Fire safety of upholstered furniture and mattresses in the domestic area

European fire services recommendations on test methods

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Foreword

This is the final report of the Federation of the European Union Fire Officer Associations (FEU). The FEU commissioned a working group to conduct research and draft an opinion on a set of test methods that the fire departments in Europe believe necessary to ensure that fires involving furniture in domestic fires affect the survivability and escape options as little as possible. By way of explanation the term furniture, relates to upholstered furniture (sofas and chairs) and mattresses in the context of this report.

This research has been carried out at this time because the rules and test methods in countries like the United States and the United Kingdom have recently been revised or are due to be revised. In addition to this we wish to understand whether fire safe furniture is possible without the use of flame retardants.

The result of this research is the European fire brigades (united in the FEU) “urgent” advice to manufacturers, suppliers, governments and standardization bodies to make sure only upholstered furniture and mattresses that meet the test methods in this report, are placed in homes.

At the present time about 5,000 people die each year as a result of a house fire in the European Union. Several American and British studies indicate that the number of deaths can be reduced by at least 25 percent by the use of fire safe furniture [1]. These figures, in the opinion of the FEU, say enough about the need for fire safe furniture. The FEU is, based on their research, convinced that if upholstered furniture and mattresses in Europe meets the test methods in this report, the number of deaths and injuries from fire and the extent of damage caused by fires in residential areas will reduce.

René Hagen
Project leader

Summary

For the last twenty years, a number of European fire service organisations have tried to make upholstered furniture and mattresses in residential properties more fire safe. As of today, these efforts have not led to the desired results. Some reasons for this are the fragmentation of the furniture market, hence the reason for the lack of pledges to make furniture more fire safe or the continuing debate on the usage of flame retardants in furniture.

Since the 80's the United Kingdom (UK) and Ireland have implemented legislation on the flammability of upholstered furniture and mattresses. Similar legislation and demands have been made by other European countries on a small scale. Most of the legislation focuses on furniture and mattresses in non-domestic buildings. Research on this legislation revealed that several European countries have requirements on the fire safety of furniture (and mattresses) in public buildings but only Finland and Norway have set requirements on the fire safety of furniture (and mattresses) in private homes.

In recent years, the Netherlands Fire Service and the Dutch Fire Service Academy tried to reaffirm to a major international manufacturer the dangers and consequences of combustible furniture and remind them of their social responsibility towards their client base. This major international manufacturer is being considered as a 'first mover'. Consequently, the first mover will pressure other factions in the industry to follow their example. This method has been used before in similar cases and appears to be working. Furthermore, the first mover is also developing new materials that are less flammable and produce a reduced amount of smoke. They are aiming to increase the survivability when a domestic fire occurs. The first mover has asked the FEU to advise them on which test methods to use to measure the effects of their new, and more fire safe, line of upholstered furniture. They asked the Netherlands Fire Service to advise them on how to show a relationship between on the one hand fire development, smoke spread and survivability in practice and on the other hand test methods for furniture. The Netherlands Fire Service subsequently asked the FEU to support this research. The FEU has agreed to cooperate with the condition that the opinion of the working group will be recorded in a public report so that it is accessible to everyone. The assignment that the FEU has given to the working group is as follows:

Define and determine a set of (existing or modified) test methods, which fire departments throughout Europe deem necessary in order to increase survivability and escape capabilities during domestic fires. The test methods have to be widely applicable to upholstered furniture, regardless of the material, and should serve as input towards manufacturers, suppliers and (legal) regulations and standards.

After the FEU had given the assignment, a working group of experts in the field of fire safety, firefighting, fire investigation and fire testing was put together. This working group had three key meetings which were funded by the 'Exchange of Experts programme' of the European Union. During those meetings one of the objectives was to gain knowledge on the field or fire safe furniture and test methods for upholstered furniture. By means of presentations and discussions it was possible to for the working group to delve into the subject, resulting in this report with recommendations.

Before focusing on determining a set of (existing or modified) test methods, the working group first discussed a number of considerations on which an opinion needed to be formed. Firstly, this concerned the need to improve the fire safety of upholstered furniture and mattresses. Secondly, the working group had to study the backgrounds of the Californian standard (TB 117) and the UK Furniture and Furnishings (Fire Safety) Regulations (FFRs), the two best known regulations for the ignitability of upholstered furniture and mattresses. Both schemes have changed during the years and the working group focused on the reasons why these test methods had been changed and the effects these changes have on fire safety. Thirdly, the working group could not ignore the use of and impact of flame retardants. Despite stating in the assignment that the test methods should be solution independent, meaning that any test could be passed with or without fire retardants, the working group could not ignore the ongoing public debate on the alleged health and environmental risks of flame retardants. The conclusions of the working group and thus the FEU regarding the objectives can be summarized as follows:

- Improve the survivability and probability of escape in dwellings
- The focus is on upholstered furniture (sofas, chairs) and mattresses
- The focus is on a standard domestic use
- The finally chosen testing method(s) should not exclude any physical nor chemical solutions.

The working group also collected statistics from several European countries about ignition sources and objects of origin in cases involving fatal fires in dwellings. These statistics show that fires often start in upholstered furniture or mattresses and these items contribute to many fire fatalities in domestic buildings. The most common ignition source for upholstery is a cigarette but other ignition sources such as smaller open flames are also common.

The FEU has considered which fire phase should be focused on regarding the recommendations that will be presented in this report. The FEU has come to the conclusion that at present the survivability and possibility of escape from fire is best served by avoiding ignition if possible. This could be achieved by using an ignition source such as a cigarette and match. However to represent the larger ignition sources that can be found in a dwelling, the FEU believes an ignition source such as Crib 5 is also necessary. By concentrating only on the ignition, we therefore focus on preventing, or at least delaying, the ignition as long as possible to increase survivability. By linking the survivability to preventing or delaying the ignition, there must be strict requirements on ignition of upholstered furniture and mattresses. Therefore the FEU recommends the following ignition sources to be used in testing upholstered furniture and mattresses:

1. ***The ignition by cigarette***
2. ***The ignition by small open flame***
3. ***The open flame ignition by a wooden crib (crib 5)***

The FEU believes that recommendations 1 and 2 are achievable at this time for most furnishings. We also want manufacturers to make a public commitment to achieve recommendation 3 in a realistic time frame.

Besides the ignition sources, the FEU has also taken into account the method of testing upholstered furniture and mattresses because this can differ. The conclusion of the FEU is that full scale testing is not realistic and that composite testing is the best alternative. The fire test is then performed in small scale but with the same material combination as the end-use product. If there are many material combinations available they can be grouped together and tests can be performed on the worst case combination.

To summarise, the FEU recommends that upholstered furniture is tested in the following way:

1. ***Testing on a composite level***
2. ***Testing on the end use combination***
3. ***Testing of representative combinations***

When it comes to testing mattresses, the FEU recommends:

1. ***Testing full scale mattress or a small scale sample***
2. ***Testing of representative combination***

When putting all recommendations together, this can be summarized as follows:

Object	**Ignition source**	**Test method**	**Comments**
Furniture	Cigarette	EN 1021-1	
	Open flame	EN 1021-2	
	Crib 5	BS 5852	Choose between BS 5852 chapter 11 or 12
Mattresses	Cigarette	EN 597-1	
	Open flame	EN 597-2	
	Crib 5	BS 6807	Test according to BS 6807 chapter 9

The test methods as mentioned above correspond to the chosen ignition sources and the way of testing the upholstery.

Contents

1. Introduction

For the last twenty years, a number of European fire service organisations have tried to make upholstered furniture and mattresses in residential properties more fire safe. As of today, these efforts have not led to the desired results. One of the fundamental reasons is the fragmentation of the furniture market, hence the reason for the lack of pledges to make furniture more fire safe. Secondly, manufacturers and suppliers state that switching to fire safe furniture could lead to a distortion of competition. In addition, consumer pressure has not produced a discernible demand for fire safe furniture. Finally there is the continuing debate on the usage of flame retardants in furniture. There has been much discussion by fire services, environmentalists, manufacturers and other stakeholders about the effects of flame retardants on the environment and health. Even though sufficient safe alternatives are available, negative associations between flame retardants and furniture are still being made.

1.1 What is fire safe furniture?

First we need to address the term “fire safe”. What does it mean? In the FEU-working group the task has been to look at how we could test furniture to make them more fire safe and increase the survivability in the domestic area.

During our meetings we discussed what fire safe furniture meant. Many in the group thought that it was furniture that could withstand different types of ignition sources for a longer period of time. We then discussed whether it was achievable to make furniture safer in terms of not contributing to the fire load in the room (i.e. that the furniture could withstand a fire if being affected by other burning objects in the same room). After many discussions it seemed to be unrealistic to test furniture using the criteria that it should not contribute to the total fire load. This is because it would mean using several types of full scale testing. This would be a large step for furniture manufacturers who today do not have any, or in some case less stringent, fire regulations to respond to.

During our second meeting, it was agreed that the most achievable goal would be to have a recommendation about (existing) test methods that look at different types of ignition sources. In chapter 5 it can be seen that there are many different standards for testing furniture. Some tests are difficult to manage because the different sources of ignition applied to the furniture vary in heat output. In other words, it means that the fire safety (regarding ignition sources) can also vary depending on the test carried out. Also, the type of ignition source does not say anything about the flaming behaviour of the furniture. Testing with a specified ignition source only means that the furniture can withstand that particular ignition source. If a larger ignition source is used the furniture can ignite and contribute to the fire load in the room. What we as the FEU aim at is making furniture’s more fire safe in the terms of making ignition more difficult. This will lead to a prolonged time for evacuation. For example, if a fire starts the furniture could have a high heat release rate even if it has been tested to withstand a match flame test. So in this case the chance for survivability increases if the fire does not start at all, or if the ignition time is prolonged/delayed so people in the building have a longer time to be alerted that a fire is about to start.

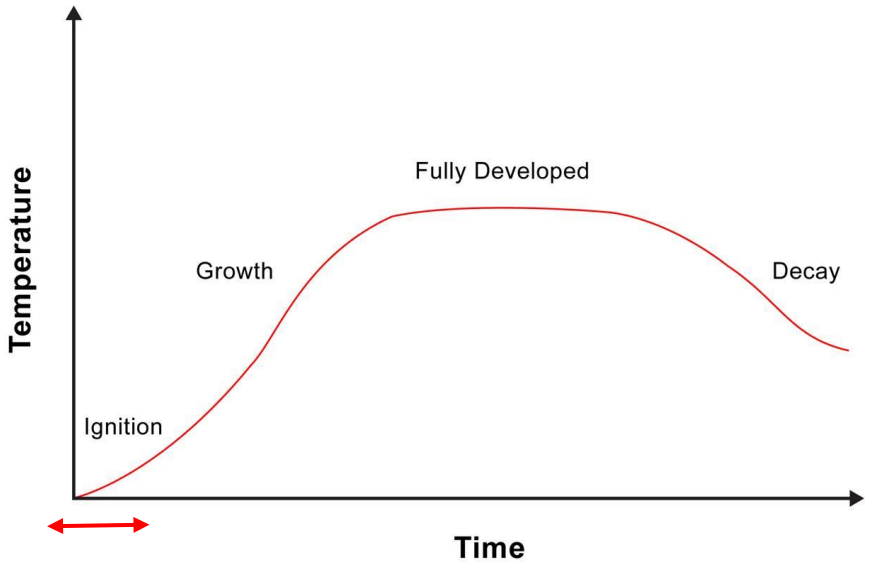

Figure 1 Stages of a fire

Figure 1 shows a simple explanation of the different fire stages. What the working group wants to achieve is to prolong or avoid the ignition (the red arrow in the picture).

So when we speak of fire safe furniture it does not simply mean that the furniture will not burn and then contribute to the fire load in the room. It means that the furniture can withstand a specific ignition source for a specified period of time.

1.2 European legislation

Since the 80's the United Kingdom (UK) and Ireland have implemented legislation on the flammability of upholstered furniture and mattresses. Similar legislation and demands have been made by other European countries on a small scale. Most of this legislation focuses on furniture and mattresses in non-domestic buildings.

Research on this legislation (see table below) revealed that several countries have requirements on the fire safety of furniture (and mattresses) in public buildings. In addition to the UK and Ireland, Germany, France, Portugal, Spain, Italy, Norway, Sweden and Finland have also set requirements. In some cases these demands applied to all public buildings. In other instances they applied only to a limited set of buildings, for example buildings with a healthcare function, prisons, theatres, hotels and restaurants. In addition to the UK and Ireland, only Finland and Norway have set requirements on the fire safety of furniture (and mattresses) in private homes. Sweden employs a recommendation regime.

Table 1 Summary of European Regulations for furniture in buildings [2]

Country	Type of building	Item
United Kingdom	Domestic	Seats, mattresses covering, padding
	Public	Seats, mattresses
Ireland	Domestic	Seats, mattresses covering, padding
	Public	Seats, mattresses
Italy	Public	Seats, mattresses
Germany	Public	Seats
Finland	Domestic	Seats, mattresses
	Public (recommendations)	Seats, mattresses
Sweden (recommendations)	All	Seats, mattresses
	Public (health-care institutions)	Mattresses
	Public (in high-risk institutions)	Mattresses
	Public (restaurants, hotels, boarding homes etc.)	Seats, mattresses
Norway	All	Seats, mattresses
France	Health care	Mattresses
	Public	Seats
	Prisons	Mattresses
Spain	Health care	Mattresses
	Public	Seats
	Prisons	Mattresses
Portugal	Health care	Mattresses
	Public	Seats
	Prisons	Mattresses
Belgium	Elderly homes	Seats
Poland	Public places	Seats

1.3 First mover

In recent years, the Netherlands Fire Service and the Dutch Fire Service Academy tried to reaffirm to a major international manufacturer the dangers and consequences of combustible furniture and remind them of their social responsibility towards their client base. This major international manufacturer is being considered as a 'first mover'. Consequently, the first mover will pressure other factions in the industry to follow their example. This method has been used before in similar cases and appears to be working.

In February 2014, the first mover started to put things into action and subsequently promised to deliver a method of approach to make their upholstered furniture more fire safe. In early September 2015, they presented their plan to the Netherlands Fire Service. Due to competitive reasons, the first mover asked the Dutch Fire Service Academy not to publish too many details. However, in essence the first mover aims to make upholstered furniture more fire safe by using so called interliners. In using this method, the polyurethane fillings do not have to be impregnated with potentially hazardous flame retardants.

Furthermore, the first mover is also developing new materials that are less flammable and produce a reduced amount of smoke. They are aiming to increase the survivability when a domestic fire occurs. The first mover has asked the FEU to advise them on which test methods to use to measure the

effects of their new, and more fire safe, line of upholstered furniture. This has been deemed necessary due to the worldwide lack of regulation regarding the fire safety of upholstered furniture without the usage of flame retardants. The first mover asked the Netherlands Fire Service to advise them on how to show a relationship between on the one hand fire development, smoke spread and survivability in practice and on the other hand test methods for furniture. The Netherlands Fire Service subsequently asked the FEU to support this research. The FEU has agreed to cooperate with the condition that the opinion of the working group will be recorded in a public report so that it is accessible to everyone. The assignment that the FEU has given to the working group is as follows:

The assignment from the FEU for the working group states:

Define and determine a set of (existing or modified) testing methods, which fire departments throughout Europe deem necessary in order to increase survivability and escape capabilities during domestic fires. The test methods have to be widely applicable to upholstered furniture, regardless of the material, and should serve as input towards manufacturers, suppliers and (legal) regulations and standards.

1.4 Fire safety is more than fire safe upholstered furniture

It is important to note that fire safety in homes does not just rely on fire safe furniture. Fire safety is always the result of several measures in combination with fire-safe behaviour by the residents. The basis for fire protection in homes is formed by the behaviours of the residents to prevent fire as far as possible. If, however, fire breaks out, it should be detected as quickly as possible by smoke detectors followed by appropriate escape behaviours of the residents. To enable this escape, the contents of houses should be such that it does not contribute to the rapid development of fire and smoke. To assist this, the interior doors of homes should be closed where possible when the residents are sleeping. Upholstered furniture and mattresses could ignite quickly and contribute to rapid spread of fire and smoke. Fire safe furniture therefore is an important parameter to the fire safety in homes, but it is not the only solution for fire safety problems in homes.

The aging population in Europe also has negative consequences for the fire safety as the elderly and vulnerable are more likely to be the victims of fire. Often fires in homes of the elderly occur close to the body. The flammability of upholstered furniture and mattresses is clearly a significant contribution to this. So here too, fire safe furniture makes an important contribution to the safety of the elderly and vulnerable.

2 Assignment and research method

2.1 Working group

As stated in the introduction, the FEU has promised to produce a public report to answer the question of which test methods furniture in the domestic environment must meet in case the furniture is involved in a fire. The purpose is to improve survivability and escape possibilities in the property or to extend the time to ignition. The report will be a public accessible report to allow every producer, supplier, standardisation institute, government or other stakeholder to use standardised methods.

After the FEU had given the assignment to Rene Hagen (Netherlands Fire Service Academy) and Eugène van Mierlo (Netherlands Fire Service), they put together a working group of experts in the field of fire safety, firefighting, fire investigation and fire testing. The members of the working group were put forward by members of the FEU. The working group consists of the following members:

- René Hagen, Netherlands (project leader)
- Margo Karemaker, Netherlands (project secretary)
- Eugène van Mierlo, Netherlands
- Daniel Maloziec, Poland
- Pasi Paloluoma, Finland
- Javier Elorza, Spain
- Ida Larsson, Sweden
- Anton Hörnqvist, Sweden
- Damian Watts, United Kingdom
- Dieter Brants, Belgium
- Lieuwe de Witte, Netherlands
- Mike Hagen, European Fire Safety Alliance (advisor)

Gerard van Klaveren, a Dutch member of the FEU, acted as delegated client on behalf of the FEU. The project leader was required to report the progress of the project periodically to the (delegated) client.

Exchange of Experts
The initial work plan of the working group included two week long key meetings and remote collaboration via email and Dropbox. A request was submitted to the European Union within the framework of the 'Exchange of Experts programme' to fund the travel, accommodation and subsistence of the participants for the two central consultation weeks and this was subsequently granted. An additional half week meeting was found to be necessary to complete the work and this was also funded by the 'Exchange of Experts programme'.

2.2 Method working group

Preparatory research
In preparation, the project leader drew up a memorandum and a program for the first meeting of the working group. In further preparation for the assignment of the working group, the project leader

and project secretary conducted research on the current requirements and associated test methods for the degree of ignitability in upholstered furniture in the private environments in the UK and California. Both of these countries have extensive experience with reducing the ignitability of upholstered furniture via legislation. Until recently, it was only possible to meet the said legislation by the use of flame retardants in the covering fabric and polyurethane filling of upholstered furniture. As a result of the growing concern of the effect of these flame retardants on the environment and health, the development of alternatives to make upholstered furniture more fire safe has become more prominent. In California the requirements and corresponding test methods have recently been revised. In the UK the requirements and testing methods have been consulted on with a view to these being revised. This research has multiple objectives. Firstly, it aims to acquire an outline of statutory requirements and testing methods regarding upholstered furniture, as applied in California and the UK. Secondly, this research aims to answer the question of why the usage of flame retardants is now subject to change. Altogether the research aims to answer the questions formulated below:

- What are the current regulations and test methods concerning the fire safety of furniture in the UK and California?
- On what requirements is the new legislation in UK and USA based?
- Which test methods are being used to reduce or remove fire retardants in the UK and California?
- What are the expected fire safety results of the revised legislations in the UK and California?

Following this research, the working group further examined these test methods. The results can be found in sections 3.3 and 3.4 below.

First meeting

The first meeting of the working group took place from May 30th to June 4th 2016 in Arnhem (The Netherlands). In that week the following items were discussed:

- The expectations and desired results of the whole project in general and in particular of that week.
- Explanation and discussion of the starting document "Developments in test methods relating to the fire safety of upholstered furniture in the US and the UK"
- Discussion between the working group and experts in the field of fire safe furniture:
  - Industry Association of upholstered furniture fabrics (Modint)
  - Producer and supplier of upholstered furniture (Doelbeek)
  - European Flame Retardant Association (EFRA)
- Discussion between the working group and experts in the field of standards and regulations in the field of fire safe furniture and mattresses:
  - Netherlands Ministry of Health
  - Dutch Standardization Organisation
  - Netherlands Food and Consumer Product Safety Authority
- Discussion between the working group and experts in the field of fire development in dwellings:
  - European Fire Safety Platform
  - Technical University of Eindhoven (Netherlands)
  - Netherlands Fire Service Academy

    - Efectis Netherlands
- Making the connection between fire development in dwellings and test methods for upholstered furniture and mattresses.
- Conclusions on the results of this week and making working arrangements (homework) to prepare for the second week.

After the first meeting

At the end of the first meeting, a number of different areas were formulated in which the working group had to delve into more detail before being able to go deeper into the test methods themselves. These areas are elaborated in Chapter 3 of this report. To make progress in the project, these work areas were spread out over a number of group members and the results, along with the results of the first meeting, were processed by the project leader in a first draft of the final report. This draft formed the input for the second meeting of the working group.

A Dropbox account was created to organize and share information and research contributions by the working group members throughout the process.

On 8th of September 2016, working group member Brants attended a meeting in Brussels. A "policy paper" about flame retardant free furniture was presented in the offices of the European Furniture Industries Confederation (EFIC) in Brussels. The content and vision of the paper was given by Markus Wiesner, EFIC, and Dr. Arlene Blum, executive director of the Green Science Policy Institute. This document was signed by the following organisations:

- The Cancer Prevention and Education Society
- European Environmental Bureau
- European Environmental Citizens Organisation for Standardisation
- Zero Waste Europe
- European Furniture Industries Confederation
- European Bedding Industries Association

The signatories of this policy paper share and stress the same concerns about the implications of the presence of harmful flame retardants chemicals in furniture products. The most important opinion in the paper is that an EU action in favour of flame retardant free furniture is necessary to ensure protection of human health and the environment, and to promote competition and fire safety.

On October 4, 2016, working group member Larsson had a meeting with representatives from EFIC in Trondheim, Norway. The purpose of the meeting was to introduce each organisation and their views of fire safe furniture. Also possibly project ideas for the future were discussed. Working group member Brants had another meeting with EFIC on February 7, 2017, explaining the point of view of the working group concerning the recommended test methods. EFIC was invited for the third meeting of the working group, but they were not able to attend. They sent the working group a letter with their point of view. The working group discussed this letter and sent EFIC a reply.

On September 20, 2016, the project leader and project secretary had a further consultation with Efectis Netherlands to further discuss a number of proposals for testing methods, which Efectis presented during the first meeting of the working group and upon which the group had not yet taken decisions on.

Between the first and the second meeting of the working group, the project leader, the project secretary and working group member Van Mierlo had a number of consultations with the 'first mover'. This was to obtain as much input as possible from the producer on the possibilities and feasibility of the test methods to be determined by the working group.

The second meeting

The second meeting of the working group took place from 18th to 21st October 2016 in Bilbao (Spain). In that week the following items were discussed:

- Results of the meeting with FEU and the first mover.
- Draft version 004 of the report.
- Which statistics and data the working group needed.
- The consultation on the revised UK regulations
- The considerations for the recommended test methods
- The connection between the test methods and the survivability together with escape conditions in dwellings.

At the end of the second week, the working group had a draft agreement on the required test methods. They also concluded that there were still items to be agreed on before a final recommendation could be made. Therefore a third (half) week meeting was thought to be necessary.

After the second meeting

After the second meeting, the draft version 005 of the report was compiled by some working group members. The other working group members collected the necessary data.

On November 28 and 29 the Dutch Fire Service Academy tested, also in the name of the working group, the fire behaviour of several benches and mattresses provided by the first mover. During those tests, the focus was on the ability to withstand several ignition sources and measuring different factors that contribute to the survivability while in a room where there is a fire. The results of this report are published[1].

The third meeting

The third meeting of the working group took place from 28th February to 3th March 2017 in Eastleigh (United Kingdom). In that week the following items were discussed:

- Results of the meeting with FEU and the progress of the first mover
- Draft version 005 of the report
- The steps to be taken after the report is finished
- The results of the tests carried out on November 28 and 29, 2016
- The letter sent by EFIC outlining their position.

At the end of the third week, the working group had a draft agreement on the test methods and the final recommendations. After the third meeting the statistics were completed and the final report was completed.

[1] This report is published on www.brandweeracademie.nl

2.3 Feedback

Throughout the project, the project leader regularly gave feedback to the delegated client on behalf of the FEU (Gerard van Klaveren) and the president of the FEU. On the 1st July 2016, working group member Elorza gave a brief explanation of the progress of the project during the FEU meeting in Barcelona. On 13th October 2016, the project leader and working group member van Mierlo gave an extensive explanation of the progress of the project during the FEU meeting in Budapest.

The FEU was satisfied with the progress the working group had made so far. After the meeting the following aspects were discussed and agreed:

- The next draft version of the report to be placed on the private website of the FEU.
- At the next meeting of FEU the project leader will present a plan on how to disseminate the final report and the recommendations.

3 General considerations

3.1 Introduction

Before focusing on the test methods, the working group first discussed a number of considerations on which an opinion needed to be formed. Firstly, this concerned the need to improve the fire safety of upholstered furniture and mattresses. Despite the FEU having already recognised the need for this study to look at test methods, the working group found it necessary to once again clarify the need of fire safe furniture by using fire statistics.

Some countries already have regulations for the ignitability of upholstered furniture and mattresses and have established test methods. The best known are the Californian standard (TB 117) and the UK Furniture and Furnishings (Fire Safety) Regulations (FFRs). The Californian standard has recently been revised and the UK regulations have been consulted on with a view to change. The working group first studied the backgrounds of these two schemes, both in the 'old' and 'new' rules. The working group focused on the reasons why these test methods had been changed and the effects these changes have on fire safety if any.

Despite stating in the assignment that the test methods should be solution independent, meaning that any test could be passed with or without fire retardants, the working group cannot ignore the ongoing public debate on the alleged health and environmental risks of flame retardants. However, it is not for the working group to take a position with regard to flame retardants. This is a debate that is ongoing with stakeholders such as governments and industry.

Choosing test methods should be independent of the construction and composition of the actual furniture. Furniture using flame retardants or furniture using other technical solutions should pass the same fire requirements. The working group has studied some new innovative alternative solutions available on the market. These new solutions are more focused on physical/technical applications rather than chemical applications. Chemical application impacts lie mainly on influencing the combustion process, while physical/technical applications focus on reduction of temperature, shielding pyrolysis gasses from oxygen or the production of non-combustible gasses.

3.2 Why fire safe furniture

In Sweden approximately 100 people die every year due to fire. The majority of fire deaths happen in the domestic area, around 90 percent [3]. The trend that the majority of fire deaths occur in the domestic area is also something that applies to, for example, the Netherlands, Finland and the UK. In the domestic area there are a lot of combustible materials such as sofas, beds and armchairs which are all contributing to the total fire load in the apartment or the house. Statistics from each country show a lot of fires start in some type of upholstered furniture such as sofas and beds (see chapter 4 Statistics). Some common ignition sources for upholstered furniture can be cigarettes, matches, candles or overheated computers. For example, where the ignition source was either a cigarette or open flame starting on a bed/sofa, there were 251 fire deaths between 1999-2014 in Sweden (from a total 1358 fire deaths in the domestic area during this time period). These statistics could in reality be even higher as in almost 45 percent of the total cases the cause was unknown. In this section,

Sweden is taken as an example but these numbers appear to apply to the vast majority of European countries. For more examples see chapter 4: Statistics.

According to statistics some groups of people are more likely to being killed in a fire in the domestic area. When the population is being divided into different age categories a trend is clear. People aged 65 or older are more likely to be killed by a fire in the domestic area. Statistics show that over the last ten years people aged over 80 years old have been overrepresented in fire deaths [4]. In 2015, 57 percent of all fatal fires affected people aged over 65 in Sweden. This also applies to other European countries. For example, in England between 2014 and 2015, 49 percent [5] of all fire fatalities were people over the age of 65, and in the Netherlands between 2001 and 2015, 38 percent were people over the age of 65. According to the People Safety Authority (Folkhälsomyndigheten), the average age of the population in Sweden is increasing. By 2050 25 percent of the population will be over the age of 65. This is a trend that applies to many other European countries. If the age related fatality statistics continue as described, this means that fire deaths might increase in the future.

If we look at why we need more fire safe furniture from a strictly socioeconomic perspective; a cost-benefit analysis made by the Swedish Civil Contingencies Agency (MSB) shows that a longer time to ignition saves money. If, for example, a sofa could withstand a match or a cigarette ignition for five minutes this could mean large cost-savings for the general population regarding injuries and property damages. The analysis shows that five minutes of prolonged ignition, provides the rescue service with five minutes extra attack on the fire, on average saves the general population 13.800€ [6] per fire. There is also estimation about cost savings from introducing the FFRs regulations in the UK, these savings are valued at around £140 million per year [7].

Many European countries do not have any regulations regarding how upholstered furniture should be tested to make them safer from a fire perspective. In 1988, regulations were introduced in the UK to make upholstered furniture more fire safe. Statistics shows that from 1988 to2011, the number of fire deaths has decreased with an almost 53 percent reduction in the domestic area [8]. This is probably due to many different factors such as people smoking less, being better trained and aware of fire risks and that smoke alarms and fire extinguishers are relatively cheap and easy to install in the domestic area. However, in a statistical analysis that investigates the effects of the Furniture and Furnishings Regulations, the key findings about the effects of the regulations concludes that there fewer deaths, fewer casualties and fewer fires each year [7].

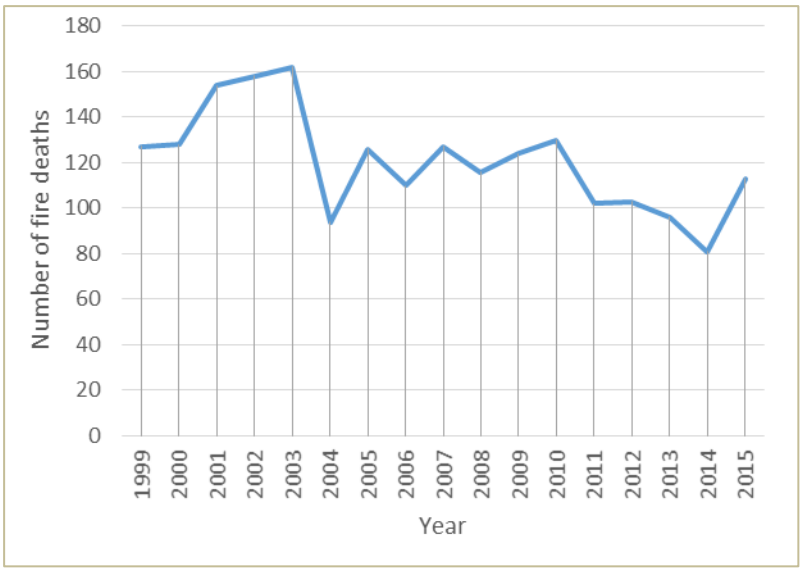

Figure 2 Number of fire deaths in Sweden 1999-2014

Figure 2 shows number of fire deaths in Sweden during the period 1999-2014. During the same period of time the UK saw a decrease of 28 percent in the number of people being killed in fires. Comparing numbers of fire deaths between the countries shows that approximately 4-8 people per million inhabitants in England are killed by a fire compared with Sweden where approximately 10 people per million inhabitants are being killed. There are however differences between Sweden and the UK both culturally and in the use of building materials, so before more conclusions could be drawn from this comparison, more data should be taken into account. The fact that fire deaths have decreased more rapidly in the UK is interesting and also supports the analysis that the FFRs have had an impact to decrease the numbers of fire deaths.

To summarise, there is an ageing population in many countries in Europe. Older people are more likely to be killed in domestic fires, which mean that the numbers of people killed in fires might increase in the future. Approximately 90 percent of all fire deaths occur in the domestic area. This means that we have to make this area more fire safe. Many of the fires which result in fire deaths in the domestic area start in the sofa or bed by a small ignition source according to statistics from different European countries (see chapter 4 Statistics).

To achieve a more fire safe home environment we need to keep working on education, home visits and other activities to make people more aware. This is the first step to avoid fire and making people more prepared to act in case of a fire. Step 2 should be to minimise the risk of a fire occurring. One way to achieve this could be to avoid or prolong the time to ignition. This could be achieved by making upholstered furniture more resistant to different ignition sources. This will hopefully lead to increased survivability, especially in cases where ignition is being avoided. In other cases where ignition still happens, there might be a longer time to ignition, which means a longer time to be aware of the danger and thereby an increased chance of survivability.

3.3 The UK regulations

3.3.1 Background

The UK is the country in Europe with the most extensive regulation for upholstered furniture and mattresses. The Furniture and Furnishings (Fire Safety) Regulations 1988(FFRs) (as amended in 1989, 1993 and 2010) set levels of fire resistance for domestic upholstered furniture, furnishings and other products containing upholstery. The FFRs were introduced in 1988 after seeing that the number of domestic fires and deaths in the UK had increased in the 1960s and 1970s. A large proportion of these fires involved furniture with foam fillings. The foam had replaced natural fire-resistant materials such as horse hair which also provided cheap furniture that everyone could afford. The introduction of the FFRs strengthened the existing requirements for making cover fabrics resistant to ignition and introduced a new flammability requirement for foam fillings [7] [9].
If comparing the time period (1981-85) before the FFRs were introduced with the period 2002-07, the numbers of fires, casualties and deaths have decreased significantly as opposed to other types of fire, see table 2. Even though the frequency and lethality of furniture and furnishings fires fell after 1988, they are still more lethal than other fires, with matches/cigarettes remain the main source of ignition. A number of ignitions sources are also more common than before, e.g. lighters, suggesting that some risk factors are rising rather than falling [7].

Table 2 Change between 1981-85 and 2002-07 in number of furniture and furnishings fires and other fires [7]

Change between 1981-85 and 2002-07 in number of:	Furniture and furnishings fires	Other fires
Fires	-37%	-10%
Non-fatal casualties	-26%	+75%
Deaths	-64%	-44%

3.3.2 Arguments for reviewing the UK regulations

The effectiveness of the FFRs in reducing the number of fires in upholstered furniture is well documented since their introduction in 1988. Due to the success, very little research has been done in identifying weak elements in the FFRs. The fact is though that the FFRs are almost 40 years old and the UK government Department of Business Innovation and Skill (BIS) has therefore been reviewing the FFRs on the basis that they are still fit for purpose but need updating. However, in recent years the general concern regarding use of chemical flame retardants has increased. Actual, potential and alleged negative effects on the health and environment, especially from bromide flame retardants, have been reported and BIS therefore wants to update the FFRs to encourage the reduction in usage of flame retardants. The FFRs do not actually stipulate use of flame retardants in upholstered furniture but in practice this is the most cost-effective way for manufacturers to fulfil the test requirements. BIS considers the flame retardants used in foam fillings benign so they have focused their work on reducing flame retardants use in the cover fabrics [9].

Other arguments for reviewing the UK regulations are cost savings for the manufacturers, including currently unregulated materials, correcting unforeseen failures in the current match test, preventing final products from being less fire safe than consumers think they are and improving regulation. [10].

3.3.3 The current UK regulations

For domestic environments all items of upholstered furniture should meet "The Furniture and Furnishings (Fire Safety) Regulations 1988" as amended in 1989, 1993 and 2010. The regulations are divided into five sections (Schedule 1-5) for fire testing, see Table 3, but the regulations also have additional sections (Schedule 6-8) dealing with labelling. For each type of filling the regulations refer to a specific test method and an ignition source. In some cases, the FFRs have other requirements over and above those given in the specific standards. One example is the test of polyurethane foam according to Schedule 1, Part 1. This schedule refers to testing with ignition source 5 (crib 5) according to standard BS 5852:Part 2. In the standard requirements it is not allowed to smoulder or burn through the full thickness or to the extremities of the test specimen. However, in the FFRs this requirement can be ignored provided that the resultant mass loss is less than 60g.

Table 3. Contents of The Furniture and Furnishings (Fire) (Safety) Regulations 1988" with amendments. Note that the tests are performed according to the specified standard but with the modifications and criteria given in the regulations.

SECTION	COMPONENT	TEST METHOD/STANDARD
Schedule 1, Part I	Polyurethane foam – slab or cushion form	BS 5852:Part 2, Ignition source 5
Schedule 1, Part II	Polyurethane foam in crumb form	BS 5852:Part 2, Ignition source 2
Schedule 1, Part III	Latex Rubber form	BS 5852:Part 2, Ignition source 2
Schedule 2, Part I	Ignitability test for non-foam filling materials singly	BS 5852:Part 2, Ignition source 2
Schedule 2, Part II	Ignitability test for composite fillings for furniture other than mattresses, bed bases, cushions and pillows	BS 5852:Part 2, Ignition source 2
Schedule 2, Part III	Composite test for ignitability of pillows and cushions with primary covers	BS 5852:Part 2, Ignition source 2
Schedule 2, Part IV	Composite test for ignitability of pillows and cushions with primary covers	BS 6807, Ignition source 2
Schedule 3	Ignition resistance test for interliner	BS 5852:Part 2, Ignition source 5
Schedule 4, Part 1	Cigarette test applied to upholstery composites	BS 5852:Part 1, Ignition source 0 (smouldering cigarette)
Schedule 4, Part II	Cigarette test applied to "invisible covers", such as covers underneath cushions etc.	BS 5852:Part 1, Ignition source 0 (smouldering cigarette)
Schedule 5, Part I	Match test applied to all visible covers	BS 5852:Part 1, Ignition source 1 (match flame equivalent)
Schedule 5, Part II	Match test for stretch covers	BS 5852:Part 1, Ignition source 1 (match flame equivalent)
Schedule 5, Part III	Match test for invisible parts of covers	BS 5852:Part 1, Ignition source 1 (match flame equivalent)

The test methods in table 3 are BS 5852-1, BS 5852-2 and BS 6807.

BS 5852-1 uses a cigarette (source 0) and a match flame equivalent (source 1) as ignition sources. The tests are performed in a test cabinet with a calibrated air flow. The cover fabric and the filling are put in a test rig to create a small sofa with a 90º angle between seat and back, see Figure 3. The ignition

sources are located in the junction between seat and back. Note that the small gas flame is not located in the test position in Figure 3.

During the cigarette test, the test assembly is not allowed to smoulder or show flaming ignition within one hour from the beginning of the test. The same smoulder requirement also applies to the match flame test where the test assembly is subjected to a small gas flame for 20 seconds. An additional requirement is that no flaming is allowed to continue for more than 120 seconds after removal of the burner tube.

Figure 3 Test setup according to BS5852-1

Tests according to BS 5852-2 are performed in a similar way as for BS 5852-1 but the test rig and the ignition sources (sources 2-7) is larger, see Figure 4.

Figure 4 Test set-up for testing according to BS5852-2

The photo in Figure 4 also shows examples of ignition sources used for BS 5852-2 testing. Ignition source 7, 5 and 2 can be seen from the left to right. Tests according to BS 6807:1986 are performed on mattresses. The tests can be performed either in full scale or in small scale. For a full scale test a mattress with scale 1:1 is required. For a small scale test, the test specimen shall be rectangular in shape and of minimum size 450 mm x 350 mm x nominal thickness of the finished mattress, see Figure 5. The ignition sources used are the same as in BS 5852:Part 2; either larger gas flames or wooden cribs (Source 2-7). The test specimen is located on top of a steel rig. Depending on the finish of the mattress, ignition sources are located on the flat surface, at taped edges, at quilted locations, tufts etc.

Figure 5 Test set-up according to BS6807

The test specimen is located on top of a steel rig. Note that the ignition sources (2-7) shown in Figure 4 can also be used during testing. The test requirements for tests according to BS 5852:Part 2 and BS 6807 include criteria on smouldering ignition, flaming ignition and combustion behaviour but differ with type of ignition source. Some of the standard requirements are also overruled by additional regiments stated in the FFRs.

3.3.4 Proposed changes of the FFRs

The proposed changes to the FFRs were first presented in 2014 and will modify Schedule 4 and Schedule 5, which both refer to testing according to BS 5852-1. The remaining schedules are unaffected.

Changes in Schedule 4 (cigarette test)

The main change to Schedule 4, Part I is that cigarette resistance is assumed for match resistant covers (tested according to Schedule 5) and therefore does not need to be tested by the cigarette test. The reason for dropping the cigarette requirements is because laboratories have reported that historically match resistant covers do not fail the cigarette test. For covers used with Schedule 3 interliners the cigarette test must still be performed [10].

Another proposed change in Schedule 4, Part II is that non-visible covers in upholstery composites no longer require cigarette resistance testing.

The benefit of the proposed changes would primarily be less testing, and thereby savings costs for the manufacturers.

Changes in Schedule 5 (match flame test)

The purpose of the match test of visible covers in Schedule 1, Part 1 is that the fabric should resist ignition by two mechanisms; by being ignition resistant and to protect the materials underneath.

In the current FFRs, visible covers are tested in combination with non-fire retardant polyurethane foam corresponding to the specification set in BS 3379: Type B Harness grade 130 N and a density of 20-22 kg/m^3. In the 2014 proposal the non-FR treated PU foam has been replaced and the visible cover is tested in combination with two types of fillings:

Filling 1 consists of combustion modified foam that shall comply with Schedule 1, Part 1 in the FFRs. The foam has a density of 24-26 kg/m^3 and a hardness of 115-150 N when determined using B 3379.

Filling 2 consists of polyester fibre wadding, covering combustion modified foam 24-26 kg/m^3 (filling 1). The polyester wadding has an area weight of 200 g/m^2 and shall be compliant with Schedule 2 Part 1 in FFRs. The wadding shall not be treated with flame retardants and have a thickness of 20 ± 5 mm.

A cover that meets the requirements when tested with filling 2 does not require testing with filling 1. It is assumed that the cover also meets the requirements with filling 1. A cover fabric that fails a test with filling 2 could be tested with filling 1 instead. If passing this test, the fabric can be used but in the actual furniture the cover must then be used directly over the foam and no wadding layers between is allowed. Stretch covers are only tested with filling 1 [10].

The reasons for changing the non-fire retardant polyurethane foam to combustion modified foam (filling 1) are several. One argument that has been stated since the FFRs were introduced is that the highly flammable non-fire retardant polyurethane foam currently used is illegal to use in actual furniture (the foam would not pass Schedule 1, Part 1) and it is therefore not relevant to include this during testing. The filling 1 foam is also already specified in the FFRs and is being used when performing the match test for stretch covers and invisible covers. Further, the current test does not take into account on the fact that combustion modified foam present in the actual product reduces ignitability of the cover fabric. Cover fabrics may therefore have higher ignition resistance than necessary (and more chemicals) when tested with highly flammable non-fire retardant polyurethane foam [10] [11].

The reason for including a polyester wadding layer during testing is that most modern furniture today uses some type of wadding layer to give a smoother appearance and increase comfort of the furniture. The wadding layer changes the distribution of the vapour phase element of the foam flame retardants and allows them to flow behind the cover, which is beneficial for preventing combustion. The wadding layer can consist of many different materials but polyester is considered to be a worst case scenario.

Another change in Schedule 5 is that current unregulated materials within 40 mm of the surface will also be tested with a modified version of the match test [10].

3.3.5 The-working group opinion

The FFRs provide ignitability/flammability requirements for all UK furniture used in domestic homes. The FFRs are successful in preventing injury and loss of life [7] and exceeds the requirements set for the rest of the EU-market. However, the FFRs are now subject to proposed changes, which are being commented on by the working group.

The current match test under the FFRs requires cover fabrics to be tested over highly flammable polyurethane foam. However, this foam would not pass the FFRs filling test and is therefore forbidden on the UK market (but not in the rest of Europe). The match test according to European standard EN 1021-2 requires cover fabrics to be tested with the same foam that is used in the final product. The Department for Business, Innovation & Skills (BIS) claims though that the combustion modified foam in the 2014 BIS proposal for the FFRs are used in EU products [11]. In our experience, this is not always accurate. Products can contain combustion modified foams but in the experience of SP Fire Research, it is common that final products have foam that has not been combustion modified. The density of the foam is usually higher than 20-22 kg/m^3, but the foam does not have to be combustion modified. Testing fabrics in combination with non-fire retardant polyurethane foam may therefore still be accurate for the rest of the EU-market. If considering the concern in UK that furniture is usually constructed with a sheet of thermoplastic fibre between cover fabric and foam, which is not tested in the current FFRs [10], this could be addressed by performing tests on fabrics with filling 1 according to the IKEA specification (non-fire retardant foam 20-22 kg/m^3, covered with 200 g/m^2 of non-fire retardant polyester wadding). However, this is only of interest for cover fabric manufacturers who want to see the potential fire performance of their fabric. The composition of the final product should still be tested as in EN 1021-2.

The elimination of the cigarette test for combinations that have passed the match test will most likely not reduce the fire safety. It is also the experience of SP Fire Research that most furniture passing the match test will also pass the less stringent cigarette test. However, there have been exceptions, especially for combinations using non-flame retardant foams, but since these foams are forbidden in the UK the chance of this happening is even smaller. The reduction in smoulder intensity of Reduced Ignition Propensity (RIP) cigarettes is also an argument that is used in supporting the elimination of the cigarette test. This argument is opposed by the working group though. The effectiveness of these cigarettes are highly debated and there are other reports saying that the cigarettes do not have the same performance in reality [12] [13].

The 2014 FFRs proposal is focusing on the problems with the current Schedule 5, Part 1 match test. The modifications are supposed to reduce the use of chemicals that appear in cover fabrics, especially brominated flame retardants. No focus seems to be on reducing flame retardants in foams. In a consultation report, it is claimed that most foam fillings are considered benign compared to those that appear in cover fabrics [9]. No reference is given to this statement and the working group questions if this is accurate? Is it typical non-halogenated melamine flame retardants they refer to? Many combustion modified foams used in Europe can contain considerable amounts of melamine flame retardants, probably larger amounts than used in fabrics. Even though this flame retardant is

considered benign compared to others, it was for example melamine that caused the Chinese milk scandal in 2008 with 300,000 victims in total [14].

The 2014 proposals on changes to the FFRs testing regime will not been implemented. The proposal has been circulated to approximately 500 stakeholders and the responses received have not been that positive. Only 18 percent of the stakeholders thought the proposal would make UK furniture greener. There was a concern that manufacturers would increase their use of flame retardant chemicals to ensure compliance. To the question on whether the proposal will help to make UK furniture more fire safe, only 15 percent of the stakeholders agreed. Stakeholders argue that there is still extra work needed [15]. It seems that there is still an uncertainty of what is being proposed (it is not simply a matter of following the FFRs and the suggested changes) and how this will affect the market. Due to the massive criticism of the 2014 proposal, the UK government presented a new proposal in September of 2016 [15], taking into consideration some of the feedback. The 2016 FFRs proposal includes the following changes:

- **Scope:** Clarifications in the scope of what products are covered by the FFRs. Unless a product which meets the definition in the scope is specifically excluded, it will be in the scope of the 2016 FFRs. Removal of some children's products from the scope have also been suggested.
- **Test structure:** For Schedule 5, the previous proposed filling 1 is dropped. Only filling 2 (combustion modified 24-26 kg/m^3, covered with 200 g/m^2 of non-fire retardant polyester wadding) would be used when performing the match test on covers.
- **Protective covers:** A cover will be defined as "protective" if it does not form a visible hole of more than 2 mm during the match test. Protective covers can be tested either on their own or in combination with the interliner that will appear in the finished product.
- **Components close to the cover:** In the 2014 FFRs proposal, all components located within 40 mm underneath the cover had to be tested with a modified version of the match test. However, there was an exemptions list for some components. In the 2016 FFRs, the exemption list has gone. Also, if using a "protective cover" (with or without an interliner) or a Schedule 3 approved interliner, the components 40 mm underneath the fabric do not need testing.
- **Traceability and enforcement:** Manufacturers are required to compile and hold technical files for their products. Manufacturers must ensure that products carry a permanent label to enable traceability. The time for Trading Standards to carry out a prosecution is extended from 6 months to 12 months.

The 2016 FFRs was circulated for consultation last year and closed on 11 November 2016. A government response is now awaited and will be published together with the responses from the stakeholders on the website gov.uk. Following the response, a new regulation may be made and laid before Parliament but there is no decision on when this will happen as yet.

3.3.6 Conclusion

In the opinion of the working group, the current FFRs including the proposed changes in 2014 and 2016, would certainly increase the fire safety of furniture if introduced across Europe. Statistics and reports from the UK have proven that the FFRs are successful in preventing injury and loss of life. However, since some countries in Europe do not have any fire requirements at all for domestic furniture, the step to follow the UK FFRs would be substantial. This would require considerable financial and political recourse. The use of flame retardants would most likely increase at introduction but the development of new interliners and other type of technical solutions for reduced flammability would evolve over time, especially if public opinion continues to demand products without chemical flame retardants.

A first step in the progression towards the FFRs would be if every European country performed the cigarette and match flame test on their upholstered furniture and mattresses (EN 1021 and EN 597). This would increase the fire safety of furniture. To further increase safety, the goal for the industry should be to also pass a crib 5 test.

3.4 The Californian standard

3.4.1 Background

The Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (the Bureau) in California, USA, is responsible for developing standards in the form of Technical Bulletins for upholstered furniture. In October 1975, the Technical Bulletin 117 (TB 117) called "Requirements, Test Procedures and Apparatus for Testing the Flame Retardance of Filling Materials Used in Upholstered Furniture" was introduced. TB 117 was applied to all upholstered furniture sold in California, irrespective of where it has been produced. The purpose of the standard was to limit and reduce fires in upholstered furniture, which accounts for a large portion of the fire deaths and injuries every year.

In TB 117, polyurethane foam and other filling materials used in upholstered furniture, must be able to withstand exposure to a small open flame (such as a flame from candles, matches, or lighters) for 12 seconds and a smouldering cigarette test. In order to pass TB 117, manufacturers have predominately used flame retardant chemicals in the fillings and foams. In recent years the resistance against chemical flame retardants has increased. Studies have found links between exposure to chemical flame retardants in upholstered furniture and cancer, fertility issues etc. [16]. In a statement, California Governor Brown said "We must find better ways to meet fire safety standards by reducing and eliminating—wherever possible— dangerous chemicals". Also the fact that the standard was nearly 40 years old and needed an update was argued. Therefore, in June 2012 Governor Brown directed the Bureau to update the standard [17].

3.4.2 Arguments for revising TB 117

In addition to the resistance against using flame retardant chemicals in upholstered furniture, there were also several other arguments supporting the revision of the standard. The Bureau determined that the current standard did not adequately address the flammability performance of the upholstery cover fabric. In an actual fire, an upholstery cover fabric is the first item to ignite and in turn exposes the foam to a much larger flame than the small open flame testing method in TB 117. Once the upholstery cover fabric burns, the foam quickly ignites. This would make the small open flame irrelevant.

Another argument is that studies have shown that there are no significant differences between the flame retardant foams formulated to pass TB 117 and untreated foams [18] [19]. The fire behaviour of the furniture is determined more by the cover fabrics than the filling materials. Low concentration of flame retardant chemicals could actually, in some cases, increase the damage to cover fabrics from a smouldering cigarette relative to untreated foam [20] [21].

According to fire statistics, residential upholstered furniture fires have also declined significantly in the USA since the beginning of the 1980s. The reduction may be attributed to a number of consumer protection improvements such as child-resistant lighters, introduction of self-extinguishing cigarettes, candle industry's compliance with voluntary fire-safe candle standards, furniture manufacturer's compliance with voluntary upholstered furniture flammability standards, residential smoke alarms and fire sprinkler requirements [22]. Statistics also show that the reduction in civilian deaths is mainly due to reduction of fires caused by smoking materials, not fires caused by candles,

lighters and matches (see Figure 6). Therefore it is reasonable to say that open flame fires in furniture are a relatively small problem, as a primary ignition source, and therefore the small open flame test in TB 117 is irrelevant. Focus should be on the cigarette smouldering test [23].

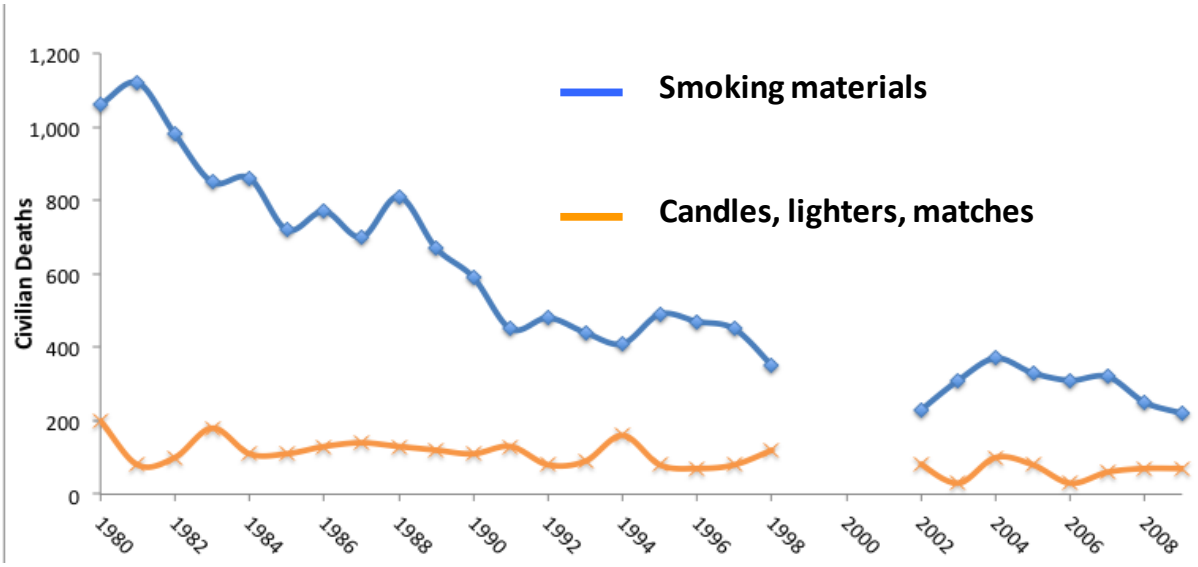

Figure 6 Home fires that began with upholstered furniture in USA

Total fire deaths from fires starting in upholstered furniture shown in Figure 6 have decreased [24]. It is also argued that flame retardant foam could increase smoulder propensity [25]. Smouldering is burning without any visible flame and it usually produces large amounts of smoke. A study conducted by the United States Department of Homeland Security, U.S. Fire Administration, concluded that smoke inhalation alone accounts for 40 percent of residential fire fatalities and is the primary source of all residential fire fatalities [22]. Eliminating the small open flame test from TB 117 would therefore reduce the need for chemical flame retardants, which would decrease smouldering/smoke production and thereby save lives.

3.4.3 The new revised TB 117-2013

On January 1 2014, the revised Technical Bulletin 117-2013 (TB 117-2013) came into effect and the new law required manufacturers to be in full mandatory compliance by January 1, 2015. In TB 117-2013, the small open flame test has been eliminated. The smouldering cigarette test remains, which is based in a large part on ASTM E-1353-08a, but with some modifications [25].

In TB 117-2013, cover fabrics, barrier (interliner) materials, resilient filling materials and decking materials are tested together with standardised foam and fabrics. The end use material combination is not in the scope of the standard. The material to be tested is mounted in a test rig together with the applicable standard material. A glowing cigarette is placed in the junction between the seat and the back in the mock-up assembly. Observations are made to establish the occurrence of any smouldering and/or flaming ignition of the materials. The length of the charring in the assembly is also measured to evaluate compliance.

Figure 7 Example of TB117 test set-up

Figure 7 shows an example of TB 117 test set-up of a filling in combination with a standard fabric. A glowing cigarette is placed in the junction between the seat and the back in the mock-up assembly.

The new TB 117-2013 standard is performance based and does not prescribe or prohibit the use of any specific materials or manufacturing methods to meet the flammability standards. Since manufacturers are no longer obliged to make their products open-flame resistant, it is believed that flame retardant chemicals will be significantly reduced or eliminated since upholstered furniture can meet the cigarette smouldering-resistance tests without adding chemicals to the filling/foam materials. It is believed that interliners and other technical solutions will be used instead to protect the foam/filling and so will pass the requirements. In addition, the revision of the cigarette smouldering-resistance tests aims to decrease the fire potential of today's primary ignition source (smoking materials).

3.4.4 FEU opinion/recommendation

In the opinion of the FEU, the fire safety requirements have been reduced in California when removing the small open flame test from TB 117. This is also an opinion shared by many other technical fire experts [26]. The resistance and fear of chemical flame retardants from the public and from health and environmental organisations would appear to override the need of fire safe furniture. Even though studies have shown that flame retardant foam does not always benefit the fire behaviour of the furniture, there are also surely cases where it does. This does not mean that the FEU promotes the use of chemical flame retardants; neither does it mean that we discourage them, at least not REACH approved flame retardants (see appendix 1).

NFPA statistics have shown that the most common primary ignition source is smoking materials and not candles, lighters, matches etc. [22]. Some therefore reason that the open flame test in TB 117 is irrelevant and focus should be on the smouldering cigarette resistance test. At the same time they are questioning the quality of the data for the NFPA statistics [24], which makes no sense. In the opinion of the FEU, both sides are using the same statistics but only present those parts supporting

their opinion. So far no statistics have been presented that show the impact on the number of fires and fire deaths due to the changed fire requirements in California.

The new cigarette test used in TB 117-2013 is based on ASTM E-1353-08a, which is a voluntary standard that has been in place since the late 1990's and is followed by approximately 80-85 percent of the U.S. manufacturers [26]. Despite this, smoking related fires are still high and the FEU is not convinced that only focusing on a smouldering cigarette resistance test is enough. The fact that the UK has done the opposite thing compared to California; i.e. eliminated the cigarette test for cover fabrics that pass a new revised open flame (match) test, supports the view of the FEU.

There has been ongoing work for the last 20 years to establish federal requirements on upholstered furniture in the U.S. The latest proposal of the standard is called 16 CFR Part 1634 and was published in March 2008. However, the finished regulation has still not been published due to disagreement. California was one part that objected to the standard since they considered 16 CFR Part 1634 to lower the fire requirements compared to TB 117 [27]. California seems to have changed their opinion about fire requirements since then in favour of reducing flame retardants.

Unlike for upholstered furniture, there are federal requirements that force all mattresses sold in the U.S. to fulfil the requirements of 16 CFR Part 1632 (smouldering cigarette test) and 16 CFR Part 1633 (open flame test). The open flame test in 16 CFR Part 1633 uses two T-shaped burners with a total burner heat output of 27 kW. This is not an ignition test but a test of burning behaviour of the mattress once it has ignited. The ignition source is considerably larger that the small open flame previously used in TB 117 and it is therefore likely that a mattress needs more chemical flame retardants, interliners etc. to be able to pass the test requirements compared to TB 117. The federal requirements, which also apply to California, therefore mean that the fire requirements on mattresses are considerably tougher than for upholstered furniture. Upholstered furniture and mattresses are both typical primary ignition sources and responsible for a large number of the fire deaths. It seems peculiar to have such high requirements on mattresses while at the same time lower the requirements for upholstered furniture.

In the opinion of the FEU, the fire requirements in TB 117-2013 are too low and we are not convinced that this would improve the fire safety and reduce the numbers of fires in Europe. Some European countries today already have a cigarette requirement for upholstered furniture and mattresses, primarily according to EN 1021-1 and EN 597-1. To introduce a California standard in Europe where adequate EN-standards for cigarette tests already exists seems pointless.

3.5 Attitudes to Flame retardants

The FEU could not ignore the ongoing debate taking place within the EU and beyond regarding the use of chemical flame retardants. Where the FEU found examples for the successful implementation of regulations for fire safe furniture such as in Ireland and the UK, the fire tests were invariably met by using combustion modified foam and flame retardant treated fabrics.

The FEU has heard the arguments for and against the use of chemical flame retardants and is neutral with regard to any particular product or technology. The sole aim of the FEU is to propose a safety standard for furniture that would save many lives.

The use of chemical flame retardants has created a polarized debate with the positon taken by the 2 'sides' described as:

1. ***Against the use of Flame Retardants***
    - *a.* Chemical flame retardants contain chemicals that are harmful to health;
    - *b.* Firefighters suffer from exposure to toxic fumes released from the combustion of materials containing flame retardants;
    - *c.* Chemical flame retardants migrate out of products and accumulate in the environment creating long term damage;
    - d. The use of chemical flame retardants in furniture impacts on competitiveness by increasing cost and reducing choice;
    - e. There are alternative fire tests not requiring chemical flame retardants that maintain fire safety;
    - f. Alternative means other than chemical flame retardants should be developed for fire safety.

2. ***Accept the use of Flame Retardants***
    - a. Less toxic chemical flame retardants are used today;
    - b. All products complying with *'Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)' are currently deemed safe to use*;
    - c. REACH is how the EU provides protection to its citizens from harmful chemicals;
    - d. Chemical flame retardants have proven to contribute significantly to fire safety when used in furniture and furnishings;
    - e. Where standards have been changed to remove chemical flame retardants these have caused an increase in fire risk such as with the revised Technical Bulletin 117-2013 (TB 117-2013) in California.

The FEU believes that technology and knowledge exists that could allow furniture manufacturers to meet the fire safety standard proposed in this report. This may be through the use of alternative technologies/techniques, flame retardants (for example REACH or ENFIRO approved see Appendix 1) or a combination of approaches provided there is a will amongst all those involved be it manufacturers, retailers or legislators.

3.6 Innovative solutions

There are several ways to make furniture fire resistant. At the present time, the most common way is the addition of flame retardants. Fortunately, we also see that innovations in the field of fire safety of furniture and mattresses take place at a high speed. We can divide the innovative methods into two categories: using barriers and using other techniques of manufacturing.

3.6.1 Other manufacturing techniques

3D woven fabrics

More and more manufacturers want to distinguish themselves by selling 3D woven fabrics. With this technique a single fabric provides a full three-dimensional reinforcement. The 3D woven fabric is a variant of the 2D weaving process, and it is an extension of a (common) technique of creating double and triple woven cloth. 3D weaving allows the production of fabrics with a considerable thickness (up to 10 cm).

Because of the structure, the fabric is less flammable. That is the reason why it is used in protective clothing (e.g. military clothes, safety vests, safety shoes, fire suits), in tents, boats and the aerospace industries. Often the fabrics are tailor-made for specific customers. Exactly because of that, the fabrics are more expensive than average. Another disadvantage is that this technique cannot simply be applied at refurbishing. It is also relatively expensive and not comfortable enough.

Fillings and composition

Chemical composition, density and addition of flame retardants in foams have a huge impact of the fire behaviour. Nowadays, almost every sofa contains polyurethane foam. However, some manufacturers are developing other types of fillings without the use of polyurethane. This is beneficiary from a fire point of view since this usually reduces the heat release rate and smoke production. One condition is that those new types of fillings do not compromise on comfort, quality and sustainability. Compared to polyurethane, the production volumes are still on a small scale. For an example, some manufacturers produce furniture with the use of down-fillings, only for an exclusive market. It is comfortable to sit on but a disadvantage is that this furniture is very expensive and hence not accessible for regular customers.

3.6.2 Barriers

Another way to improve the fire safety of upholstered furniture and mattresses is using fire barriers between the fabric and the foam. We also call them interliners. Over the years, as the fire properties of upholstered furniture and mattresses have become an increasing concern, the concept of a fire barrier interliner has emerged, to prevent an accidental surface fire from igniting the interior filling of the upholstery. Interliners can act as a thermal barrier (reducing heat transfer) and as a physical barrier (reducing transport of oxygen and volatiles). Interliners prolong the heat up and pyrolysis time for the interior filling. As an example, some manufacturers develop their barriers using a polyester layer that melts and ‘seals’ the foam in case of a fire. Also, barrier materials are often inherently non-flammable, such as polyamides like Kevlar, or glass fibres.

There are also exterior barriers, such as fire resistant covers. They may be treated with flame retardants or consist of naturally fire resistant materials such as wool. When the covers are treated with flame retardants, especially when sprayed on the cover, the effect of the flame retardant usually decreases with factors such as ageing, cleaning and UV light. Exterior barriers may affect breathability and comfort.

Interior barriers in the foam also exist, but they are difficult to add during the production process and are therefore expensive.

4. Statistics

As extra support for the recommendations in this report, the working group decided to collect statistics on fatal fires from several countries in Europe. During the first two meetings, the working group has briefly focused on the collection of statistics and decided which data we wanted to collect. Because the FEU is trying to come up with recommendations about which test methods are necessary for improving the safety of upholstered furniture, it would be important to collect data on how many fires start in furniture. Besides the starting object of the fire, it would also be interesting to collect data on the ignition source. This would be helpful in any discussion about which test methods are being recommended.

4.1 Data collection

To provide a good overview of the available data in Europe, the working group has asked several members of this working group to collect data in their own country. To make sure the data is representative for whole Europe, it was desirable to collect data from Northern-, Eastern-, Southern- and Western-Europe. The decision was made to focus on the following countries:

- Netherlands
- Sweden
- Finland
- Spain
- Italy
- Romania

The statistics we requested from the different countries were the following:

- How many fatal fires in dwellings happened between 2008-2015?
- What was the cause of fire?
- In what object started the fire?
- If the starting object is upholstered furniture or a mattress, is it possible to give an overview of the combination between the cause of fire * object where fire started?

During the collection of the data from the different countries, the problem that was encountered is that countries collect data in different ways. It turned out that some countries collect data on the numbers of fatal fires while others focus on fatalities caused by fires in dwellings which makes it different to compare the data between the different countries. Because of that reason, the collected data will be described instead of statistically analyzed.

Table 4 gives an overview of the data that has been collected in different countries across Europe. Besides data from the countries as mentioned above, Denmark also provided data. We weren't able to get the requested data from Romania and Italy. It can be seen that the data that was provided is derived from different years. Also, it should be noted that, besides Finland and Spain, all countries focus on collecting data about the number of fatal fires. Finland and Spain focus on how many people were killed by a fire.

After completion of this report, efforts to collect relevant data from more European countries will continue by the Dutch Fire Service Academy and will be completed in June 2017.

Table 4 Overview of the data (domestic fires) that has been collected in different countries across Europe.

Country	Years	Received data			
		Fatal fires	Fatalities	Object of origin	Ignition source
Netherlands	2008-2015	X	X	X	X
Sweden	2008-2014	X	X	X	X
Finland[2]	2008-2015		X	X	X
Spain	2010-2013		X		X
Denmark	2007-2015	X		X	X

Another challenge was that, if countries were able to provide data such as the cause of fire, this data was classified in different ways. This also made it difficult to compare data from different countries.

Before looking at the ignition source and object of origin in the collected data, Table 5 provides an overview of the number of fatal fires/fatalities in the different countries.

Table 5 Number of fatal fires/fatalities in the different countries.

Country	Population[3]	Year	Number of fatal fires in dwellings	Number of fatalities caused by fires in dwellings
Netherlands	**17,019,250**	2008-2015	228	246
Sweden	**9,902,924**	2008-2014	184	
Finland	**5,536,828**	2008-2015		572
Spain	**46,068,734**	2010-2015		727
Denmark	**5,706,435**	2007-2015	582[4]	602[5]

4.2 Cause of fire

For each category, only the countries that had data available are used in calculating the percentages as shown in Figure 8. In the data we received from Denmark, no data was available on candles or small open flame as an ignition source so the percentage of fires that are ignited by these two ignition sources are calculated for 4 countries.

Looking at the different ignition sources, it can be said that almost a fourth of all fatal fires are ignited by a cigarette. Less fires (7%) are ignited by candles or a small open flame. It is also shown that high percentages are categorized as 'other' or 'unknown'. This is because data on ignition

[2] All data from Finland and Spain in this chapter focuses on fatalities instead of fatal fires.
[3] Retrieved from www.worldometers.info at 30-03-2017.
[4] Estimate based on Gummesen P.(2017) *RESIDENTIAL FIRES IN DENMARK*- A Background analysis. Figure 2
[5] Estimate based on Gummesen P.(2017) *RESIDENTIAL FIRES IN DENMARK*- A Background analysis. Figure 2

sources is categorized is many different ways. Because the test methods that are mentioned in this report focus mostly on ignition by a cigarette or small open flame, it was decided to categorize those ignition sources a separate categories. All other known ignition sources are categorized as 'other'. It must also be mentioned that the high percentage of 'unknown' does not necessarily mean that the ignition source is unknown, it can mean that the recording of the data after a fatal fire is not completed adequately.

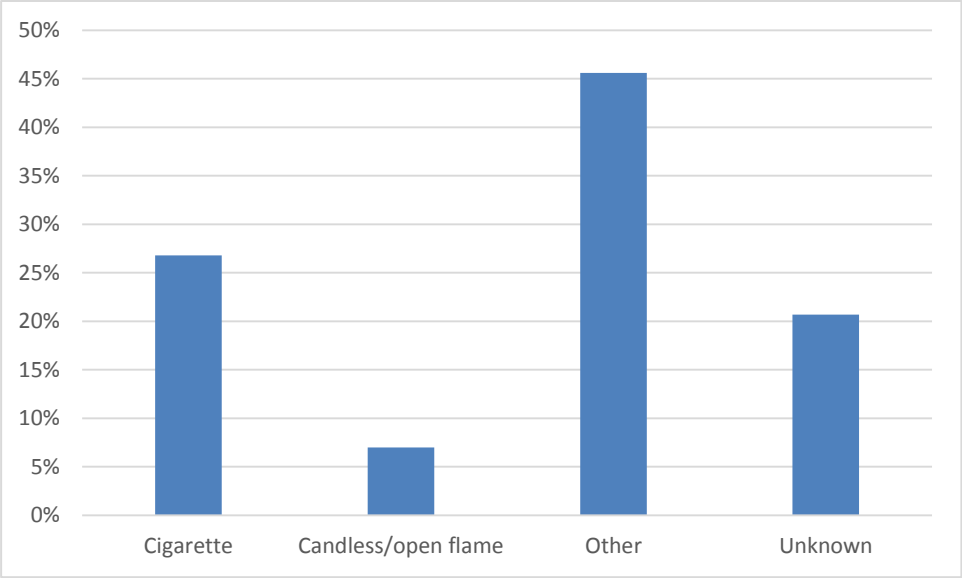

Figure 8 Ignition sources causing fatal fires/fatalities (N=2293)

4.3 Object where fire started

Not all countries had data available about the object where the fire started so the following data is missing:

- Spain has no data on where the fire started
- Finland only had data about furniture and bed/mattresses available so data about other starting objects or unknown starting objects is missing
- Denmark has no data about fires that started in furniture

For each category, only the countries that had data available are used in calculating the percentages as shown in Figure 9. So for example the percentage of fires that started in furniture are calculated for 3 countries (Denmark is missing) and the percentages of fires that started in bed/mattresses are calculated using the data of all 4 countries.

Looking at furniture or bed/mattresses as the origin, it can be said that in about 25% of all fatal fires, the fire started in one of these objects. It is also shown that high percentages are categorized as 'other' or 'unknown'. Just as was the case in the data on ignition sources, data on starting objects was categorized in many different ways. Just as is the case for ignition sources, also the high percentage of 'unknown' does not necessarily mean that the starting object is unknown, it can mean that the recording of the data after a fatal fire is not completed adequately.

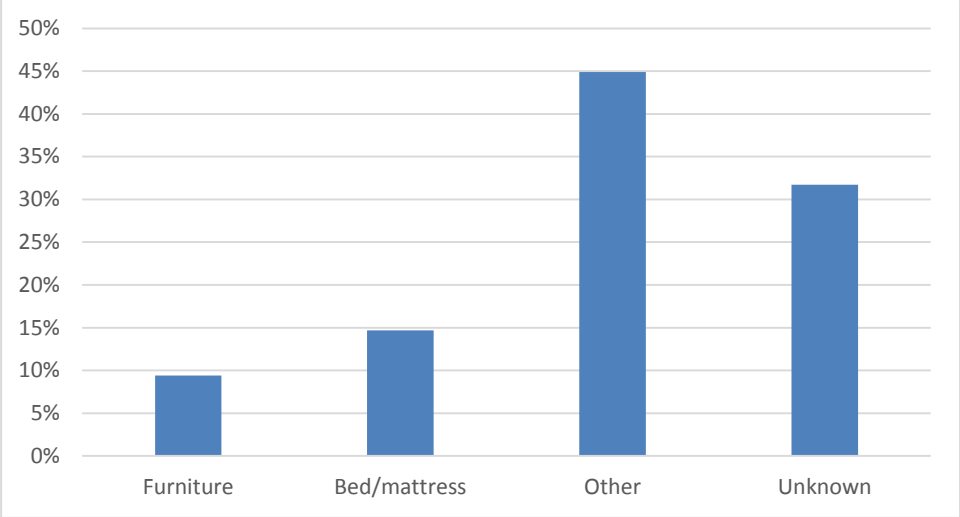

Figure 9 Object where fire started (N=1566)

4.4 Combination ignition source * object

For three out of the five countries, it was possible to make an overview of the percentage of fatal fires (fatalities for Finland) starting in furniture/mattresses, caused by a cigarettes/open flame. This data is shown in Figure 10-12. Looking at the figures below, it can be concluded that between 11-19% of all fires resulting in fire deaths in the domestic area start in furniture or mattresses by a small ignition source.

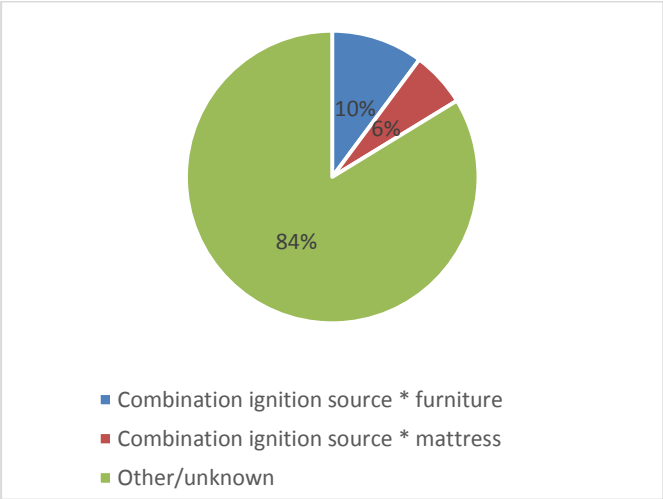

Figure 10 Combination ignition source * object The Netherlands

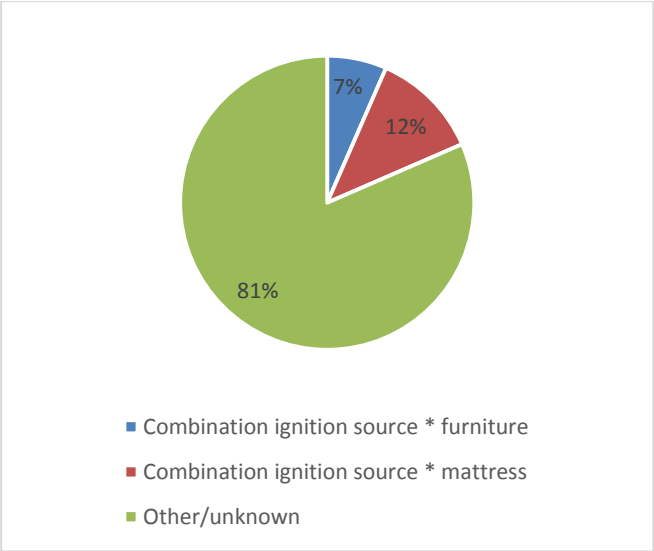

Figure 11 Combination ignition source * object Sweden

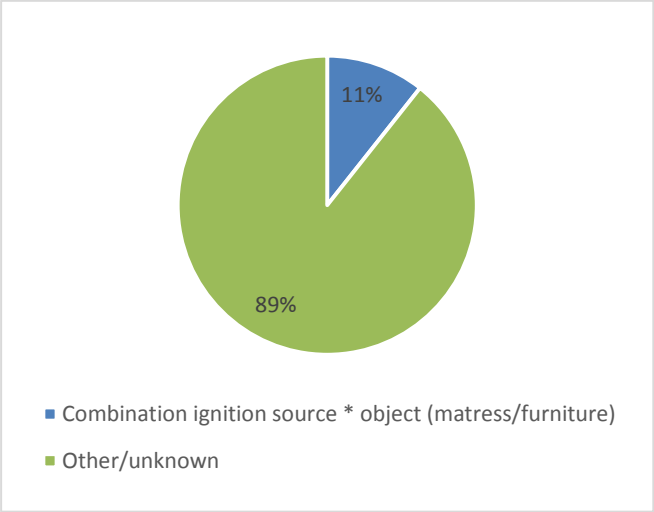

Figure 12 Combination ignition source * object Finland

From the statistics above it can be concluded that cigarettes and a small open flame are ignition sources of fatal fires in almost 34% of all fatal fires. Looking at the objects where fatal fires start, it can be concluded that furniture and mattresses are the starting objects in many cases (24,1%).

It is important to keep in mind that, for a number of reasons, the statistics above do not give a complete overview of all data available in Europe. First of all it can be seen in the graphs that a high percentage of ignition sources and starting objects are categorized as 'other' or 'unknown'. In this case 'unknown' does not necessarily mean that the ignition source or object is unknown, but it can also mean that the recording of the data after a fatal fire is not completed adequately. This means that the statistics above are not complete and only give a general indication of the percentages of fatal fires caused by the different ignition sources and starting objects.

It should also be mentioned that in the statistics that are presented in this chapter about small open flame as an ignition source, they only cover sources like candles, matches and lighters. However products that start to burn with a small open flame as soon as they ignite, for example adapters, are

not categorized in this way but are categorized as ‘other’. Therefore it is important to keep in mind that higher percentages of fatal fires can be caused by ignition sources with a small open flame.

Finally, the method of data collection is also a reason why it is possible that the statistics presented in this chapter may not be complete. The countries that were chosen to collect the data from were not chosen randomly but were chosen because members of the FEU come from these countries. Therefore it seemed easier to get access to the data from those countries. Only Denmark is an exception because that data was sent to one of the members of the working group. Also, the data was collected by different persons in different ways so it may be that additional data is available but was not found during the data collection for this project. Other European countries may have data that is not taken into account here and this may affect the overall statistics. Therefore it is important to keep in mind that these statistics may not be complete but that they give a good representation of the data that is available in the different countries.

For the recommendations that form the conclusion at the end of this report, the FEU will not rely solely on the statistics presented in this chapter but also on discussions and reports from other studies. It should be noted that the statistics presented here are in line with those seen in previous studies, for example the NFPA report [28].

5 Considerations on test methods

5.1 Introduction

In chapter 3 some of the considerations the working group had to form an opinion on were discussed before focusing on the research question. The working group has formed an opinion about the following:

- The necessity of making upholstered furniture and mattresses more fire safe
- The published Californian standard (2013)
- The consultation on UK regulations
- The use of flame retardants
- New innovative alternative solutions that present themselves now and where the emphasis lies on a physical rather than a chemical application
- Several other aspects which, ahead of thinking about test methods, should be taken into account.

The considerations and conclusions of chapter 3 were used by the working group to examine the test methods. Also on this topic, the working group had to form an opinion on some considerations before the research question could be answered. However, these considerations have, in contrast to chapter 3, a direct relationship with the determination of the test methods. The considerations in this chapter are related to the objectives and objects, the fire scenarios and fire phase, the test methods for preventing ignition, heat release and smoke spread and the way of testing.

5.2 Objectives

5.2.1 Reducing Fatalities

The primary objective is to reduce the number of fatalities due to domestic fires. Chapter 3 of this report shows the number of fatalities that can be saved by more fire safe upholstered furniture and mattresses. To reach this objective the FEU wants to improve the survivability and means of escape in dwellings by improving the fire performance of upholstered furniture and mattresses.

It was considered if upholstered furniture and mattresses (the assignment of the FEU) were the only major furniture components, major being in terms of the contribution to phases of fire developments (ignition, growth, flashover etc.). Other components that were taken into account were sheets, blankets, pillows, pillowcases/covers, cushions, curtains, carpets and draperies. The working group concluded that we should focus on upholstered furniture (sofas, chairs) and mattresses. This is not just because that was what we were assigned to do by the FEU and not because these other items are not flammable. The reason was mainly because the contribution these smaller items make to an increased survivability and means of escape are less significant than upholstered furniture and mattresses.

The working group also took into account that the ageing of the population will lead to more elderly and disabled people staying in their own homes. It was therefore discussed if the working group should focus on safe furniture for ‘standard’ domestic use or to focus on elderly and disabled people. It was agreed that there is a major difference between survivability and means of escape between

the general population and elderly/disabled people. The working group also concluded that a difference in requirements for the fire performance of upholstered furniture and mattresses is not the solution. In addition, in terms of what is said about the fire safety measurements in the introduction, we conclude that fire safe upholstered furniture and mattresses are helpful for the elderly, but there are also other helpful measures needed to give vulnerable people the same level of fire safety in dwellings compared to the general population. The FEU therefore decided to focus on a standard domestic use.

5.2.2 Way of improving

The working group discussed the way of improving the fire performance. This can be achieved by physical or by chemical means. There are three ways of improving the performance by physical means. The first is the reduction of temperature rise by an insulating top layer or increased thermal inertia. The second is shielding pyrolysis gasses from oxygen by a gastight top layer which is continuously present or activated by a raised temperature. The third way is the production of non-combustible gasses which absorb heat and dilute combustible gasses. The fire performance can also be improved by chemical means, by the production of reactive gasses which interfere in the combustion process.

In chapter 3 we saw the problems with the chemical solution. We think this will not be a sustainable solution for the future. However the assignment from the FEU stated that the testing methods should be regardless of material or the method of improving fire resistance. So the final chosen testing method or testing methods should not exclude any physical or chemical solution. The working group agreed that we are not in a position to question chemical solutions with flame retardants, as long as the flame retardants used are approved by REACH, the European list of permitted chemicals. It is up to manufacturers, suppliers, legal bodies and standardisation bodies to make a final choice in relation to with or without flame retardants.

5.2.3 Conclusions

The conclusions of the FEU regarding the objectives are:

- Improve the survivability and probability of escape in dwellings
- The focus is on upholstered furniture (sofas, chairs) and mattresses
- The focus is on a standard domestic use
- The finally chosen testing method(s) should not exclude any physical or chemical solutions.

5.3 Fire scenarios and stages

5.3.1 Upholstered furniture fire scenarios

There are five relevant fire scenarios to take into account [29]:

1. Cigarette ignition scenarios: smouldering ignition by lighted tobacco product, principally cigarette.
2. Open flame ignition by another fire: where upholstered furniture is the principal item contributing to fire spread but not the first item ignited.
3. Ignition by arcing or heat from operating equipment.
4. Small open flame ignition: by candle, match or lighter.

5. Smouldering ignition by ember, ash or other means or an unclassified hot or smouldering object.

To protect upholstered furniture against these fire scenarios, there are several (possible) tests:

1. The cigarette ignition scenario is addressed by cigarette ignition test.
2. The open flame ignition by another fire can be addressed by tests that measure rate of heat release and time to flashover.
3. The ignition by arcing or heat from operating equipment is not covered by any specific test, but maybe covered by other tests.
4. The ignition by small open flame is addressed by the small open flame (match or simulated match) ignition resistance test. Also larger ignition sources like wooden cribs and larger gas flames could be applicable.
5. Smouldering ignition by ember, ash or other means or unclassified hot or smouldering object is not directly addressed in a test, but could be addressed by the cigarette ignition test.

5.3.2 Fire phases

The ignition scenarios mentioned in chapter 5.3.1 could result in fire growth (and smoke spread). This fire growth can be divided into three phases. In Figure 13, phase 1 is the incipient part, phase 2 is the growth, flashover and fully developed burning of the object and phase 3 is the decay part of the fire.

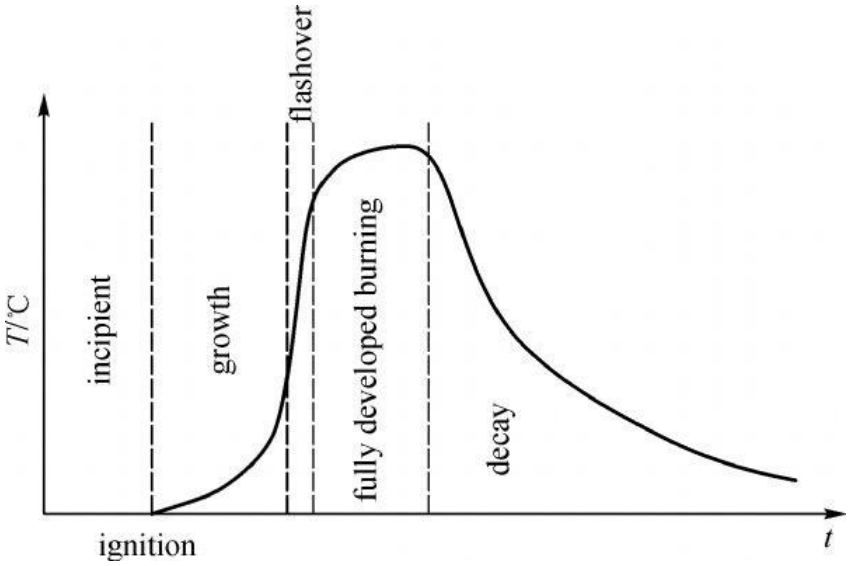

Figure 13 Fire development curve of the object

All these phases have an impact on the conditions of the dwelling. The first phase says something about how difficult it is to ignite the object. Ignition can be avoided or at least delayed if the object can withstand a rather large ignition source. The second phase occurs after ignition of the object. Depending on the fire growth rate and when flashover occurs, this could affect not only the fire and smoke production in the room of origin, but also impact other parts of the dwelling.

5.4 Survivability

The discussion was on which phase of the fire to focus on (see Figure 13). As the objective is to improve the survivability and possibility of escape in dwellings, it looked logical to focus on phase one and two. People die in domestic fires not only in the room of origin, but it is also common for people to die in other rooms due to smoke and fire spread. Also the results of the experiments in The Netherlands in 2014 [30] and 2016[6] show that the conditions of survivability and possibility of escape from other rooms as well as the room of origin should be taken into account. Most important for the survivability and the possibility of escape are the smoke and heat. However for practical reasons we chose to focus on phase one because phase two would require large scale testing which is not achievable at this time for the furniture manufacturing industry.

5.5 Requirements

5.5.1 Requirements for fire spread and smoke development

The working group considers that a fire in upholstered furniture and mattresses should not have a large negative effect on the survivability and possibility of escape. It therefore seems to be a logical choice not only to focus on the ignition of the object, but also to the speed of the fire spread and the smoke production once the object has ignited. However, after extensive discussions, the working group concluded that the fire behaviour of the object and the effect of the smoke on the survivability and escape conditions for those present in the dwelling also depends greatly on factors not tested, such as insulation and ventilation of the dwelling, air flows, open windows and doors, location of the object in the dwelling, and so on. Besides this problem, the working group sees a number of difficulties in proposing test standards for the measurement of burning behaviour and smoke production. These difficulties are:

- It is not very common to test burning behaviour and smoke production for furniture and mattresses for the domestic use. These types of tests are mostly used for furniture and mattresses in public environment and these test methods are rather extensive and therefore often expensive. The only test method that the working group is aware of is the US federal standard 16 CFR 1633 used on mattresses.
- The working group considers that requirements on burning behaviour and smoke production can be met mostly with the use of flame retardants. The assignment was that the solution must be solution independent. This means that no specific solution or material should be excluded.
- The acceptance of the recommendations on the test methods is voluntary. That is why the recommendations should not be too strict otherwise they might not be attractive for the manufacturers and suppliers.
- At the moment, much of continental Europe does not have any requirements for the fire safety of domestic upholstered furniture and mattresses. Introducing requirements on ignition would therefore be a large step forward for fire safety in dwellings.

All considered, the FEU has come to the conclusion that at present the survivability and possibility of escape from fire is best served by avoiding ignition if possible. By preventing or delaying the ignition

[6] This report is published on www.brandweeracademie.nl

of upholstered furniture and mattresses, you also prolong the survivability and escape possibilities. This could be achieved by using an ignition source in testing such as a cigarette and match. However to represent the larger ignition sources that can be found in a dwelling, the FEU believes an ignition source such as Crib 5 is also necessary.

5.5.2 Requirements for ignition testing

By concentrating only on the ignition (see Figure 13), we therefore focus on preventing, or at least delaying, the ignition as long as possible to increase survivability. By linking the survivability to preventing or delaying the ignition, there must be strict requirements on ignition. In section 5.3.1 the test methods for the different scenarios were presented. The working group discussed them all and considered:

- The cigarette ignition test is the most important because it covers the most common scenarios.
- The ignition by small open flame is also important because it covers more existing scenarios than those covered by the cigarette test.
- The open flame ignition by a wooden crib covers larger scenarios than the small open flame test and reflects a larger ignition source located on the upholstery.

The working group also investigated the current use of these test methods. The cigarette ignition scenario was the first upholstered furniture fire scenario to be addressed by formal requirements, beginning in 1975 in California with TB 117 and in 1988 in the UK with requirements built around BS 5852-1. The small open flame scenario was also first addressed by TB 117 in California in 1975 and by the UK in 1988 using tests based on BS 5852-1 & 2. The changes in the test methods in California and the UK are described in chapter 3. Some requirements use a larger open flame igniting heat source, such as the wooden crib fire used in one part of the UK requirements. So the test methods to prevent ignition already exist and are therefore easier to use rather than to introduce new test methods.

To summarise, the FEU concluded that the focus on increasing survivability and possibility of escape should be achieved by introducing requirements to prevent ignition of upholstered furniture and mattresses. The FEU recommends the following ignition sources:

<u>Upholstered furniture and mattresses</u>

1. ***The ignition by cigarette***
2. ***The ignition by small open flame***
3. ***The open flame ignition by a wooden crib (crib 5)***

The FEU believes that recommendations 1 and 2 are achievable at this time for most furnishings. We want manufacturers to make a public commitment to achieve recommendation 3 in a realistic time frame.

5.6 Way of testing

The way of testing upholstered furniture and mattresses differs. For that reason we first looked at the way of testing upholstered furniture and thereafter the way of testing mattresses.

5.6.1 Full scale and small scale

After the FEU decided which test methods should be recommended, a discussion was started on the possible scales and ways of testing. With full scale testing the complete object is tested, including non-uniform elements like crevices and buttons. Small scale testing is usually performed on a smaller furniture mock-up, on samples of the fabric, interlayer or filling material taken from the complete furniture. Small scale testing has the advantage that less material is needed and cost and transportation will be less for the manufacturer. However, small scale tests do not always give a good representation of the whole product.

5.6.2 Component and composite

Small scale testing can be performed either as component testing or as composite testing. Component testing means testing and assessment of each individual component/material from the upholstered furniture, i.e. testing of the filling material, the interlayer or the cover separately. However, the components are often tested in combination with standardized materials. For example, component fabrics are often tested in combination with standard non-flame retardant polyurethane foam and filling materials are often tested in combination with a standard flame retardant treated polyester fabric. Component testing does not indicate anything about the ignitability for the end-use product. For filling materials, the component fire test can be harder compared to testing the complete product since the filling will be directly exposed to the ignition source. When testing complete products the filling material will have some protection from the ignition source by the cover and interliners.

Composite testing means testing on combinations of components. Usually samples of the fabric, interlayer and filling material are taken from the complete furniture and tested in the same combination but on a smaller furniture mock-up.

5.6.3 Representative samples for testing

Upholstered furniture is often manufactured in numerous different combinations. The manufacturer could have different filling and interliner combinations and the buyer of the sofa can also usually choose between different fabrics. For example, if a manufacturer have three different types of foam (or foams with different densities), three different interliners and 25 different covers (top layers), there are 675 different material combinations. Should a manufacturer therefore be forced to test every possible combination?

Testing the worst case combination is of course mandatory. However, knowing the worst case combination is not always possible and testing only one combination if there are 675 possible combinations is not enough. This problem is usually solved by grouping similar materials together and performing tests on selected combinations from each group.

5.6.4 Conclusions for Upholstered Furniture

The conclusion of the FEU is that full scale testing is not realistic and that composite testing is the best alternative. The fire test is then performed in small scale but with the same material combination as the end-use product. If there are many material combinations available they can be grouped together and tests can be performed on the worst case combination.

To summarise, the FEU recommends that upholstered furniture is tested in the following way:

Upholstered furniture

1. ***Testing on a composite level***
2. ***Testing the end use combination***
3. ***Testing of representative combinations***

5.6.5 Mattresses

A number of the above discussed problems and considerations for testing furniture are also the same when testing mattresses, for example the problems with choosing representative samples. However, the problems with scale and composite versus component testing are irrelevant. A mattress is always tested in its end-use combination, independent whether it is a full size mattress or a smaller sample. If a smaller sample is used the test specimen shall still have the thickness of the finished mattress. The type of proposed edge finishing system shall be incorporated, e.g. plain, piped or tape edged. Representative tension shall be maintained in the cover. The proposed mattress finish shall be represented in the test specimen, e.g. tufted or quilted.

From an ignition point of view there is no difference between testing a full scale mattress or a small scale sample. It is more practical with small samples during testing and the material and transportation costs are probably smaller for the manufacturer. However, some manufacturers find it more difficult to manufacture small scale samples, especially if the mattress has a wooden frame and a spring system. For that reason the FEU has no opinion on the size of the mattress during testing. The ignition test can be performed either on a full scale mattress or a small scale sample.

To summarise, the FEU recommends:

Mattresses

1. ***Testing full scale mattress or a small scale sample***
2. ***Testing of representative combinations***

6 Conclusions and recommendations

6.1 Conclusions

The statistics in chapter 4 show that fires often start in upholstered furniture or mattresses and these items contribute to many fire fatalities in domestic buildings. The most common ignition source for upholstery is a cigarette but other ignition sources such as smaller open flames are also common. A domestic fire usually follows the different phases of a fire development curve, as described in Figure 13. To reduce fires and save lives the FEU wants to focus on the incipient phase of the curve; to avoid or at least prolong the ignition of upholstery items. To do so, it was concluded that domestic furniture and mattresses should be able to withstand different ignitions sources:

- Cigarette ignition test. This is the most important because it covers the most common ignition scenario's
- Ignition by a small open flame. This is also important because it covers more ignition scenarios than those covered by the cigarette test
- Open flame ignition by a wooden crib. This covers larger ignition scenarios than the small open flame test.

By introducing requirements to prevent ignition of upholstered furniture and mattresses, the FEU believes that the survivability and possibility of escape from dwelling fires will increase.

When it comes to testing furniture, the FEU concluded that full scale testing of furniture is not realistic and that composite testing is the best alternative. The fire test is then performed in small scale but with the same material combination as the end-use product. If there are many material combinations available they can be grouped together and tests can be performed on the worst case combination. For mattresses the ignition test can be performed either on a full scale mattress or a small scale sample.

6.2 Recommendations

The following test methods correspond to the chosen ignition sources described in section 5.5 and the way of testing the upholstery as described in section 5.6 (i.e. testing on a composite level and the end use combination).

Object	Ignition source	Test method	Comments
Furniture	Cigarette	EN 1021-1	
	Open flame	EN 1021-2	
	Crib 5	BS 5852	Choose between BS 5852 chapter 11 or 12
Mattresses	Cigarette	EN 597-1	
	Open flame	EN 597-2	
	Crib 5	BS 6807	Test according to BS 6807 chapter 9

The cigarette ignition source is covered by testing upholstered furniture according to EN1021-1. The standard describes composite testing of small scale samples. Mattresses are tested with a cigarette according to EN 597-1. In this test method you can choose to test either a representative small mattress or a full scale mattress. Both of these test methods are European standards that are familiar to the industry and used by many manufacturers today already.

The small open flame (match) test is covered by testing upholstered furniture according to EN1021-2 and EN 597-2 for mattresses. The test set-up, samples and procedure are more or less identical to the cigarette tests, only the ignition source differs. Also these European standards are familiar to the industry and used by many manufacturers, although perhaps not as frequent as the cigarette test.

For the crib 5 ignition source there are no European standards (EN) available. Instead the FEU refers to the British standards BS 5852 for testing upholstery furniture and to BS 6807 for testing mattresses. Even though these are British standards, both standards are known and sometimes used by the industry also outside of the UK.

BS 5852 allows for both composite testing (BS 5852 chapter 11) or for the complete furniture to be tested (BS 5852 chapter 12). The FEU considers both ways of testing to be adequate. If testing the complete furniture, the crib should be located at positions offering the worst case ignition scenarios. Example figures of this are given in BS 5852 chapter 12.

In BS 6807 a representative small mattress or a full scale mattress shall be tested as described in chapter 9. The standard also allows for made up beds to be tested as described in BS 6807 chapter 10 of the BS but that is out of the scope of the FEU recommendations.

The FEU believes that the cigarette and match flame tests in the European Standards are achievable at this time for most furnishings. We want manufacturers to make a public commitment to achieve the Crib 5 test as described in British Standards within a realistic time frame.

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Appendix 1: A view on Flame Retardants

Fire and combustion are gas phase reactions that involve both a fuel source and oxygen. The combustion process is characterised by four stages: heating, decomposition/volatilisation, combustion and propagation. Once a material is set on fire, the combustion process is self-propagating and continues until one of the necessary ingredients run out (oxygen, heat or fuel). In a free-burning fire, this is mostly the burnt material.

Flame retardants have the ability to interfere with any of the combustion stages. Because they differ in physical and chemical properties, various flame retardants have different flame retarding mechanisms, capacity, and applications.

A flame retarding compound may, for example, function by decomposing through endothermic processes, which cools down the burning material to temperatures below those required for pyrolysis. A different mechanism uses the ability of the chemical to form a protective coating layer of either liquid or solid state over the surface of the combusting material, which prevents oxygen and volatile combustion products to reach the flame.

One very effective way of flame retardants activity is the capture of free radicals, which are produced during the combustion process and are necessary for the propagation process. Halogens are very effective in capturing free radicals, hence removing the capability of the flame to propagate. All four halogens are effective in eliminating free radicals, but not all of the halogens are suitable for use in flame retardants. Fluorinated and iodinated compounds do not have the optimal decomposition properties. Decomposition occurs either when a temperature is too high or too low, respectively. Consequently, only organochlorine and organobromine compounds are used as flame retardants.

More than 175 different commercial flame retardants (organic and inorganic) are available on the market. There are three main families of flame retardants chemicals, namely:

- inorganic flame retardants
- halogenated products
- organophosphorus and nitrogen based flame retardants

Inorganic flame retardants are salts, such as aluminium trihydrate, ammonium phosphate, magnesium hydroxide, borates or boric acid, and so on. Inorganic flame retardants make up 50 percent of the total amount of flame retardants produced worldwide. Inorganic flame retardants are not only used as such, but also in combination with organic flame retardants, in order to enhance their flame retarding capacity. Antimony trioxide [SbO_3], for example, is often used together with brominated flame retardants. Organic flame retardants are either halogenated substances, corresponding to approximately 25 percent of the total amount of flame retardants produced or phosphorous and/or nitrogen containing organic substances, which are estimated to be 20 percent of the demand of flame retardants. Examples of phosphorous containing flame retardants are the organophosphate esters that are used for their flame retarding as well as for their plasticising properties.

Next to several non-halogenated organophosphate esters that are in use, various organophosphate esters are substituted with halogens. For the reasons mentioned above, the halogenated organic flame retardants are either chlorinated or brominated. The class of the brominated flame retardants (BFRs) is currently receiving most of the attention because they are characterised by their Persistent Organic Pollutant [POP]-like properties, such as persistence, lipophilicity long-range atmospheric transport (LRAT] and toxicity.

REACH

To better protect its environment and citizens against the continuously increasing presence of (synthetic) chemicals, the EU has developed a new policy concerning newly introduced chemicals, which is known as REACH. REACH stands for registration, evaluation, authorisation and restriction of chemicals. It came into force on 1 June 2007.

Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

REACH (EC 1907/2006) aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances. This is done by the four processes of REACH, namely the registration, evaluation, authorisation and restriction of chemicals.

In principle, REACH applies to all chemical substances, not only those used in industrial processes but also in our day-to-day lives, for example, in cleaning products, paints as well as in articles such as clothes, furniture and electrical appliances. Therefore, the regulation has an impact on most companies across the EU.

"No data no market": the REACH Regulation places responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. Manufacturers and importers are required to gather information on the properties of their chemical substances, which will allow their safe handling, and to register the information in a central database in the European Chemicals Agency (ECHA) in Helsinki. The Agency is the central point in the REACH system: it manages the databases necessary to operate the system, co-ordinates the in-depth evaluation of suspicious chemicals and is building up a public database in which consumers and professionals can find hazard information.

The Regulation also calls for the progressive substitution of the most dangerous chemicals (referred to as SVHC "substances of very high concern") when suitable alternatives have been identified.

One of the main reasons for developing and adopting the REACH Regulation was that a large number of substances have been manufactured and placed on the market in Europe for many years, sometimes in very high amounts, and yet there is insufficient information on the hazards that they pose to human health and the environment. There is a need to fill these information gaps to ensure that industry is able to assess hazards and risks of the substances, and to identify and implement the risk management measures to protect humans and the environment.

If the risks cannot be managed, authorities can restrict the use of substances in different ways. In the long run, the most hazardous substances should be substituted with less dangerous ones.

The last registration deadline for existing chemicals will be on 31 May 2018. This deadline concerns companies that manufacture or import substances in low volumes, between 1-100 tonnes per year.

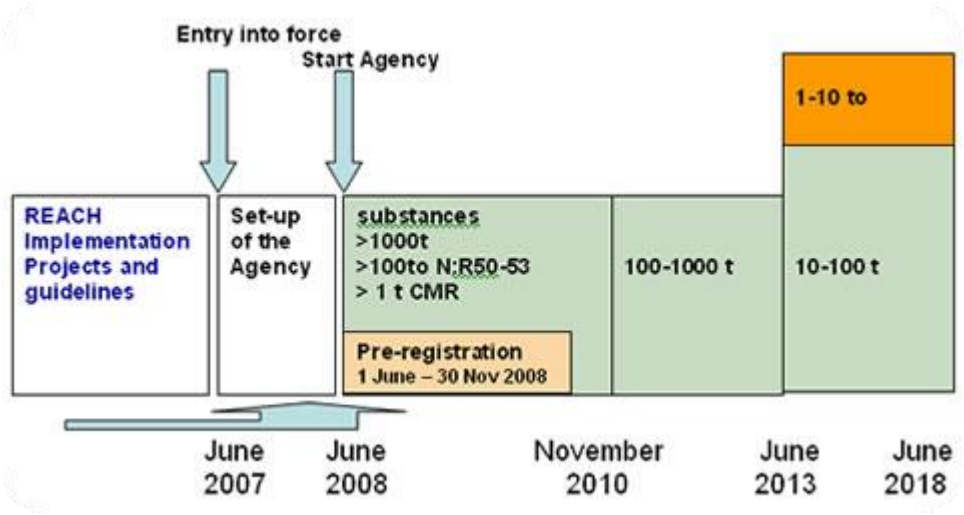

Figure 14 Deadlines for compliance with REACH

REACH 2018 will complete the gathering of data on substances on the European market, resulting in the most comprehensive chemicals database in the world. Once the registration is successfully carried out, REACH will result in a large scale improvement of human health and the environment in Europe. This is realised through the increased knowledge of companies in their everyday operations and the information in ECHA's database for authorities to use in regulatory risk management. In addition, the increased knowledge on chemicals and their uses will be drivers for future innovations.

Using flame retardants in upholstered furniture, yes or no?

The internet was consulted in order to make an “objective” decision on whether or not to use flame retardants in upholstered furniture. The World Wide Web contains a lot of documents about flame retardants. These documents are most of the time “coloured “by the personal interests of the authors which makes it very difficult to take a position on the use of flame retardants.

The different advantages and disadvantages of the use of flame retardants can be read below:

Why should we ban the use of flame retardants?

What are the consequences of the use of flame retardants on health, environment and competitiveness?

Impact on health:

The scientific community has identified many flame retardant chemicals as substances of concern for several adverse effects such as persistence, bioaccumulation, toxicity, mutagenicity, endocrine disruption and carcinogenicity. In furniture items, flame retardants are added to foam and textiles. The San Antonio Statement on Brominated and Chlorinated Flame Retardants [31] documents the scientific consensus about health, environmental and fire safety concerns associated with the use of these chemicals. It was signed by more than 150 scientists worldwide.

Firefighters suffer from the exposure to toxic fumes released from the combustion of materials containing flame retardants. The exposure leads to adverse impacts on firefighters like multiple myeloma, Non Hodgkin lymphoma, prostate and testicular cancer. These are all associated with dioxin and furan exposure.

Impact on Environment:

Flame retardants migrate out of products and accumulate in the environment. Many flame retardants are persistent and can undergo long range environmental transport. Many products containing flame retardants cannot be recycled for material re-use. Additionally, the end-of-life treatment of products containing flame retardants is 2 to 3 times more expensive than normal waste.

Impact on Competitiveness:

Furniture producers must comply with several different flammability standards and test methods in order to place their products on the EU internal market. The different flammability standards and bans throughout Europe are complicated to comply with and place a costly burden on the producers. This system prevents the free circulation of goods and hinders competition. When flame retardant chemicals are necessary in order to comply with regional or national regulations, consumers are left with a smaller range of products with lower quality, higher prices and less durability.

Impact on Fire Safety:

A study from ARCADIS EBRS, commissioned by DG Heath and Consumers in 2011, demonstrates that early detection by smoke detectors is a very effective measure to deal with fires in the initial stage of development and to reduce the number of fire deaths. Latest studies declare no clear link between the use of flame retardants and fire safety *(Study from ARCADIS EBRS).* The use of flame retardants in furniture may even increase the production of soot, smoke, toxic gasses and other harmful combustion products in a fire.

Using alternatives:

Other regulators recognise fire safety without hazardous flame retardants to protect health and environment. The State of California has identified many flame retardant chemicals as being known to, or strongly suspected of, adversely impacting human health or development. In view of consumer protection, health and safety concerns, the State of California has updated its furniture flammability standard TB 117. Introducing TB 117 2013 enabled the sale of furniture without added flame retardant chemicals and has maintained fire safety.

Why should we accept the use of flame retardants?

Some brominated flame retardants (BFRs) have unintended negative effects on the environment and human health. Less toxic alternatives appear to be available already but comprehensive information on their possible toxicological effects are lacking.

The European Commission-funded project, ENFIRO [32], investigated the substitution options for some BFRs and compared the hazard, exposure, fire, and application performances. Based on these results, risk and impact assessments were carried out.

In total, 14 halogen-free flame retardants (HFFRs) as alternatives for decaBDE, TBBP-A, and brominated polystyrenes were selected. These flame retardants were studied in five applications:

- printed circuit boards (PCBs)
- electronic components
- injection moulded products
- textile coatings
- intumescent paint.

ENFIRO showed that all of the selected alternative flame retardants do fulfill the regulatory fire test. A method was developed using intrinsic flammability properties as well as a simple method for characterizing the fire performance and fire toxicity of polymers using three parameters (fire spread, smoke/carbon monoxide, inefficiency of combustion).

With this model, a comparative fire performance assessment of HFFRs vs BFRs could be made. An important finding was that halogen free systems have clear benefits as demonstrated, e.g. less visible smoke, in some cases lower peak heat release rate with halogen free products, and less toxic components in smoke.

From the initial selection of 14 alternative flame retardants, seven were found to be less toxic and also accumulated less in the food chain than the BFRs. Environmental fate models predicted that the organic HFFRs would be found primarily in soils, sediments and dust and to a lesser extent in water and air. Controlled air emission experiments showed that all organic HFFRs emitted from polymers at elevated temperature but not at lower temperatures. Leaching experiments showed that both HFFRs and BFRs can leach into water. For some polymers, no differences in leaching behaviour were found between BFRs and HFFRs, but some HFFR systems had higher leaching properties than polymeric based BFRs. The type of polymer is the main parameter determining the leaching behaviour. Analysis of organic HFFRs in dust from microenvironments and environmental samples showed the highest concentrations on and around electronic equipment, in sediment and sewage sludge. The environmental and human risk assessments showed that the predicted environmental and human exposure concentrations were below the toxicity thresholds for the selected HFFRs. However, the lower risk of HFFRs compared to BFRs is mainly due to the lower hazards of the HFFRs, and not due to a lower exposure. Reducing the leaching of HFFRs from polymer materials is a next challenge for the development of new FRs. The comparative life cycle assessment (LCA) of BFR vs HFFRs, using a laptop as a case study, showed that the waste phase was the most relevant. Overall the LCA performance of the HFFR scenario was better than for the BFR scenario. The same life cycles were also evaluated on social criteria using a social
life cycle assessment. Several hotspots are found in the raw material mining phase.

In conclusion, ENFIRO showed that viable alternative flame retardants are available. Some HFFRs showed less risk for the environment and human health, and show similar fire performance and technical application capabilities as BFRs.

FEU opinion/recommendation

Important steps to restrict or regulate hazardous flame retardants have already been taken through REACH and other regulatory approaches in the EU. HBCCD and TECP are forbidden for use in the EU since 21 August 2015. The flame retardant DecaBDE is currently in the final stages of the restriction process.

The FEU recommends the use of alternatives to achieve safe furniture in European dwellings but underlines the conclusions of the European funded ENFIRO project. The study showed that viable alternative flame retardants are available. Some halogen free flame retardants showed less risk for the environment and on human health, and show similar fire performance and technical application capabilities as brominated FRs.

The FEU accepts the use of flame retardants to increase the fire safety of upholstered furniture if they meet the requirements of the REACH legislation.

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