test method for surface ignition is presented. It is remarked that this last test method is not very accurate.

The method should be used solely to assess the properties of materials or systems in response to heat and flame under controlled conditions. Results may not apply to situations where there is restricted air supply or prolonged exposure to large sources of intense heat as in a conflagration.

United States of America

* ASTM D 3411 - Tentative Test methods for Flammability of Textile Materials (1975)

The scope of this standard is formulated as follows:
"These methods are intended primarily for research and development evaluations. They cover specific conditions for the determination of two separate flammability properties of textile materials, namely, ignition time and burning time.

These methods should be used to measure and describe the properties of materials, products, or systems in response to heat and flame under controlled conditions and should not be used for the description or appraisal of the fire hazard of materials, products, or systems under actual fire conditions."

The "Summary of Methods" runs as follows:
"These methods cover the determination of two specific flammability properties using two separate procedures with the same instrument. Method A determines the time necessary to ignite the fabric. Method B determines the time for the flame to spread over a 6-in. (152 mm) distance on specimens held at a 45-degree angle. The rate of burning (distance per unit time) can be easily calculated."

1.4 Other test methods

United Kingdom

* BS 4569 - Ignitability (surface flash) of pile fabrics and assemblies having pile on the surface (1983)

The scope of this standard is formulated as follows:
"This British Standard describes a test, the result of which is expressed as pass or fail, which is suitable for pile fabrics and simulated fur fabrics, except floor coverings, and is intended solely for determining whether

The pile of these fabrics will promote the rapid spread of flame with which it is in transient contact. The method is applicable to raised fabrics if required and to assemblies having pile on the surface."

An "important note" is added:
"The result of this laboratory test relates to the behaviour of the test specimens as supplied under the particular conditions of test, and does not take into consideration the effects of ageing, washing, soiling, etc. that may be encountered during the life of a product. It has to be recognized that this test cannot give a full assessment of fire properties in all situations, for instance a pass result does not guarantee freedom from surface flash after heating e.g. by exposure to radiant heat."

In this standard "surface-flash" is defined as:
"Rapid spread of flame over the surface of a material without ignition of its basic structure. However, if ignition of the basic structure occurs simultaneously or sequentially with surface flash, it is not considered as part of surface flash."

The principle runs as follows:
"A sheet of fabric is held vertically in a substantially draughtfree enclosure and a flame is moved across the surface of the pile at a known speed to determine whether flame from the igniting sources flashes over the surface of the pile."

It should be noted that the pile of fabric is raised before the test is carried out.

The International Standards Organization has a similar test method under preparation as ISO-International Standard, as is mentioned in a note in ISO/DIS 8124-3 (1988). This standard will be discussed later in this section.

Federal Republic of Germany

* DIN 54 331 - Testing of textiles; determination of the burning behaviour; method of test by semicircle (1974)

The principle and scope of this standard can be summarized as follows. Test specimens are attached to a semi-circular test apparatus, defined in this standard. The test specimens are, at their small edge, subjected to a standardized flame during 15 seconds. Several burning behaviour characteristics are determined, including possible melting characteristics. The standard can be used for the determination of the fire behaviour of all kinds of textiles.

Australia

* AS 1176, Parts 1 to 3 - Methods of Test for Combustion Characteristics of Textile Materials (1976)

The Australian Standard AS 1249, concerning the fire hazard of children's nightclothes, (see section 3 of this Annex) is partially based on AS 1176.
The scopes and principles are distinguished for the three different parts of the standard. Some parts of this standard concern similar aspects as the test methods regarding vertically oriented textile fabrics (see section 1.1) and those regarding horizontally oriented textile fabrics (see section 1.2).
As this standard also includes other fire aspects like heat output and surface burning properties, it is discussed in this section.

Part 1. Method for the Determination of Ease of Ignition

The scope of this part is formulated as follows:
"This method determines the ignition time of a textile material. The method is not applicable to textile floor coverings. It does not measure fire hazard, but is used to describe the response of the material to heat and flame under the conditions specified herein."

And the principle of this part:
"The test specimen is attached to a frame held horizontally while an igniting flame is placed beneath the specimen mechanically for a predetermined period of time. The minimum time of contact between the igniting flame and the specimen that produces ignition of the fabric is detemined.

Part 2. Method for the Determination of Burning Time and Heat Output

The scope of this part is formulated as follows:
"This method determines the burning time of textile materials as the time to burn a defined distance. It also indicates the heat output of the burning material by measuring the rise in temperature of a copper rod placed in the flue of the test apparatus."

And the principle of this part:
"A conditioned strip of textile material is supported vertically and its lower end is ignited in a standard manner. The progress of the flame past two predetermined points is measured. The rise in temperature of a copper rod placed in the flue of the apparatus is used as an indication of the heat output of the specimen during burning."

Part 3. Method for the Determination of Surface Burning Properties

The scope of this part is formulated as follows:
"This method determines the time required for the pile or nap of a fabric to burn a defined distance. It also determines whether flame propagation can occur on the surface of a fabric."

And the principle of this part:
"A dry specimen of the fabric is supported on a vertical plate and its raised surface is ignited near the top in a standard manner."

International Standards

* ISO/DIS 8124-3 Draft International Standard: Safety of toys - Part 3: Flammable properties (1988)

This part of ISO 8124 (1988) applies to toys for children, including toys of textile materials, among others. References are made to ISO 6940 (see 1.1) and BS 4569 (see before in this section). Although this standard does not exclusively consider the flammability of textile products, elements of the standard are relevant to this study. The contents of this part of ISO 8124 will be summarized briefly.

The scope of this part is formulated as follows:
"This part of ISO 8124 specifies requirements and methods of test for flammable properties to be taken into account in the manufacture of toys for children in order to eliminate toys presenting a dangerous fire hazard to a child. It covers the categories of flammable materials which are prohibited in the manufacture of all toys and requirements concerning flammability of certain toys when they are submitted to a small source of ignition. The test methods described in (...) are used for the purpose of determining the flammability of toys under the particular test conditions specified. The test results thus obtained shall not be considered as providing an overall indication of the potential fire hazards of toys or materials when subjected to other sources of ignition. Its aim is to reduce as far as possible those risks which are not evident to users."

The field of application refers to Part 1 of ISO 8124 and is specified for this part as follows:
"This part of ISO 8124 includes general requirements relating to all toys and specific requirements relating to the following toys which are considered as being those presenting the greatest hazard:
a. beards, moustaches
b. wigs
c. masks

d. soft toys with a pile surface
e. soft toys with a textile surface.

NOTE. Dresses for dolls and soft toys are not covered by this part of ISO 8124."

The principle of the methods of test is described as follows:
Each test is carried out on three representative toys or samples except that, in case of soft toys, the tests may be carried out on one toy if the toy is sufficiently large and if any part destroyed is sufficiently small. If only two samples or toys comply with the requirements, the test is repeated on three new representative samples or toys and if those three samples or toys comply, the toys are deemed to meet the requirements of this part of the standard.

Each test is carried out on new toys as first offered for sale or samples obtained from such toys. If the manufacturer:
a. indicates that the toy is not intended to be washed, it shall not be washed or soaked before testing;
b. recommends a method of washing or cleaning, the toy shall be tested before and after treatment in accordance with these recommendations;
c. gives no information relating to washing or cleaning, the toy shall be tested before and after treatment, in accordance with the instructions given in (...).

The toys used for the tests shall be representative of a group of toys. Samples are taken from toys so that they are representative of the whole toy."

The principle contains also a description of the conditioning of the test specimens before each test, including both moderate and tropical temperatures and relative humidities.

The test flame is obtained from a burner as specified in ISO 6940 (see 1.1). Soft toys with a pile surface and soft toys with a textile surface are tested in a vertical orientation. A 20 mm high test flame is applied to the toy for 2 s with the burner at an angle of 45^{o}, so that the distance between the edge of the burner tubes and the toys is approximately 5 mm and the flame makes contact at least 20 mm above the lower edge of the sample. After removal of the flame the time taken for the flame to spread over the distance between the point of application of the flame and the upper edge of the toy is measured. The rate of spread of flame shall be not more than 50 mm/s (except for soft toys with a maximum dimension of 150 mm or less).

The test methods regarding beards, moustaches, wigs and masks will not be specified here.

2 Soft furnishings

In this section standards and regulations concerning the fire safety of soft furnishings are summarized. Many standards regarding different product groups of soft furnishings are available in the Member States of the EEC and various other Western countries. The standards characterized here are selected on the basis of the criteria mentioned before. They are distinguished for upholstered furniture, mattresses and bedding materials, curtains and textile floor coverings. Concerning textile wall coverings no standards were traced.

2.1 Upholstered furniture

United Kingdom

In the United Kingdom the British Standard BS 5852: Part 1 plays an important part in the regulation for domestic furniture. This British Standard - BS 5852 Fire tests for furniture: Part 1. Methods of test for the ignitability by smokers' materials of upholstered composites for seating (1979) - was introduced to assess the resistance of seating to small smouldering and flaming ignition sources aimed at simulating cigarettes and matches. Since 1983 all upholstered seating offered for sale in the United Kingdom has had to meet the BS 5852: Part 1 test with respect to resistance to cigarette ignition and to carry a warning label if it does not pass the test with respect to a match size flame, according to "The Upholstered Furniture (Safety) (Amendment) Regulations, 1983". Furniture constructed from fabric and infill materials which pass both tests also carry a label showing their ignition performance (Ames in: Rogmans and Jackson, 1987). A more severe set of tests was introduced in 1983 with BS 5852: Part 2 - Methods of test for the ignitability of upholstered composites for seating by flaming sources - for non domestic applications, which incorporated larger sources of ignition like wood cribs. These tests are often used to select seating for areas of particular concern such as psychiatric and geriatric hospitals (Ames in: Rogmans and Jackson, 1987) and are therefore not taken into consideration here.

In the first half of 1988 new regulations were drafted with the intention of providing increased protection against the risks of flammability of domestic upholstered furniture. The new regulations are planned to replace "The Upholstered Furniture (Safety) Regulations", of 1983 within a short time (Draft Furniture and Furnishings (Fire) (Safety) Regulations, Department of Trade and Industry, March 1988: DTI statement June 1988). The part of the regulations concerned with foam filled furniture manufacture have come into force on 1 November 1988 and the remainder of the regulations on 1 March 1989 (retail sale of foam filled furniture), on 1 March 1990 (outer covers to resist match test; garden furniture;

furniture built into new caravans) and on 1 March 1993 (second hand furniture). The effect of the regulations is to prohibit the use of standard and high resilience polyurethane foam in domestic upholstered furniture and to require permitted combustion modified foam and other fillings to meet stringent standards from 1 November 1988, and to require that the upholstered covers of both domestic furniture and beds, excluding mattresses, meet a match test from 1 March 1990. Some fabrics which are difficult or impossible to treat but whose burning characteristics are less likely to ignite the filling materials, will be permitted provided they are used with interliners or barrier cloths with a certain resistance to ignition (DTI, June 1988). (The requirements for filling materials will apply to beds and mattresses from 1 November 1988 and the covering materials for mattresses will be dealt with by the approval of a British Standard specification; see also 2.2 of this Annex).

The smouldering cigarette requirement based on BS 5852: Part 1 is maintained in the new regulations. The labelling requirements will be adapted with the coming into force of the new regulations (Department of Trade and Industry, March 1988).

According to Babrauskas (1988a) Ireland has recently announced that it will implement an essentially identical regulation.

* BS 5852 - Fire tests for furniture - Part 1: Methods of test for the ignitability by smokers' materials of upholstered composites for seating (1979)

The principle of this standard is described as follows:
"The principle is to subject an assembly of upholstery materials arranged to represent, in stylized form, the joint between the seat and back (or seat and arm) surfaces of a chair to two sources of ignition; one being a smouldering cigarette, and the other a flaming source approximating to the calorific output of a burning match."

It is considered important that a complete finished item of furniture is tested and therefore tests have been developed to test upholstery materials combined together to give information regarding the ignitability properties of assemblies that might be used in a number of different circumstances. The position at which accidentally dropped cigarettes or lighted matches are most likely to cause ignition is at the angle between vertical and horizontal surfaces. This situation has been simulated in the tests, although in practice an assembly might only be used on a single surface. It is stated in this standard that the results provide a measure of the ignitability of a combination of cover and filling which is equally valid for

the different designs of furniture in which the combination might be used.

As ignition sources standardized smouldering cigarettes and butane flames, with calorific outputs approximating to a burning match (flame height approximately 35 mm, the gas burning 20 $\pm$ 1 s) are used.

The progress of combustion is observed during the tests and any evidence of so called "progressive smouldering" or flaming in the interior and/or cover is recorded. ("progressive smouldering" to be defined as an exothermic oxidation not accompanied by flaming which is self-propagating i.e. independent of the ignition source. It may or may not be accompanied by incandescence.)
If progressive smouldering or flaming of the upholstery components is observed after 1 h with the smouldering cigarette as ignition source or 120 s with the match simulating butane flame, the test piece is extinguished and a failed result recorded. If no smouldering or flaming occurs under certain conditions, the test is repeated. To detect progressive smouldering not visible from the outside the assembly is dismantled and examined internally. If progressive smouldering is present a failed result for the relevant test source is recorded.

The tests are only concerned with ignitability, other aspects of fire performance such as rate of fire development, heat output, rate and quantity of smoke production and toxic gas evolution are not taken into consideration in these tests.

The tests give an indication of, but cannot guarantee, the ignition behaviour of the finished item of furniture. Design features of the furniture can greatly affect its fire properties (Appendix A, BS 5852: Part 1, 1979). Design is not taken further into consideration in these tests.

* Draft Document 88/37988 DC - Draft British Specification for the flammability behaviour of single filling components (foams or fibres) used in domestic upholstered furniture, April 1988.

This Draft Document has been prepared by the British Standards Institution in response to the announcement of "The Draft Furniture and Furnishings (Fire) (Safety) Regulations" and is therefore mentioned in this report. It is based on the BS 5852 part 2 (1982) standard, but incorporating mass loss measurements (Babrauskas, 1988a). This draft will not be discussed further. It is important to mention that it should be realized that the approach of dealing with the filling only is a contradiction of BSI policy on flammability testing in a manner as realistic as possible, requiring that materials used in composite constructions should be tested in those composite constructions (Foreword of Draft Document 88/35700

(Amended) (private circulation) which was an early stage draft in response to the new regulations).

According to Babrauskas (1988a) a "Furniture Calorimeter Test" is developed at the Fire Research Station (Borehamwood, England, 1988). This is a full-scale test method intended for applications in high-risk occupancies, measuring among other things the rate of heat release, using a similar test apparatus to the "Nordtest" one (see the end of this section). This test method is currently a research tool only but could, according to Babrauskas, readily be adopted to regulatory testing.

United States of America

In the United States of America various regulations concern the flammability of upholstered furniture for domestic use. Voluntary regulations function on the federal level, based on a Voluntary Action Programme initiated by the Upholstered Furniture Action Council (UFAC). The UFAC test programme is founded on the principle of testing separate components of upholstered furniture, concerning their resistance to smouldering cigarettes. The Consumer Product Safety Commission (CPSC) has adopted the UFAC programme since 1981 (UFAC, 1984). Several other standards were developed. The State of California supplies both mandatory regulations, involving the testing of components of upholstered furniture, and voluntary regulations involving the testing of complete items of upholstered furniture, combined with labelling requirements (Greater Manchester Council, 1986). The UFAC programme and the Californian approach will be discussed here briefly. Several other test methods summarized by Babrauskas (1988a) will be mentioned.

The UFAC programme

The UFAC programme (UFAC, 1984) includes, among others, fabric classification, dividing cover fabrics into two categories of ignition propensity. This rating system measures the ability of these fabrics to resist ignition when exposed to a burning cigarette. The UFAC Fabric Classification Test Method-1983 uses a burning cigarette to test each fabric over a standard foam substrate. A burning cigarette placed on the fabric produces a length of char which determines the fabric class. The burning cigarettes are covered by standardized small pieces of cloth, like in the American test method concerning the flammability of mattresses, simulating the covering of a cigarette by a sheet, discussed in section 2.2 of this Annex. Fabric classification is used to determine which construction methods must be used with a given fabric in order to comply with the UFAC construction criteria, which will not be discussed. Neither will the American CPSC-standard be

discussed here, this standard running largely parallel with the UFAC-programme, although it is covering a more extensive scope.

The Californian approach

The California Legislature enacted a Statute requiring all mattresses and upholstered furniture for sale in California to be fire retardant. The California Bureau of Home Furnishings has established flammability standards for mattresses and upholstered furniture, so called "Technical Bulletins". All filling materials contained in any article of upholstered furniture and all filling materials added to re-upholstered furniture must meet the test requirements of Technical Bulletin No. 117. In addition, finished articles of upholstered furniture should not ignite when tested in accordance with the Technical Bulletin No. 116. This addition is not mandatory. The regulations also require labelling for upholstered furniture conforming with the requirements referred to above (Greater Manchester Council, 1986). The Californian test methods and criteria for the flammability of upholstered furniture, as described in several "Technical Information Bulletins", will be discussed here briefly.

* Technical Information Bulletin 117 (TB 117): Requirements, Test Procedures and Apparatus for Testing the Flame Retardance of Resilient Filling Materials used in Upholstered Furniture (Bureau of Home Furnishings, Department of Consumer Affairs, California, 1980)

Various test methods involving different filling materials and upholstery fabrics applied in upholstered furniture, are presented in this Technical Information Bulletin. The test methods are divided in five sections and subdivided in different parts. The scopes and principles of the various test methods will be summarized here.

Section A - Part I Resilient Cellular Materials

The scope of the test procedure is formulated as follows:
"This procedure is intended for use in determining the resistance of resilient cellular materials to flame and glow propagation and tendency to char."

The test procedure is largely based on the Federal Test Method Standard No. 191 method 5903.2 or FF 3-71 (see section 3). A test specimen is suspended vertically in a cabinet. The maximum and average char length, afterglow and afterflame shall be determined for each resilient cellular material, with a minimum of 10 test specimens tested; 5 specimens before ageing and 5 specimens after ageing for 24 hours in a forced air circulating oven at 104°C. Requirements in this section regard, among others, the average char length, the maximum char length, the average afterflame time and the

average afterglow time. The phenomena of afterflame and afterglow include afterflame and afterglow of molten drops of material.

Section A - Part II Shredded Resilient Cellular Materials
(e.g. shredded polyurethane foams)

The resilient cellular material used for shredding shall meet the requirements of Section A and D of the Technical Bulletin prior to shredding, or a post flame treated shredded foam may be used. The test procedure is based on the testing of a pillow/cushion fabricated from a fabric/ticking filled with flame retardant foam. Test requirements are presented. The pillow/cushion shall meet the test requirements both before and after ageing for 24 hours at 104°C. The fabric/ticking used to encase the shredded resilient cellular material shall meet certain requirements of the Technical Bulletin, Section A, when tested in accordance with Federal Test Method Standard No. 191 method 5903.2.

Section A - Part III Expanded Polystyrene Beads

The requirements of this part regard the weight loss of the test material, after ageing for 48 hours in an air circulating mechanical convection oven (at 150 $\pm$ 5°F) and the following test procedure. A burning methenamine tablet is placed on the top center of the test material, which is a wire basket filled with the artificially aged expanded polystyrene beads. The test is continued until all flames are completely extinguished. The percentage weight loss is determined and evaluated. A total of five test samples of each material shall be evaluated.

Section B - Part I Non-Man-Made Filling Materials

Non-man-made filling materials should meet the requirements under Section A of the Technical Bulletin, with some modifications. The test specimens, among others, have to be vertically suspended into the flame and they shall not be aged for 24 hours at 104°C.

Section B - Part II Shredded and Loose Fill Materials
Feathers and Down

Feathers and down may be used in articles of upholstered furniture provided that the requirements in this part are met. These requirements include, among others, that the feathers and down shall be encased in a flame retardant fabric/ticking, which has to meet certain requirements of the Technical Bulletin, Section A, when tested in accordance with Federal Test Method Standard No. 191 method 5903.2.

Section C - Man-Made Fibre Filling Materials

The scope of the test procedure is formulated as follows:
"This procedure is intended for use in determining the resistance of resilient man-made fibre filling materials to flame spread, when tested using a modified version of Commercial Standard 191-53."

16 CFR 1610, formerly CS 191-53, is summarized in section 3 of this Annex. A test specimen in its holder is supported at an angle of 45 degrees. The time of flame spread of individual specimens is noted and the average flame spread is determined. If a specimen burn does not reach the specified end point, the self-extinguishing time is noted. Requirements regard the average flame spread time of all specimens and the minimum flame spread time of any individual specimens, among others.

In a note at the end of this section is indicated that "Mixed Fibre Fillers" have to meet the requirements of Section B, Part I and/or Section C, depending on their composition.

Section D - Part I Resilient Filling Materials - Cigarette Resistance

The test procedure involves the burning of cigarettes, meeting the cigarette specification of DOC FF 4-72 (see section 2), on the surface at the centre of the specimen. Specimens shall be tested with cigarettes both uncovered and covered with one layer of sheeting material, laundered and dried at least once before use. A minimum of 3 specimens both covered and uncovered shall be tested. The char dimensions of each specimen shall be measured and, among others, a certain maximum char length of each specimen in any direction from the cigarette is required.

Section D - Part II Resilient Cellular Materials - Smouldering Screening Test

The test method is based on an assembly of foam test panels, standard fabric, cigarette and cover fabric, comparable with the assembly used in the UFAC-programme. The cigarette shall be placed at the crevice created by the abutment of the vertical and horizontal panels, such that the cigarette contacts both horizontal and vertical panels. The cigarette is covered by sheeting material, laundered and dried at least once before use. Test criteria on the smouldering performance of the specimens of the test foam are presented.

Section E - Part I Upholstery Fabrics

The test method referred to in this Section is CS 191-53 (45°-method, see section 3). Fabrics which do not meet the Class 1 requirements of U.S. Department of Commerce

commercial standard CS 191-53 shall not be used on articles of upholstered furniture. Both surfaces of the fabric have to be tested and specimens are not laundered or dry cleaned prior to testing.

Babrauskas (1988a) mentions a 1985-version of Technical Bulletin 117, which is not compared with the 1980-version in this study.

The Technical Bulletin No. 116 involves a cigarette test for finished articles of upholstered furniture, which is not mandatory. This Technical Bulletin can be summarized as follows.

* Technical Information Bulletin 116 (TB 116): Requirements, Test Procedures and Apparatus for Testing the Flame Retardance of Upholstered Furniture (Bureau of Home Furnishings, Department of Consumer Affairs, California, 1980)

The article of upholstered furniture tested shall be either the finished product ready for sale to the consumer, or a prototype mock-up of actual components which duplicate the design and structure of the finished product. Each differently-dyed area of the furniture fabric is included in the test locations. All exposed horizontal surfaces (including smooth, welted, quilted, decking, tops of arms and backs, tufted or button locations plus all crevices created by the orientation of seat cushions and furniture side and back panels) are tested. Three burning cigarettes are placed on the different locations that are to be tested. All test cigarettes shall be covered with one layer of sheeting material during the test, laundered and dried at least once before use. The kind of cigarettes used and the covering of the cigarettes are comparable to these elements of the UFAC-programme. The requirements have regard to, among others, the char dimensions.

Another Technical Bulletin (TB 133) regards the flammability of seating furniture for use in high risk occupancies, like jails, nursing care homes, health care facilities, hotels etc. This is a large-scale test, using a full-scale test article. As this test procedure is not intended to be used for the evaluation of residential furniture, it will not be discussed here.

Other test methods

Other test methods concerning the flammability of upholstered furniture in the United Stated are mentioned by Babrauskas (1988a).

Identical to the above mentioned Technical Bulletin 133, with measuring devices for HCl and HCN added, is the "International Association of Fire Fighters Proposal", being proposed by the IAFF to the individual States to adopt as a law under the suggested title of "Furniture Safety Act". It is intended to be applicable to high risk occupancies and therefore not discussed here.

In the City of Boston the "Boston Fire Department Procedure BFD IX-10 (1986)", intended for high risk occupancies, is mandatory and is also used extensively by surrounding jurisdictions. This is a large-scale test, using a full-scale test article. The Boston Fire Department will also accept passing results from the above mentioned Technical Bulletin 133 as a substitute for doing the BFD IX-10 test. As the BFD IX-10 test is not intended to be used for the evaluation of residential furniture, it will not be summarized here.

Another large-scale test method mentioned by Babrauskas is the "Underwriters Laboratories Test UL 1056 (1988)". This method uses a full-scale test article and measures, among other things, the rate of heat release. It is intended for items in hotels, public occupancies and similar applications and therefore not discussed here. It is used for testing at the Underwriters Laboratories (Northbrook, IL).

In the United States a bench-scale test "NBS Cone Calorimeter Test (NFPA proposal)" is under development at the moment. One of the advantages of this test method is that it gives rate of heat release information, correlated to large-scale performance. The test method is intended to be used only for high-risk occupancies, public occupancies or other similar applications and is therefore not discussed here.

Canada

The Canadian Council of Furniture Manufacturers has taken the initiative in a voluntary programme concerning the fire safety of upholstered furniture, patterned on the UFAC initiative in the United States of America (Doyle, 1987). The Canadian approach runs largely parallel with the American approach and is therefore not discussed here further.

International Standards

The International Organization for Standardization has the intention to publish a series of tests concerned with the ignitability of upholstered furniture using different ignition sources. Part 1 of ISO 8191 is summarized here. Further parts utilizing a series of flaming ignition sources of increasing severity are not yet available.

* ISO 8191-1: 1987 "Furniture - Assessment of the ignitability of upholstered furniture - Part 1: Ignition source: smouldering cigarette".

This standard is derived from BS 5852: Part 1, characterized above. The standard differs from this BS as far as the smouldering cigarette part is concerned only in details. The scope and field of application as well as the principle of this standard, as mentioned in the original standard text, is given here.

Scope and field of application:

"This part of ISO 8191 lays down a method of test to assess the ignitability of material combinations, such as covers and fillings used in upholstered seating when subjected to a smouldering cigarette as an ignition source. The tests measure only the ignitability of a combination of materials used in upholstered seating and the ignitability of a particular finished item of furniture incorporating these materials. They give an indication of, but cannot guarantee, the ignition behaviour of the finished item of furniture."

Principle:

"Subjecting an assembly of upholstery materials to a smouldering cigarette ignition source. The assembly is arranged to represent in stylized form a junction between a seat and back (or seat and arm) such as might occur in a typical chair. Determination of the ignitability of an assembly by applying smoker's material such as a cigarette. The test method measures the ignitability of the overall composite of materials, i.e. cover(s), interliner, infill material, etc., as constructed on the test rig. The results shall not be stated as being applicable to the general behaviour of any individual component."

Sweden

According to Sundström (1988) the fire safety of upholstered furniture in Sweden is mainly controlled by the Rescue Service Legislation and the Marketing Legislation. The Rescue Service Legislation (1986) is among other areas also directed towards furnishings. Test methods, criteria, approval procedures are not yet at hand.

In May 1988 the National Swedish Board for Consumer Policies issued "Guidelines for Upholstered Seating Furniture Ignitability", coming into force in January 1991. It is stated that it must not be possible for furniture to be ignited by a smouldering cigarette. Testing has to take place according to ISO 8191-1: 1987 with some modifications of this test procedure.

According to Babrauskas (1988a) the "Nordtest; Upholstered Furniture: Burning Behaviour - Full Scale Test (NT FIRE 032), 1988" is being actively considered in the Nordic countries for adoptation for regulation. It is a large-scale test using full-scale test articles, measuring among other things the rate of heat release. It is intended only to be applicable to high-risk occupancies and is therefore not discussed here.

Italy

According to Messa (1988) the Italian standards prescribe and establish the use of upholstered furniture, having better fire performances, only for public buildings application at the moment. The possibility of extending them for private building application has not yet been examined.

France

France has regulations on upholstered furniture (Chesne, 1988). Some specifications concerning flammability have been established for the public market, which are based on tests carried out on the complete final product. According to Chesne (Communication at the 1st European Conference on Furniture Flammability) new regulations can be expected in France.

2.2 Mattresses and bedding materials

United Kingdom

As indicated in section 2.1 of this Annex, new regulations are planned to replace "The Upholstered Furniture (Safety) Regulations" of 1983 within a short time. The new "Draft Furniture and Furnishings (Fire) (Safety) Regulations", issued by the Department of Trade and Industry in March 1988, also apply to beds and mattresses, which were not included in the old Furniture Regulations. The requirements for filling materials will apply to beds and mattresses from 1 November 1988. Upholstered covers of beds, excluding mattresses, have to meet a match test from 1 March 1990. The covering materials for mattresses will be dealt with by the approval of a British Standard specification. This specification is expected to be published shortly by the BSI and will contain a requirement for cigarette resistance but will be modified to include a direct match test requirement from 1 March 1990. The Regulations will apply, among others, to beds, sofa-beds and convertibles. The requirements for beds will apply to bed bases and headboards in respect of both filling materials and covering fabrics, and to mattresses in respect of filling materials only. Requirements for bedding materials are not included. Labelling requirements with regard to beds, divans and headboards, excluding mattresses (DTI, March 1988; DTI, June 1988).

The British Standard concerning the ignitability of mattresses, dating from 1986, will be summarized here. Detailed references to specific tables etc. in the standard itself are replaced by "(...)". It should be noted that the Draft/Documents mentioned in section 2.1 also have regard to the flammability behaviour of fillings used in beds and mattresses.

* BS 6807 - British Standard Methods of test for the ignitability of mattresses with primary and secondary sources of ignition (1986)

The scope of this standard is specified as follows:

"This British Standard describes methods of test for the ignitability of mattresses when subjected to smouldering and flaming types of primary and secondary ignition sources of differing severities. It does not include the ignitability of the bed base.

The following test options are described:

(a) mattress alone tested with primary ignition sources (section two);

(b) mattress tested with secondary ignition sources composed of known bedcovers (section three);

(c) mattress tested with secondary ignition sources simulating unknown bedcovers (section four)."

A primary source in a test is defined as the initial heat supply; a secondary source in a test as the combination of primary source and the actual or simulated effect of bedcovers. The general principle of the standard is formulated as follows:

"A test specimen is subjected to smouldering and flaming ignition sources placed on top of and/or below the test specimen. The range of intensity of the primary sources has been selected to imitate that of actual sources which might be encountered in various end use environments, while the range of intensity of the secondary sources reproduces the effects of varying amounts and types of bedcovers. Normally the ignitability of a mattress is measured by working up through the sources in the sequences indicated (...). Alternatively, for specific end use requirements, the tests can be used to assess the ignitability at any level but always including the cigarette ignition test."

The principles of the test options described in the sections two, three and four of this standard are formulated as follows:

Section two. Mattress tested with primary ignition source.

"When mattresses are used or stored on their own it is necessary and desirable to know the ignitability of the mattress in its own right (see note), therefore, in this section of this standard, a mattress or smaller specimen is tested without bed covers or pillow present. The sources used (...) are therefore the primary range of smouldering

and/or flaming ignition sources as described in BS 5852: Parts 1 and 2. The source is positioned either above or below the test specimen, but the minimum source required for ignition may be different in the two arrangements.

NOTE. The situations in which a mattress may be used alone can incur the risk of exposure to more severe ignition sources than are usually encountered in domestic fires."

Section three. Mattress tested with secondary ignition sources of known bedcovers.

"When the total bed assembly is known, the most effective tests will be those that reproduce details exactly (see note). Therefore, in this section of this standard the bedcovers and pillows can be used as a secondary source to which the primary smouldering and/or flaming ignition sources as defined in BS 5852: Parts 1 and 2 can be applied commencing with ones of low severity. The intensity is then increased until ignition occurs (...). The primary source may be positioned either above or below the test assembly, but the minimum source required for ignition may be different in the two arrangements.

NOTE. This situation will apply mainly to mattresses not sold in the retail trade, i.e. for contract use."

Section four. Mattress tested with secondary ignition sources simulating unknown bedcovers.

"The tests in this section of this standard will be of assistance to the mattress manufacturer when assessing the ignitability of the mattress offered for sale to the domestic market which may be used with a variety of bedcovers. It is intended that secondary smouldering and/or flaming ignition sources which model the behaviour of different types of bedcovers that may be used by a domestic consumer are used commencing with ones of low severity. The intensity is then increased in steps until ignition occurs (...). These sources are for use on the top of the test specimen. Experimental evidence has shown that the presence of a small amount of bedcovers (e.g. two sheets) on a mattress gave some protection against smouldering ignition. For this reason the cigarette is used on its own (...) as it provides a more severe test, and the bedcovers are omitted. In (...) and (...) the cigarette is used with non-smoulderable and smoulderable insulation respectively. At present, the only flaming source is the butane gas flame: (...).

NOTE. The flaming behaviour of larger amounts of added bedcovers is intended to be modelled by burning balsa wood cribs. These are at present under consideration as a Draft for Development."

In the Foreword it is mentioned that the ignitability of a composite arrangement is very dependent on the interactions between the components. The domestic consumer has a wide range of bedding products to choose from. For a test to be usefully related to safety it should be capable of imitating these variables; this is achieved by using smoulderable or non-smoulderable insulation pads. It cannot be assumed that protection against large flaming sources will automatically give protection against smouldering ignition. The described test methods are not intended to reproduce full fire hazards that may be encountered in practice.
The International Standards Organization has published a "Working draft for methods of test for the ignitability of mattresses with primary and secondary sources of ignition" (ISO/TC 38/SC 1/WG 4; dating from 6 March 1988) which is derived from BS 6807 (1986).

United States of America

The Federal Government of the United States of America has established regulations concerning the flammability of mattresses and mattress pads in the Flammable Fabrics Act. The requirements have regard to ticking filled with a resilient material intended or promoted for sleeping upon, including mattress pads. Pillows, boxsprings and sleeping bags are excluded. All mattresses and mattress pads manufactured for sale in interstate commerce must meet the requirements. The regulations require that a minimum of 9 cigarettes be allowed to burn on the smooth, tape edge, and quilted or tufted locations of a bare mattress. The char length on the mattress surface must not be more than 2 inches in any direction from any cigarette. Tests are also conducted with 9 cigarettes placed between two sheets on the mattress surfaces above. Mattresses which meet the standard are not required to have a label to that effect (Product Safety Fact Sheet, 1978). Mattress pads must pass a test too. Those which have had a flame retardant treatment must be labelled with the letter "T" and care labelling is required on the treated mattress pads to inform the consumer how to protect the pad against loss of flame retardancy (Guide to fabric flammability, 1975). The test methods and requirements providing the basis of the Flammable Fabrics Act concerning mattresses and mattress pads are laid down in the 16 CFR 1632 standard (FF 4-72), which will be summarized here. Detailed references to the standard itself are replaced by "(...)".

* 16 CFR 1632 - Standard for the Flammability of Mattresses and Mattress Pads (FF 4-72, amended) (1986)

A mattress is defined in this standard as a ticking filled with a resilient material alone or in combination with other products intended or promoted for sleeping upon; a mattress pad is defined as a thin, flat mat or cushion, and/or ticking

filled with resilient material for use on top of a mattress. The purpose of the standard is described as follows:

> "This standard prescribes requirements for testing of prototype designs of mattresses and mattress pads before the sale in commerce or the introduction in commerce of any mattress or mattress pad which is subject to the standard. The standard prescribes a test to determine the ignition resistance of a mattress or a mattress pad when exposed to a lighted cigarette. The standard sets forth a test (...) which may be used to classify ticking materials for resistance to cigarette ignition. The standard sets forth a test (...) which may be used to demonstrate that the substitution of tape edge materials will not reduce the ignition resistance of a mattress prototype or a mattress pad prototype."

The following summary of the test method is given:

> " The method measures the ignition resistance of a mattress or mattress pad by exposing the surface to lighted cigarettes in a draught-protected environment. The surfaces to be tested include smooth, tape edge, and quilted or tufted locations, if they exist on the mattress or mattress pad surface. A two-sheet test is also conducted on similar surface locations. In the latter test, the burning cigarettes are placed between the sheets."

From the "test criterium" is learned that individual cigarette test locations pass the test if the char length is not more than 2 inches (5.1 cm) in any direction from the nearest point of the cigarette. The sheets (or sheeting material) have to be laundered and dried once before use. At least 18 cigarettes are burned on each mattress test surface, 9 in the bare mattress test and 9 in the 2-sheets tests.

The State of California is prohibited from having a more stringent test or standard than the federal law. The federal law allows the use of untreated polyurethane foam in mattresses and therefore the Californian regulations concerning the flammability of flexible polyurethane foam are not mandatory. These regulations intend to prevent the sale in any form of untreated polyurethane foam. They are based on the Technical Bulletin No. 117 (Greater Manchester Council, 1986). As no mandatory regulations regarding the flammability of upholstered furniture exist, the State of California is allowed to issue its own regulations for the flammability of upholstered furniture, as was indicated already in section 2.1 of this Annex, on a mandatory basis. According to Zorgman (1988 b) the State of California requires labelling information if the foam applied in a mattress does not meet the requirements of the Technical Bulletin No. 117.

Canada

In Canada the "Hazardous Products (Mattresses) Regulations", effective January 1, 1982, prescribe regulations concerning

the advertising, sale and importation of hazardous products (mattresses). These regulations are formulated as follows:

> "A product may be advertised, sold or imported into Canada if, when it is tested in accordance with METHOD 27.7-1979 of CAN 2-4.2 M 77, a standard established by the Canadian Government Specifications Board, published in July 1979, not more than one test specimen as therein described exhibits melting or charring of its surface that extends more than 50 mm in any horizontal direction from the nearest point of the original location of the test cigarette, or continuing combustion in the mattress assembly 10 minutes after the said cigarette has extinguished."

The mentioned Canadian test method (the 1977 version) is summarized by Johnsen (1985), who gives a survey of test methods and regulations for the flammability of beds and bedding materials.

* CAN - 4.2 - M77 Method 27.7 - 1977. Method of test for combustion resistance of mattresses - Cigarette test. Canadian Government Specifications Board (1977)

The test specimen consists of a scale-model of 300 x 300 mm^2 consisting of filling and cover, simulating a mattress. The test is carried out in a box (according to Zorgman, 1988 b to avoid edge effects). Prior to the test, an unignited cigarette is placed as near to the mid-point of the specimen as possible, preferably at a seam. A line is drawn around the cigarette where every point is 50 mm from the outer edge of the cigarette. The cigarette is ignited and it is observed whether the fire spreads horizontally beyond the 50 mm limit. If progressive smouldering does not occur, observations are made 10 minutes after the cigarette has ceased to burn (after Johnsen, 1985). The requirements accompanying this test method are established in the regulations discussed before. The differences between the 1977 and the 1979 versions respectively are not discussed.

Johnsen mentions that bedding textiles have to meet certain requirements laid down in the Products Act and the Hazardous Products (Mattresses) Regulations, based upon the American test method ASTM D 1230-61. This test method (the 1985 version) will be discussed in section 3 of this Annex. Zorgman (1988 b) doubts the merits of this test method for the evaluation of bedding textiles, because of the short time of contact with the ignition source and the lack of testing of the possibility of smouldering, among others.

The regulations and test methods summarized by Johnsen, which are not yet described in this section, will be discussed here briefly.

Norway

According to Johnsen, proposals for regulations for testing and assessment with regard to the flammability of mattresses and bedding materials have been prepared by the Norwegian Fire Research Laboratory, which have been submitted to the Ministry of Local Government and Labour (nota bene: this was written in 1985, no document of more recent date was traced concerning this subject).

* Provisional rules for testing and evaluation of the flammability of bedding 1983-08-30. Norway. A method for testing bedding on a small-scale bed (1983)

Test specimens, taken from products which are ready for delivery and consisting of materials in combinations similar to those occurring in practice, are submitted to the ignition sources glowing cigarettes and/or methenamine tablets. (The components separately are not tested, only the combination of materials as such.) The testing includes a series of tests of the different components of the bedding in the following order: mattress alone; mattress cover on the mattress; sheet on the mattress; loose cover, on duvet and quilt respectively; quilt and duvet and quilt and duvet with respectively cover in made-up bed. The tests are carried out on unlaundered as well as on laundered specimens. Evaluation requirements are presented for the different components of the bedding (after Johnsen, 1985).

France

In France no regulations, neither on a mandatory nor on a voluntary basis, were established. Johnsen gives a summary of the French standard for the determination of the ignitability of mattresses.

* Bulletin Officiel des Services des Prix, 21 Décembre 1978. La Recommendation no: D1-78 du GPEM/CP. Method of test for ignitability of mattresses, (1978)

This standard, which determines the ignitability of mattresses, makes use of a glowing cigarette as ignition source. The test is performed on a mattress alone and on a mattress covered by a sheet. A total of 20 tests is carried out, 10 tests concern the mattress alone and 10 tests concern the mattress covered by a sheet. The cigarette is placed both in the centre of the mattress and at the edges. The damaged area around the cigarette must not exceed 5 cm (after Johnsen, 1985). According to Zorgman (1988 b), this French standard is closely related to the American test method CFR part 1632, discussed before.

Federal Republic of Germany

In the Federal Republic of Germany a regulation has come into force on 1 August 1980, concerning fireproof materials, with respect to the utilization of certain substances which are harmful to health in fireproof textile materials, coming frequently into contact with the human body. The regulation deals with, among other things, bed linen (Van Erdewijk and Jaartsveld, 1989). No regulations, neither mandatory nor voluntary, concerning the flammability of mattresses and bedding materials were traced. Johnsen gives a summary of a German test method regarding the ignitability of bedding components.

* Hoechst Werkrichtlinie 93-0666 Brennverhalten von Betten. Teil 1. Prüfmethoden und Kennwerte. Teil 2. Empfehlungen für Bettkombinationen. Method of test for the ignitability of bedding components, Hoechst AG, (1981)

The test objects of this standard are mattresses, sheets, quilts and duvets on a small-scale bed. The test objects simulate mattresses, sheets, quilts and duvets on a small scale: the mattresses consist of the inner part (plastic foam and the like) with appurtenant ticking and sheet, the quilts consisting of fill or blanketing with permanent cover and loose cover and duvets consisting of fill plus permanent cover and loose cover. The ignition sources of the test method are glowing cigarettes, matches, methenamine tablets and 1 page of newspaper, screwed into a ball. A series of tests is conducted with different ignition sources, first using a glowing cigarette, progressing to ignition sources with a higher intensity. If combustion occurs with any of the ignition sources, the series is discontinued. The cigarettes or matches are placed on the mattress between the duvet and the quilt, parallel with the duvet. Three parallel tests are conducted to trace flaming or progressive smouldering. A burning match is also placed on top of the quilt and/or on top of the duvet in five parallel tests. Similar tests are carried out using the methenamine tablet, where the burning tablet is placed on the mattress, the quilt and the duvet in three parallel tests. The newspaper ball is ignited in two places and placed on top of the bed on the mattress, quilt or duvet. According to this method, bedding components are placed in four classes. The classification is made on the basis of the afterflame time or the afterglow time. The size of the damaged area and its thickness is measured and other special observations are noted (after Johnsen, 1985).

Finland

According to Johnsen, the safety department of the Ministry of Home Affairs in Finland has published recommendations for the fire safety of fittings and furnishings at the end of 1984. The fittings/furnishings are grouped into ignitability

classes, ranging from SL 0 (the best: non-flammable) to SL 3 (the worst: readily ignitable). There are also recommendations for the application of furnishing materials, with definitions of test methods and the basis for classification. In the case of bedding, the classification implies that in class SL 1, difficult to ignite, neither bedding fabrics nor mattresses shall become ignited when tested with a glowing cigarette or methenamine tablet. The classification SL 2, normally ignitable, includes mattresses which are not ignited by a cigarette and quilts and duvets which are not ignited by a cigarette and which, during the tablet test, do not burn rapidly along the surface and do not burn through. Covers, blankets and bed linen are considered normally combustible when they are not ignited by a cigarette and when the burning time is longer than 8 seconds for 127 mm when tested according to method SIS 650083 (after Johnsen, 1985). According to Zorgman (1988 b) the test method SIS 650083 runs parallel with ASTM D 1230, which will be discussed in section 3 of this Annex. The Finnish test methods will not be discussed here, as no other references to their scope and principles were traced in literature.

Japan

According to Johnsen, the Fire Defense Agency in Japan has issued recommendations concerning bedding: "Voluntary flame retardant regulations for beddings and tentages, etc. under the guide line of Fire Defense Agency in Japan, 1983." In principle, the different bedding components are measured individually, and often at an angle of 45^{o}. In the case of plastic foam mattresses, both plastic foam and cover are tested, as well as the mattress as a whole. The same principle applies to fibre filled sewn quilts. The criteria are listed together with the description of the method. A glowing cigarette, a methenamine tablet and a small gas flame are used as ignition sources. Special attention is given to the possibility of melting (after Johnsen, 1985).

Final remarks

Apart from the regulations and standards summarized in this section, some aspects of the standardization of mattresses and bedding materials should receive attention here: firstly the existing standards for the flammability testing of blankets and duvets/quilts exclusively and secondly the existing standards for high risk occupancies.

According to Zorgman (1988 b), the standards for the testing of the fire safety of blankets and duvets or quilts, as existing in the United States (ASTM D 4152) and in the United Kingdom (DOE/PSA FTS 5), are inadequate. The results of the American test method are questionable and the British test method is not realistic, as blankets are tested on a

mattress, according to Zorgman. Therefore these standards will not be summarized here.

In several countries various test methods were designed for mattresses and bedding materials for use in high risk occupancies, like prisons, hospitals etc. As the scope of this study covers domestic fire accidents, these standards will not be summarized here.

2.3 Curtains

Federal Republic of Germany

In the Federal Republic of Germany no regulations are established with regard to the fire safety of curtain materials. A standard concerning this subject will be summarized here.

* DIN 66082 - Classification of burning behaviour of textile products; drapery and curtain materials (1980)

This standard classifies the burning behaviour of drapery and curtain materials on the basis of the results of certain test methods. These test methods are laid down in either DIN 4102 Teil 1, concerning the fire behaviour of building materials which is therefore not discussed here, or in DIN 54 336, concerning the fire behaviour of vertically oriented textile fabrics, discussed in section 1.1 of this Annex. The materials are tested in their original state, not after laundering or (dry) cleaning etc. Five classes are distinguished and if the requirements of the fifth class cannot be met, the curtain materials involved cannot be classified according to this standard.

The Netherlands

In the Netherlands no regulations concern the flammability of curtain materials. The standard NEN 1722, discussed already in section 1.1, is accompanied by an Appendix (A) containing a test method and evaluation criteria with regard to curtain materials. This Appendix A will be summarized here briefly.

* NEN 1722 - Burning behaviour of textile vertically oriented fabrics. Determination of the ease of ignition and flame spread properties (1986); Appendix A (1986)

The scope and general principle of this standard are already discussed in section 1.1 of this Annex. Appendix A (1986) regards textile fabrics intended to be used for curtains and draperies etc.

Curtains that are suspended in folds should be simulated by positioning three layers of cloth behind each other, at a distance of 10 mm between the different layers. The

orientation of the test specimens should correspond with the orientation of the cloth in complete curtains in practice. Evaluation criteria concern afterflame time, afterglow time and dimensions of the burnt area. The possible effects of ageing, soiling and cleaning are brought under attention, but no specific test procedures on these subjects are given.

Austria

In Austria there are no regulations regarding the flammability of curtain materials. A standard concerning this subject will be summarized here.

* ÖNORM B 3820 - Fire behaviour of curtains (1986)

The scope of this standard can be translated as follows. This standard applies to all flat items which are used as curtains or curtainlike decorations. It does not apply to ceiling and wall coverings. The purpose of the standard is to evaluate the burning behaviour of curtains and draperies.

The test specimens are vertically oriented and are subjected to a flame at their lower edge. Several burning properties are determined. Both new and cleaned specimens can be tested by this test method; cleaning and washing procedures conform to certain DIN standards. Three flammability categories are classified.

2.4 Textile floor coverings

United Kingdom

The Draft Furniture and Furnishings (Fire) (Safety) Regulations, discussed already in the sections 2.1 and 2.2 of this Annex, explicitly do not include regulations for floor coverings, including carpets and mats (DTI, 1 March 1988). No other regulations concerning the flammability of textile floor coverings are established in the United Kingdom. A British Standard which deals with some aspects of the fire behaviour of textile floor coverings is summarized here.

* BS 4790 - British Standard Method for Determination of the effects of a small source of ignition on textile floor coverings (hot metal nut method) (1987)

The scope of this standard is formulated as follows:
"This British Standard describes a method for the determination of the effects of a small source of ignition on textile floor coverings using a hot metal nut. It is applicable to all types of textile floor coverings whether loose-laid or fully adhered and used with or without an underlay."

And the principle:

"A heated stainless steel nut is placed on the use-surface of the material to be tested. The times of flaming and of afterglow and the greatest radius of the effects of ignition from the point of application of the nut are measured."

The test specimens include any backing or underlay that forms part of the final installation. Specimens with pile surface should have their pile raised. Surface flash in pile structures may be assessed by the method given in BS 4569, discussed in section 1.4. It is mentioned in the Foreword that the method takes no account of smoke and toxic fumes that may be produced and that the method is not intended to be used to assess the effects of other sources of ignition nor to assess the contribution a textile floor covering will make to an established fire.

Federal Republic of Germany

In the Federal Republic of Germany there are no regulations concerning the flammability of textile floor coverings. Three standards relating to this subject will be summarized here.

* DIN 54 332 - Testing of textiles; determination of the burning behaviour of textile floor coverings (1975)

This standard describes a test method to determine some aspects of the burning behaviour of textile floor coverings. All kinds of textile floor coverings can be tested. The test specimen is oriented vertically and subjected to a flame at the lower edge. The flame is applied during different periods, to establish whether the specimen continues burning or not and which area is damaged, as well as how much time it takes a flame to travel a certain distance.

* DIN 66 081 - Classification of burning behaviour of textile products; textile floor coverings (9176)

This standard classifies the burning behaviour of textile floor coverings on the basis of the results of test method DIN 54 332, summarized above, slightly modified. Three classes are distinguished and if the requirements of these classes cannot be met, the involved textile floor coverings cannot be classified according to this standard.

* DIN 66 090 Teil 1 - Textile floor coverings; requirements of construction, burning behaviour (1980)

This standard supplies requirements regarding the construction of textile floor coverings. If these requirements are met, the concerned textile floor coverings can be classified as class T-b (that is the second class) of DIN 66 081, summarized above, without subjection of the floor

coverings to any kind of flammability test. Their fire behaviour is derived from several properties of the material like the kind of material applied in the top layer and its thickness, among others. This standard cannot be applied to textile wall coverings.

The Netherlands

In the Netherlands there are no regulations regarding the flammability of textile floor coverings. A standard concerning this subject will be summarized here.

* NEN 1775 - Burning behaviour of floor surfaces with floor coverings or finishing coat. Determination of the ease of ignition and the contribution to fire propagation (1985)

This standard is derived from DIN 4102 Teil 1, concerning the fire behaviour of building materials which is therefore not summarized here, and from ASTM E 648-78, which was developed to simulate fires that may develop in corridors or exitways of buildings and is not intended for use in estimating flame spread behaviour of floor covering in building areas other than corridors or exitways, which is therefore not summarized here either. This Dutch Standard describes a method of test to determine the ease of ignition of floor surfaces with floor coverings or a finishing coat, as well as a method of test to determine the contribution to fire propagation of such floor surfaces.

The principle of the first method can be summarized as follows. A test specimen, consisting of a foundation, combined with a sample of floor covering or a finishing coat, is oriented vertically and subjected to a standardized gasflame at its lower edge during fixed periods, in order to determine the fire behaviour of the test specimen. On the basis of the results of this test method floor surfaces with floor coverings or finishing coats are classified, according to certain criteria, in two classes. If the requirements of these two classes are not met, classification is not possible on the basis of this standard.

The principle of the second method is indicated here briefly. A horizontally oriented test specimen is subjected at its surface to a given radiant heat energy source and the contribution to fire propagation of the test specimen is determined. Test specimens are classified in two distinct classes.

United States of America

In the Flammable Fabrics Act, issued by the federal government, two standards form the basis of the regulations concerning carpets and rugs. The difference between these two standards and the accompanying regulations lies in the

dimensions of the carpets and rugs: for small carpets and rugs less stringent requirements are made. Carpets and rugs which have one dimension greater than 6 feet and a surface area greater than 24 square feet are defined as large carpets and rugs, whereas those with no dimension greater than 6 feet and a surface area not greater than 24 square feet are considered small. Linoleum, vinyl tile and asphalt tile are excluded. A burning tablet test is used to determine the fire behaviour of the carpets and rugs: large carpets and rugs have to meet a standard, whereas small carpets and rugs that do not meet the standard may be sold if labelled with a warning (Product Safety Fact Sheet, 1978). All carpets and rugs must be labelled with the letter "T" if a flame retardant treatment has been applied. A fibre which is inherently flame retardant is not required to be labelled. The two standards which form the basis of the regulations concerning carpets and rugs will be summarized here, as well as another - closely related - American standard concerning textile floor coverings.

* 16 CFR 1630 (FF 1-70) - Standard for the Surface Flammability of Carpets and Rugs (1986)

The scope and application of this standard are formulated as follows:

"(a) This standard provides a test method to determine the surface flammability of carpets and rugs when exposed to a standard small source of ignition under carefully prescribed draft-protected conditions. It is applicable to all types of carpets and rugs used as floor covering materials regardless of their method of fabrication or whether they are made of natural or synthetic fibres or films, or combinations of or substitutes for these.
(b) One of a kind, carpet or rug, such as an antique, an Oriental, or a hide, may be excluded from testing under this Standard pursuant to conditions established by the Consumer Product Safety Commission."

As "Summary of test method" is presented:

"This method involves the exposure of each of eight conditioned, replicate specimens of a given carpet or rug to a standard igniting source in a draft-protected environment, and measurement of the proximity of the charred portion to the edge of the hole in the prescribed flattening frame."

As "Test criterion" is formulated:

"A specimen passes the test if the charred portion does not extend to within 2.54 cm (1.0 in.) of the edge of the hole in the flattening frame at any point."

And as "Acceptance criterion":

"At least seven of the eight specimens shall meet the test criterion in order to conform with this standard."

"Carpet" means in this standard any type of finished product made in whole or in part of fabric or related material and intended for use or which may reasonably be expected to be used as a floor covering which is exposed to traffic in homes, offices, or other places of assembly or accomodation, and which may or may not be fastened to the floor by mechanical means and which has one dimension greater than 1.83 m (6 ft.) and a surface area greater than 2.23 m^2 (24 sq.ft.). Products such as "carpets squares", with one dimension less than 1.83 m and a surface area less than 2.23 m^2 but intended to be assembled upon installation into assemblies which have greater dimensions/surface areas are included, as well as mats, hides with natural or synthetic fibres and other similar products in the above defined dimensions. Resilient floor coverings such as linoleum, asphalt tile and vinyl tile are not included. If the carpet or rug has had a fire retardant treatment it shall be labelled with the letter "T". Such carpets or rugs are tested after being washed, dry cleaned or shampooed 10 times in such manner as is normally used for that type of carpet or rug in service.

* 16 CFR 1631 (FF 2-70) - Standard for the Surface Flammability of Small Carpets and Rugs (1986)

The scope and application of this standard are the same as those of the standard 16 CFR 1630 (FF 1-70) discussed above. The "Summary of test method", the "Test criterion" and the "Acceptance criterion" are similar to those of the standard 16 CFR 1630 (FF 1-70) too. "Small Carpets" differ from "Carpets" because of their dimensions: they have no dimension greater than 1.83 m (6 ft.) and an area not greater than 2.23 m^2 (24 sq.ft.). "Carpets Squares", intended to be assembled, are not considered as "Small carpets", as was already indicated in the summary of the standard 16 CFR 1630 (FF 1-70).

If a small carpet or rug does not meet the acceptance criterion, it shall, prior to its introduction into commerce, be permanently labelled. Small carpets or rugs with fire retardant treatments shall also be labelled with the letter "T", like large carpets and rugs (see 16 CFR 1630 (FF 1-70)). Such small carpets or rugs are also tested after the normally used cleaning method, 10 times, like large carpets and rugs.

* ASTM D 2859 - Standard Test Method for Flammability of Finished Textile Floor Covering Materials (1976)

The scope of this standard is formulated as follows:

"This method covers the determination of the flammability of finished textile floor covering materials when exposed to an ignition source under controlled laboratory conditions. It is applicable to all types of textile floor coverings regardless of the method of fabrication or

whether they are made from natural or man-made fibres. Although this method may be applied to unfinished material, such a test is not considered satisfactory for the evaluation of a textile floor covering material for ultimate consumer use.

This standard should be used to measure and describe the properties of materials, products, or systems in response to heat and flame under controlled laboratory conditions and should not be used for the description or appraisal of the fire hazard of materials, products or systems under actual fire conditions."

A "Summary of Method" is given:
"This method involves the exposure of conditioned and oven-dried specimens to a standard source of ignition in a draft-protected environment and the measurement of the resulting char length."

The principle of this standard is comparable with that of the standards 16 CFR 1630 (FF 1-70) and 16 CFR 1631 (FF 2-70); these two standards, which provide the basis for the federal mandatory regulations, are more extensive and differ in details (for instance in the cleaning procedures) and status from ASTM D 2859.

International Standards

A summary of the International Standard concerning textile floor coverings will be given.

* ISO 6925 - 1982: Textile floor coverings - Burning behaviour - Tablet test at ambient temperature

The scope and field of application of this standard is formulated as follows:
"This International Standard specifies a method for the assessment of the burning behaviour, often superficial, of textile floor coverings in a horizontal position when exposed to a small source of ignition under controlled laboratory conditions.

The method specified in this International Standard is applicable to all types of textile floor coverings whatever their construction or their fibre composition. The method may also be applicable to unfinished material. In this case, the result does not indicate the behaviour of the material in the condition in which it is used.

The results obtained on specimens in a horizontal position, as specified in this International Standard, do not apply to the behaviour of the textile floor covering when used in another position, particularly in a vertical position.

The present method should be used solely to assess the properties of materials or systems in response to heat and flame under controlled laboratory conditions and should not be used for the evaluation or regulation of the hazard of textile floor coverings under actual fire conditions (...)."

As principle is indicated:
"Exposure of a specimen in a horizontal position to the action of a small ignition source (methenamine tablet) under specified conditions and measurement of the resulting damaged length."

It should be noted that no cleaning procedures etc. are included in this standard. No evaluation criteria are given.

Sweden

According to Van Erdewijk and Jaartsveld (1988) guidelines have been issued with respect to carpets (KOVFS 1979: 2). They include, among others, the requirement that they do not spread fire.

3 Clothing textiles

In this section standards and regulations concerning the fire safety of clothing textiles are summarized. Many standards regarding clothing textiles and apparel (especially nightwear) are available in the Member States of the EEC and various other Western countries. The standards characterized here are selected on the basis of the criteria mentioned before.

United Kingdom

In the United Kingdom the Nightwear (Safety) Regulations 1985 are based upon the British Standard BS 5722: Flammability performance of fabrics and fabric assemblies used in sleepwear and dressing gowns (1984). This standard refers to the test methods of BS 5438 (1976) (see section 1.1 of this Annex) and presents flammability performance requirements for fabrics, including multi-layer fabrics and fabric assemblies, for use in the production of sleepwear and dressing gowns. Children's nightdresses, dressing gowns and other similar garments commonly worn as nightwear must satisfy these flammability performance requirements. Children's pyjamas and cotton terry towelling bath robes do not have to comply with the flammability standard. However, they must carry a permanent label showing whether or not they meet the flammability standard. Babies' garments must carry a permanent label showing whether or not they meet the flammability standard. Adults' nightwear and garments commonly worn as nightwear must also carry a permanent label showing whether or not they meet the flammability standard.

The flammability performance requirements relate to the whole area of the garment including all threads, trimmings, decorations and labels. Elastic materials used in the garment are exempt from the flammability requirements. Nightwear made of and trimmed with synthetic fabric (e.g. nylon or polyester) which melts without decomposing when ignited as part of the British Standard test can be taken to meet the flammability performance requirements. Nightwear which has been treated with flame retardant chemicals must carry the appropriate warning label about washing and the suitability of the washing agent.
To classify the category of a garment (babies', children's or adults') measurements are given. Labelling requirements are included, e.g. letter sizes and position of the labels (Department of Trade and Industry, 1985).

According to Zorgman (1986) the regulations in Ireland comply more or less with the Nightwear (Safety) Regulations in the United Kingdom.

* BS 5722 - Flammability performance of fabrics and fabric assemblies used in sleepwear and dressing gowns (1984)

The scope of this standard is described as follows:
"This British Standard specifies flammability performance requirements for fabrics, including multi-layer fabrics and fabric assemblies, for use in the production of sleepwear and dressing gowns."

Specimens are tested in accordance with test 3 of BS 5438 slightly modified, using a 10 s flame application time, or test 2 of BS 5438 using a 10 s flame application time (see section 1.1). Performance requirements are presented in relation to the test results of the specimens. Instructions are supplied on the face of the fabric that has to be tested, as well as on the appropriate cleansing procedures, on the basis of BS 5651, complying with the (product) information given on the care of the fabric.

In the Foreword it is mentioned that professional and home makers of garments have to be aware that the use of certain trims, accessories and sewing threads can have an adverse effect on the flammability of a garment. The use of different fabrics to produce a multi-layer garment can also have a similar effect and if such a design is to be used, it is important to test the fabrics in the same combination as they will be used. The importance of design is also mentioned, with reference in the foreword to, among others, the Australian Standard 1249, which will be discussed later in this section. It is said that the requirements of the standard may not give protection against exposure to large sources of heat but is intended to give protection against rapid flame spread arising from accidental contact with small sources of ignition. The standard is intended to apply to

fabrics and fabric assemblies used in the manufacture of sleepwear for use in normal circumstances.

The Netherlands

In the Netherlands no mandatory regulations on the flammability of clothing textiles are in force yet. A Decree under the Commodities Act (Warenwet) is in preparation with regard to nightwear for both children and adults.

* NEN 1722 - Burning behaviour of textile vertically oriented fabrics. Determination of the ease of ignition and flame spread properties (1986); Appendix B (1987).

The scope and general principle of this standard is already discussed in section 1.1 of this Annex. Appendix B (1987) concerns textile fabric intended to be used in nightwear (e.g. pyjamas, nightdresses, dressing gowns etc.). Test pieces should contain all materials (e.g. threads, decorations etc.) used in the garment and are tested before and after the appropriate cleansing procedures, complying with the instructions on the garment, according to ISO 6330 (1984) or ISO 3175 (1979).

Specimens are tested in an orientation complying with the orientation of the fabric in the garment. Multi-layered garments should be simulated in the test specimens. The contact time of the test specimen with the ignition source is 5 seconds and 15 seconds, respectively. The specimens are also tested with regard to surface flash (defined as spread of flame over the surface of a material with or without ignition of its basic structure), the contact with the flame lasting 1 second. Criteria are formulated regarding the rate of flame spread, surface flash and glowing or flaming debris.

United States of America

In the United States of America the Federal Government has established the Flammable Fabrics Act. Various standards and test methods (see Krasny, 1986) concern the flammability of clothing textiles and children's sleepwear.

Requirements on the flammability of clothing textiles have regard to articles of wearing apparel, excluding interlining fabrics and certain hats, gloves and footwear. The rate of flame spread is measured in a specimen in a holder in a 45^{o} orientation and classified according to given criteria (Code of Federal Regulations, 16, 1984; Zorgman, 1986). This standard was designed to keep highly flammable apparel out of the marketplace (Guide to fabric flammability, 1975).

Requirements on the flammability of children's sleepwear have regard to any product of wearing apparel, such as nightgowns, pyjamas, or similar or related items such as robes intended

to be worn primarily for sleeping or activities related to sleeping; excluding diapers and underwear. Fabrics or related material intended or promoted for use in children's sleepwear must also meet the standards. Test criteria are the average char length and the full specimen burn. Labelling requirements are made, differing for two groups of children's sleepwear sizes (sizes 0-6X and 7-14, respectively) (see Product Safety Fact Sheet, 1978 and OECD, 1977). Instructions must be given on the protection of the sleepwear items from agents or treatments known to cause deterioration of their flame resistance (Product Safety Fact Sheet, 1978).

A summary of the various flammability standards and tested methods is presented here.

* 16 CFR 1610 (formerly CS 191-53) - Standard for the Flammability of Clothing Textiles (1986)

The purpose of this standard is described as follows:
"The purpose of this standard is to reduce danger of injury and loss of life by providing, on a national basis, standard methods of testing and rating the flammability of textiles and textile products for clothing use, thereby discouraging the use of any dangerously flammable clothing textiles".

The scope of the standard is formulated as follows:
"The standard provides methods of testing the flammability of clothing and textiles intended to be used for clothing, establishes three classes of flammability, sets forth the requirements which textiles shall meet to be so classified, and warns against the use of those textiles which have burning characteristics unsuitable for clothing".

Specimens are tested in their original state and/or after being dry cleaned and washed, according to the instructions in this standard. They are tested in a specimen holder at an angle of 45^{o}. A standardized flame is applied to the specimen for a period of 1 second. Based on the test results, the textiles are placed in the proper given classification.

* 16 CFR 1615 (FF 3-71) - Standard for the Flammability of Children's Sleepwear, Sizes 0 through 6X (1986)

* 16 CFR 1616 (FF 5-74) - Standard for the Flammability of Children's Sleepwear, Sizes 7 through 14 (1986)

These standards contain test procedures and requirements for children's sleepwear, distinguished for different sizes.

16 CFR 1615 (FF 3-71):
The scope of this standard can be summarized as follows:
a test method is provided to determine the flammability of children's sleepwear items or any fabric or related material

intended or promoted for use in children's sleepwear. Children's sleepwear is defined as any product of wearing apparel up to and including size 6X, such as nightgowns, pyjamas, or similar or related items, such as robes, intended to be worn primarily for sleeping or activities related to sleeping. Diapers and underwear are excluded from this definition.

A summary of the test method is given:

> "Five conditioned specimens, 8.9 x 25.4 cm (3.5 x 10 in.) are suspended one at a time vertically in holders in a prescribed cabinet and subjected to a standard flame along their bottom edge for a specified time under controlled conditions. The char length is measured."

Test criteria have regard to the average char length and the full specimen burn. Finished items (as produced or after one washing and drying) are tested and evaluated, as well as items that have been washed and dried 50 times (see also Product Safety Fact Sheet, 1978, and Zorgman, 1986). Trimmings etc. are also tested. Labelling requirements are made as well.

16 CFR 1616 (FF 5-74):
The scope of this standard can be summarized as follows:
a test methods is provided to determine the flammability of children's sleepwear, sizes 7 through 14 and fabric or related material intended or promoted for use in such children's sleepwear.
The definition of children's sleepwear is already given under the description of 16 CFR 1615, with a difference in sizes.

As summary of the test method is given:

> "Conditioned specimens are suspended one at a time vertically in holders in a prescribed cabinet and subjected to a standard flame along their bottom edges for a specified time under controlled conditions. The char lengths are recorded."

The test criteria, as in 16 CFR 1615, have regard to the average char length and the full specimen burn.
Both finished items in the original state (or after one washing and drying) and items that have been washed and dried 50 times are tested, as in 16 CFR 1615. Trimmings etc. are also tested.

With some exceptions, technical requirements are similar to those for sleepwear sizes 0-6X but slightly less stringent (Guide to fabric flammability, 1975). The labelling requirements differ from those for sleepwear sizes 0-6X (see Product Safety Fact Sheet, 1978 and OECD, 1977).

* ASTM D 1230-85 - Standard Test Method for Flammability of Apparel Textiles

The scope of this standard is formulated as follows:
"This test method covers the evaluation of the flammability of textile fabrics as they reach the consumer for or from apparel other than children's sleepwear or protective clothing."

It should be noted that:
"This standard should be used to measure and describe the properties of materials, products, or assemblies in response to heat and flame under controlled laboratory conditions and should not be used to describe or appraise the fire hazard or fire risk of materials, products, or assemblies under actual fire conditions. However, results of this test may be used as elements of a fire-risk assessment which takes into account all of the factors which are pertinent to an assessment of the fire hazard of a particular end use."

A summary of the test method is presented:
"The standard provides methods of testing the flammability of textiles from or intended to be used for apparel, explains three classes of flammability, sets forth requirements for classifying textiles, and warns against the use of single or multilayer textile fabrics that have burning characteristics considered by the trade to make them unsuitable for apparel.

Specimens cut from the textile are prepared by brushing if they have a raised fibre surface, by dry cleaning and laundering if they have been flame-retardant-treated. A dried specimen is inserted in a frame and held in a special apparatus at an angle of 45°, a standardized flame is applied to the surface near the lower end for 1 s, and the time required for the flame to proceed up the fabric a distance of 127 mm (5 in.) is recorded. Notation is made as to whether the base of a raised surface fabric ignites, chars, or melts."

It should be noted that this test is not identical to 16 CFR part 1610, Flammability of Clothing Textiles. This test method D 1230 is not recommended for acceptance testing, since federal regulations require apparel fabrics to meet the criteria of 16 CFR 1610.

Krasny (1986) summarizes several -more or less standardized- test methods regarding apparel flammability, including the federal children's sleepwear tests CFR 1615 and 1616 discussed above. The other test methods mentioned by Krasny are summarized here.

* Thermoperson full-scale garment burns (see Krasny, 1986)

Thermoperson is a manikin of adult size (about 1.8 metre tall with a 0.86 metre waist). About 110 thermosensors are distributed evenly over its surface. This manikin can be used for male and, with properly sensored attachments, for female garments. Different garment styles can be tested. The time from ignition (by paper tab, near the bottom of the garment) to 5, 10 and 20 % injured area is reported, which can be used to characterize the early stages of the fire. The injured area, total heat release, and rate of heat release are reported at 80 and 150 s (both contribute to the trauma caused by burn injury, as well as the derived values B-80 and B-150, which incorporate the injury area weighted by the depth of burn. The sensor output is converted to the depth of burn injury in human skin.

* Apparel flammability modelling apparatus (AFMA) (see Krasny, 1986)

The AFMA is a semicylinder covered by 54 heat sensors. The apparatus is designed to test fabrics under two extreme conditions possibly occurring during a garment burn: the garment hanging freely, or the garment being in contact with the body. In the free hanging mode, the specimens hang freely from a frame suspended near the top of the semicylinder, which is inclined at 20^{o} to the vertical and remains in this position throughout the test. The same configuration is used initially in the contact mode, but when one of four sensors registers a heat rise of 5^{o} C, the semicylinder moves to the vertical position and makes contact with the specimen. This simulates movement of, for example, a leg in burning slacks (like the garment-skin distance is changed by the victim's movements during real-life accidents).
In both the free-hanging and contact modes, fabrics are allowed to burn until they self-extinguish. The results for the free-hanging and contact modes are expressed in terms of total heat release and maximum rate of heat release. For the contact mode the injured area is also reported. The time until one of the sensors registered a 5^{o} C temperature rise, called here the recognition time, is also listed.

* Sensor tests (see Krasny, 1986)

The single sensor test uses semirestrained specimens (see ASTM D 3659-80: Test method for flammability of apparel fabrics, semirestraint method), suspended rigidly on top. A moderate outward and downward pull is exerted on the bottom of the specimen by chains attached to its corners and the apparatus frame. The specimen and a plate with a copper sensor embedded in it are vertical, and heat flow is directed towards the sensor plate as well as upwards. The

specimen-sensor plate distance is 13 mm., and only one sensor, about half-way up the specimen, is used. The maximum temperature of the sensor is measured, as well as the total heat and the rate of heat transfer to the sensor.

In the multi-sensor test a flat specimen is held in a U-frame 6 mm from a board containing 24 copper sensors. The total heat and the rate of heat transferred to the sensor system is measured.

In both the single and the multi-sensor test ignition takes place at the bottom edge.

* Mushroom apparel flammability test (MAFT) (see Krasny, 1986)

In this test the specimen is suspended from a round metal plate located on top of a cylinder of smaller diameter (which looks like a dressed mushroom). Thermocouples are located in the copper cylinder inside the specimen and a copper ring in the ceramic top plate. Ignition is 100 mm above the bottom specimen edge, so that burning can take place sideways and downward as well as upward. The heat release and time to ignition are measured.

* Flat plate sensor test (see Krasny, 1986)

This test is a simplified MAFT test (see above). Eight thermocouples are mounted in a vertical plate and two in a rectangular plate mounted on top of the vertical plate. The specimen is suspended from the top plate and thus is box-shaped, with the side towards the sensor plate open. Ignition is 100 mm from the bottom edge and the maximum and average heat transfer rates are measured, as well as the average heat transfer rate 30 s after 40 ^{o} C.

* TRI Convective Calorimeter (see Krasny, 1986)

This instrument measures the air entrained during the burning of the specimen, which is considered to be proportional to the heat release. It is an indirect method for measuring heat release and total heat. Several "harm functions" are derived from the maximum heat release rate, the time from ignition until this maximum is reached, and the time after the maximum until a heat release rate of one half of the maximum is reached.

* NBS Isoperibol Calorimeter (see Krasny, 1986)

In this instrument, the specimen is placed on a wire screen and burned in a calorimeter. Air is forced over the specimen, and through the double walls of the calorimeter. The rise in calorimeter temperature is measured and thus the total amount and rate of heat release.

* Weight loss method (see Krasny, 1986)

  Specimens are suspended as in the semirestraint test (see ASTM D 3659-80 and the single sensor test, mentioned above). The bar from which they are suspended is attached to a load cell, and weight loss during burning is recorded.

Australia

In Australia the statutory requirements are based on the Australian Standard AS 1249: Children's nightclothes having reduced fire hazard (1983). No detailed information was found on the Australian legislation concerning the Trade Practices Act.

* AS 1249 - Children's nightclothes having reduced fire hazard (1983)

In the preface this standard is summarized as follows:

"The standard specifies the requirements for three categories of garments: those made from fabrics with low flame propagation properties which are stated herein; garments which because of their design are less likely to catch alight, and if they do the spread of flames is reduced because of design features; and garments which do not fall into either of these categories of garments.

Limitations on mass and content of cellulosic, acetate and acrylic fibres are placed on garments in the last category because of their highly flammable characteristics. This standard limits the use of such fabrics in children's nightclothes to fabrics complying with either an ignition time or a burning time requirement."

The scope of the standard is formulated as follows:

"This standard specifies requirements for children's nightclothes having reduced fire hazard. It covers-

(a) nightclothes made from fabrics of the low fire hazard type
(b) nightclothes styled to reduce fire hazard
(c) nightclothes not covered by (a) or (b) above
(d) labelling of nightclothes and of envelopes containing paper patterns for retail sale."

The standard applies to children's nightclothes in sizes ranging from 0 to 14 in accordance with AS 1182. Children's nightclothes shall be classified for the purpose of labelling as follows:

"Category 1 - garments made from fabric of the low fire hazard type and which comply with Section 2 (that is requirements for category 1 garments). These garments include pyjamas, pyjama-style overgarments, nightdresses, dressing gowns, infant sleepbags, and the like.

Category 2 - garments designed to reduce fire hazard and which comply with Section 3 (that is requirements for category 2 garments). These garments include pyjamas and pyjama-style overgarments.

Category 3 - garments such as pyjamas, pyjama-style overgarments, nightdresses, dressing gowns, infant sleepbags which comply with Section 4 (that is requirements for category 3 garments) but do not comply with Section 2 or Section 3."

Category 1 requirements include fabrics and trims. The requirements are partially based on the test method of AS 1176, Part 2 (see 1.4 of this Annex). Category 2 requirements include style and design - nightclothes of this category should be of a form-fitting style. Fabrics with a pile or nap used for children's nightclothes should meet requirements on the surface burning time. Dimensions should comply with certain limits, and trims and fastenings have to meet requirements as well. Category 3 requirements include, among others, requirements on the fire behaviour of the fabrics, the use of certain fibre types and their percentages, quilted fabrics and infant sleepbags. Labelling requirements are distinguished for garments and paper patterns. Garments labelling requirements include, among others, requirements on the fire hazard in accordance with the classification stated in this standard, the garment size in accordance with the size coding scheme set out in AS 1182 and cleaning instructions most suitable for preserving the treatment applied to the fabric when a garment is made from fabrics which have been treated by chemical means to reduce the risk of burning. Paper patterns for children's nightclothes within the scope of this standard shall bear a fire warning paragraph on the outside of the envelope containing it.

Norway

Norway's Ministry of Environment has laid down regulations concerning a prohibition on highly flammable textiles, having come into force on the 1st of September 1984 for children's apparel, blankets, quilts and such like and on the 1st of September 1985 for general wearing apparel and fabrics intended for use in clothing. The aim of these regulations is to protect the public against unreasonable risk of fire leading to death or injuries (the Norwegian State Pollution Control Authority, July 1984).

The regulations are based on the test method ASTM D 1230-83. The scope and summary of ASTM D 1230-83 are similar to the scope and summary of the 1985-version of ASTM D 1230, described before in this section. Some additions to this standard are made in the Norwegian regulations. The regulations contain criteria on the flame spread time of the above mentioned products and on the use of flame retardant

substances. The test method describes laundering/dry cleaning of the textiles before testing the flammability, in cases where the textile has been treated with flame retardant substances (The Norwegian State Pollution Control Authority, July 1984).

According to Zorgman (1986), with reference to the Norwegian State Pollution Control Authority, the Norwegian criteria are derived from the criteria of the Canadian regulations.

Canada

De Graaf (1988) sketches the Canadian regulations concerning the flammability of children's sleepwear, with reference to the Flammability Hazards Division, 1986. Since 1971 these regulations are based on ASTM D 1230-61. (The principles of the 1985-version of this standard were already discussed before in this section.) In addition more stringent requirements were formulated to prevent more domestic fire accidents with children's sleepwear. Nowadays ASTM D 1230 provides the basis of the requirements for polo-pyjamas, track suit pyjamas etc. More stringent requirements for nightdresses, dressing gowns and bath robes etc. are provided by the standard FF 5-74 (16 CFR 1616 - Flammability of Children's Sleepwear, Sizes 7-14, 1986), discussed before in this section.

The more stringent requirements concern so called "category 1 sleepwear styles", such as nightdresses, nightshirts, dressing gowns, bath robes, loose-fit pyjamas ("tailored pyjamas"), babydolls etc. A sketch of the style and design of these garments as they should be is presented, certain maximum dimensions are required and certain variable characteristics within a specified category are described (such as the length of a nightdress or the legs of a pair of pyjamas). The "category 2 sleepwear styles" include babies' garments, polo-pyjamas and track suit pyjamas. These garments have to meet less stringent requirements because of a positive influence of their style and design on their fire behaviour.

Other European countries

The regulations concerning the flammability of clothing (textiles) in other European countries are mentioned here briefly.

Sweden

From the Product Safety Handbook (Van Erdewijk and Jaartsveld, 1988) - an outline of product safety regulations in countries within the European Region - it is learned that in Sweden guidelines have been issued on the flammability of clothes (KOVFS 1985: 5).

Federal Republic of Germany

According to Van Erdewijk and Jaartsveld (1988) a regulation with respect to the utilization of certain substances which are harmful to the health in fireproof textile materials, coming frequently into contact with the human body, has come into force on the 1st of August 1980 in the Federal Republic of Germany. The regulations deal with, among other things, pyjamas and nightdresses, underwear and garments. No other regulations concerning the flammability of clothing textiles were traced.

Belgium

Van Erdewijk and Jaartsveld (1988) report that regulations related to dangerous substances in Belgium are laid down in numerous decrees. The Decree of 5 June 1978 "portant interdiction au commerce des vêtements et tissus traités au tris (2,3 bromopropyl phosphate)", Moniteur Belge of 16 June 1978, prohibits garments and fabrics treated with tris (2,3 bromopropyl phosphate). This Decree is, according to Van Erdewijk and Jaartsveld, analogous to the European Directive 79/663/EEC which amends the European Directive 76/769/EEC. Other regulations concerning the flammability of clothing textiles were not found.

ANNEX 2

DEFINITIONS

- afterflame time	- The length of time for which a material continues to flame, under specified test conditions, after the ignition source has been removed.
- afterglow time	- The length of time for which a material continues to glow, under specified test conditions, after the ignition source has been removed and /or cessation of flaming.
- bedding materials	- All items placed on the bed by a user to provide comfort and warmth, including sheets, blankets, bedspreads, continental quilts, duvets, quilt covers and mattress covers etc.
- burning behaviour	- All the physical and/or chemical changes that take place when a material or product is exposed to a specified ignition source.
- chimney effect	- Upward thrust of smoke and hot gases by convection currents confined within a vertical enclosure.
- clothing textiles	- Textile materials intended to be used in apparel.
- combustion	- Exothermic reaction of a substance with an oxidizer, generally accompanied by flames and/or glowing and/or emission of smoke.
- fabric	- A woven, knitted or non-woven textile material in the form of single or multicomponent (coated, quilted and multi-layered sandwich construction and similar combinations) materials.
- fire	- 1. A process of combustion characterized by the emission of heat accompanied by smoke and/or flame.

	2. Rapid combustion spreading uncontrolled in time and space.
- fire behaviour	- All the physical and/or chemical changes that take place when a material, product and/or structure is exposed to an uncontrolled fire.
- fire hazard	- The potential for loss of life (or injury) and/or damage to property by fire.
- fire load	- The sum of the calorific energies which could be released by the complete combustion of all the combustible materials in a space, including the facings of the walls, partitions, floors and ceilings.
- flame retardant (substance)	- A substance added, or a treatment applied to a material in order to suppress, significantly reduce or delay the propagation of flame.
- flame spread time	- The time taken by a flame on a burning material to travel a specified distance under specified test conditions.
- flaming	- Undergoing combustion in the gaseous phase with the emission of light.
- flammability	- The ability of a material or product to burn with a flame under specified test conditions.
- flash over	- The rapid transition to a state of total surface involvement in a fire of combustible materials within an enclosure.
- heat release rate/ rate of heat release	- The calorific energy released per unit time by a material during combustion under specified test conditions.
- ignitability	- The measure of the ease with which a specimen can be ignited due to the influence of an external heat source under specified test conditions.

- ignition	- Initiation of combustion.
- ignition source	- An applied source of heat which is used to ignite combustible materials or products.
- melting behaviour	- Phenomena accompanying the softening of a material under the influence of heat (including shrinking, dripping, burning of molten material, etc.)
- progressive smouldering	- An exothermic oxidation not accompanied by flaming which is self-propagating, i.e. independent of the ignition source. It may or may not be accompanied by incandescence.
- pyrolysis	- Irreversible chemical decomposition of a material due to an increase in temperature without oxidation.
- sleepwear	- Nightdresses, pyjamas and other similar garments intended to be worn next to the skin, normally in bed.
- smoke	- A visible suspension of solid and/or liquid particles in gases resulting from combustion or pyrolysis.
- smouldering	- The slow combustion of a material with or without light being visible and generally evidenced by an increase in temperature and/or by smoke.
- soft furnishings	- All textile products placed in living-rooms and bedrooms etc. of houses by occupants to provide comfort, including upholstered furniture, mattresses and bedding materials, curtains, textile floor coverings and textile wall coverings.
- surface flash	- Rapid spread of flame over the surface of a material without ignition of its basic structure.
- upholstered furniture	- Any furniture stuffed or filled in whole or part with any material, covered by fabric, including cushions, pillows etc.

The fire safety of textile products for private use is since long a matter of public concern. In many countries all over the world a great number of safety standards and laws are in force or in process of being issued soon. However, the approaches in the different countries show considerable variations, and the development of international standardization proceeds slowly.

In Europe the Member States of the European Communities agreed to remove all national trade barriers in order to have a free internal market by the year 1992. It can be foreseen that a strong public debate will develop by that time if the years to come do not lead to a common understanding in Europe about the required fire safety levels for textiles.

This study provides a basis for discussion about fire safety requirements for textile products. In order to facilitate the application of the research results, the legal approach of the European Communities has been chosen as the basic philosophy of this study.