Chapter 10
Prevention of Ignition and Limitation of Fire Development in Furnishing and Home Environment

Anne Steen-Hansen and Karolina Storesund

Abstract Some fire safety measures will benefit all types of homes and occupants, while other measures may not be helpful for people who are considered as especially vulnerable in a fire situation. Fire safety should therefore be planned and designed with a holistic perspective, taking both the specific building and individual into account.

One important factor in residential fire safety is the furnishing. The furnishing may be easily ignited and may represent large amounts of fuel that can lead to a rapid fire development with high heat release and large amounts of toxic smoke.

Fire statistics has shown that the most typical ignition sources in dwelling fires are open flames, smoking materials and electrical apparatuses and installations. Upholstered furniture and mattresses are often involved in residential fires, both as the first items ignited and as objects responsible for fire development. This chapter describes the problem connected to soft furnishing and proposes ways of solving it. Other types of furnishing, their role in fire development and possible solutions to the problem are also described.

1 Strategies for a Holistic Assessment of Residential Fire Safety

Fire safety in private homes should be regarded as an obvious quality, just as personal safety in cars, trains and aircrafts has become the standard. Therefore, the chosen fire safety measures should be simple, easy to implement, aesthetically

A. Steen-Hansen (✉)
Department of Civil and Environmental Engineering, Norwegian University of Science and Technology, Trondheim, Norway

RISE Fire Research, Trondheim, Norway
e-mail: anne.steen-hansen@ntnu.no

K. Storesund
RISE Fire Research, Trondheim, Norway

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pleasing and cost-effective. They should also be durable, with a long life-time and require a minimum of maintenance.

The assessment should as far as possible include environmental and sustainability considerations; e.g. does the intended safety measure represent any obvious negative effects on health or environment? Which raw materials are required, and will the solution be recyclable? Could another measure give the same level of safety?

The probability of ignition can be reduced by simple measures, like by:

- Avoiding that combustible items are placed in the close vicinity of ovens and other heat producing units (e.g. sofas and beds close to wood stoves, electric heaters placed below curtains).
- Avoiding the use of extension leads.
- Avoiding the use of flaming candles, and instead using battery-powered candles.
- Controlling that electrical equipment has no obvious faults like loose connections, hot parts or irregular behaviour.
- Using timers on kettles and coffee makers.
- Allowing smoking only in safe areas, or under supervision if necessary.

In the context of fire safety in dwellings, Arvidsson et al. [1] defined the term *forgiving system* as a "System or product that allows an individual to make mistakes without being injured or killed by fire". Technical measures that may be implemented and may target different needs with regard to prevent fires or make the fires hard to arise and thereby work as a "forgiving" solution include:

- Stove guards.
- RIP cigarettes and different measures aimed at reducing the fire risk from smoking.
- Self-extinguishing candles and candle extinguishers.
- Fire protection of electronic equipment.
- Fire safe furnishing.
- Measures aimed at reducing the risk from open flame.
- Detection and alarms.
- Automatic extinguishing systems.

Although many of these measures could be helpful for all on a general basis, individuals who experience an increased vulnerability to fire will, depending on their specific challenges, be helped by targeting the preventive measures to their specific needs. Targeting and adjusting technical preventive measures to specific challenges is just a part of a necessary holistic view of the circumstances that influence the probability and consequences of fires in dwellings, as is described in [2–4] and it includes recognizing the physical, social and organizational surroundings of the individual, as illustrated in Fig. 10.1.

The prevention of fatal fires for vulnerable groups of people is an issue that requires attention and cooperation from several public sectors as well as cooperation between different fields of science. Having identified the fire safety challenges for an individual, it is important to select suitable measures to target these specific challenges. Changing attitudes, raising the awareness and teaching fire safety are all

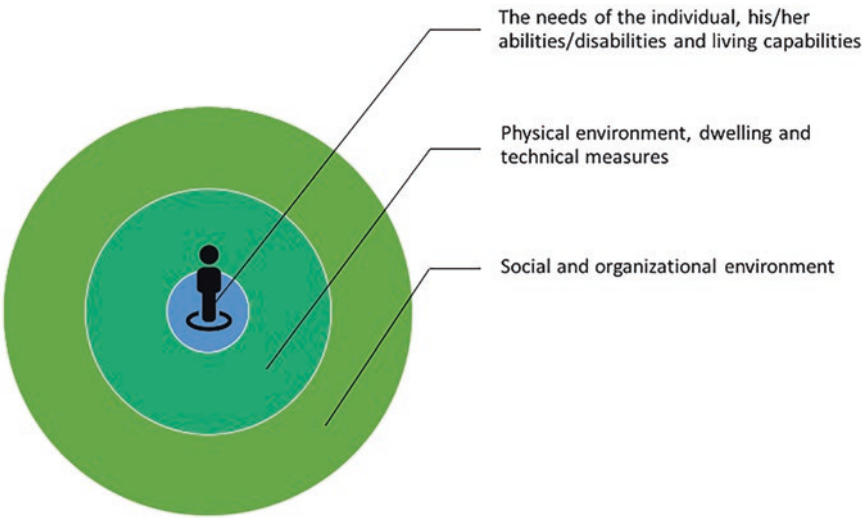

Fig. 10.1 Circumstances that influence the risk of fatal dwelling fires [2, 5]

important measures in all of these situations. Fire safety for vulnerable groups is further described in Chap. 17.

New products and solutions for fire prevention are continuously being developed and made available on the market. Not all technical solutions are clearly defined with respect to performance requirements, properly documented or certified. However, clear and defined requirements for function and documentation will strengthen the availability and the quality of fire preventive technical solutions and thereby help improving the fire safety for people in general, and for people who experience an increased fire risk in particular.

This chapter is focusing on fire safety in connection to the content of a home, especially the furnishing. However, in a holistic view the combination of products with good fire properties and other types of fire safety measures is important to obtain the desired fire safety level. Such measures can, e.g., be fire detectors, stove guards, automatic extinguishing systems and manual extinguishing equipment, which are described in other chapters of this anthology. Implementation of organizational measures may also be important.

2 Fire Development and the Role of the Content of the Dwelling

The furnishing of homes – or more specifically the amount and types of materials in items like sofas, mattresses, carpets and curtains – is of great importance for residential fire safety. Materials that are easily ignitable, spread fire fast and release

large amounts of heat and toxic smoke can lead to a rapid fire development and result in too little available time for safe egress (ASET) [6]. This period of time can be increased by introduction of barriers that prevent heat development, prevent ignition or mitigate the fire development [7]. Examples of such barriers could be choice of materials with good fire properties in furnishing items, and implementation of fire safety measures that efficiently can lead to mitigation of the fire.

The following factors related to the room are important for the fire development:

- Size and location of the ignition source.
- Furnishing: type, amounts, location, geometry and surface area.
- Reaction to fire properties of the furnishing.
- Reaction to fire properties of walls, ceiling and floor.
- Ventilation conditions.
- Room geometry.

To be able to design and apply efficient fire safety measures, it is necessary to know how, where and why residential fires start, how these fires may develop and how fires pose a threat to people in the dwelling.

2.1 Fire Development in a Compartment

A fire can be described by a series of stages: First, a material is ignited by an ignition source; e.g. an open flame, a spark or a smouldering cigarette. The fire then develops in the ignited object, and the development may be slow or fast dependent on factors like ignition source, material, geometry, ventilation, etc. Some fires start as smouldering fires, i.e. as a low temperature combustion with no flames, but with considerable smoke production. Smouldering combustion takes place on the interior surface (e.g. in pores and cavities) of a material. Upholstery foam, combustible insulation materials and porous wood products are examples of materials in which smouldering combustion may occur [8]. A smouldering fire may transform into a flaming fire when the conditions are changed, which can happen when the combustion front reaches the material surface and the access to air is increased.

When a flaming fire is established the development may escalate, the fire can spread to other objects in the room. This may lead to flashover, which is when the room is completely involved in the fire. Flashover is a very critical point in the fire development, as it enables the fire to spread out of the room to other parts of the building. The chances to survive in a room after flashover are minimal. After flashover, the fire is fully developed and will continue to burn until either all combustible materials are consumed, there is too little oxygen to support the combustion, or until the fire is extinguished by manual or automatic firefighting equipment. A schematic presentation of fire development in a compartment is shown in Fig. 10.2.

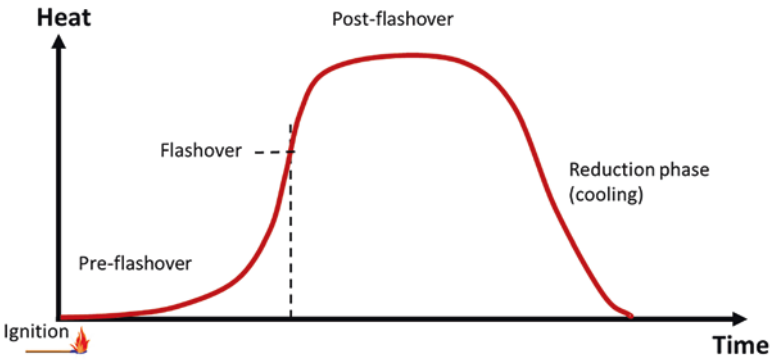

Fig. 10.2 Schematic presentation of fire development in a compartment

2.2 How and Where Residential Fires Start

There are many potential ignition sources in a regular dwelling, but the most common according to, for example, Norwegian fire statistics are electricity and open flame [9]. In this context, *open flame* includes smoking materials, like matches, lighters and cigarettes. Fires starting on the cooking top are, in the case of Norwegian statistics, included in the number of fires with electric start. For example, in 2018 as much as 55% of all fire brigade call-outs to Norwegian dwelling fires started on the cooking top, including incidents where the fire service reported that they avoided that a dangerous situation developed into a flaming fire [9]. The number of cooking incidents that actually do develop into a fire is considerably lower and was estimated to be just below 8% of all dwelling fires in the period 1998–2007 [10, 11]. Cooking fires caused about 10% of the fire fatalities in Norway in this period. Smoking is the most common cause of ignition of upholstered furniture, the ignition source being either a smouldering cigarette, or a match, or lighter [12, 13].

As concerns the cause and origin of fire, fatal fires do not reflect the average residential fire. It is, e.g., reported that the bulk of all residential fires start in connection with cooking in the kitchen, but that the leading cause of fatal fires is smoking. The majority of fatal fires occurring in Norway, Sweden and Denmark start in the living room, followed by the bedroom as a common point of origin [9, 14, 15]. In the USA, it is most common that fatal fires start in the bedroom, followed by the living room [16]. The bed and furniture are usually the first ignited objects in fatal fires, often related to ignition caused by cigarette smoking or use of open flames. A Swedish study showed that 17% of fires starting in a bed were fatal [15]. Electrical appliances are involved in many fires, both those resulting in fatalities and those without. During the 1998–2007 period, stoves stand out in the Norwegian fatal fire statistics as the most common appliance when the cause of fire is faulty electrical equipment, or incorrect use of such equipment [10, 11].

It is being maintained that a large proportion of residential fires start as smouldering fires [17]. This is, however, hard to document, because the majority of fires

develop into flaming fires, which makes it hard or impossible to identify the smouldering afterwards. The majority of fatal fires have grown large when the fire brigade arrives and have spread out of the room in which the fire started [15]. However, it is a well-known fact that fires may start through smoldering in a number of materials, e.g., when upholstered furniture and mattresses are exposed to a smouldering cigarette, or through overheating in electrical installations near combustible insulation or wood.

2.3 Role of Furnishing in Fatal Fires

Furnishings, such as upholstered furniture, mattresses and textiles, are very important for the fire development in the early stages. Some of these products can be easily ignited, contribute to rapid spread of fire and produce a lot of smoke and heat when they burn. This limits the time available for safe egress, rescue and firefighting.

US statistics shows that more people die in residential fires that start in upholstered furniture, mattresses and bedding than in any other items. It is estimated that about 1% of the fire services' responses to home fires in the period 2013–2017 comprised fires that started in furnishings of these types, while as much as 17% of the fire fatalities could be related to these fires [12].

The picture is quite similar in other countries. Fire statistics from England for the period April 2019 to March 2020 shows that close to 5% of fires in dwellings started in soft furnishings. These fires led to 26% of the fatalities in dwelling fires [18]. Fires that started in all kinds of furniture and textiles in interior in the same period comprised 22% of all dwelling fires and 37% of related fatalities. Furnishing and textiles (clothing not included) were assessed to be the items mainly responsible for the fire development in 20% of these fires. These fires resulted in close to 47% of the dwelling fire fatalities [19]. This implies that fires involving such furniture items are more hazardous for people than other fires.

One of the conclusions from a Swedish study of residential fatal fires in the period 1999–2013 was that fires starting in the living room or bedroom more often result in fatalities than fires starting in other rooms [15]. Twenty-seven percent of fatal fires started in the living room, while 22% in the bedroom. Of the two thirds of the fatal fires where the first ignited object was known, 57% fires started in upholstered furniture, bed or other types of furnishing.

In a Norwegian study of fatal fires in the period 2005–2014, 37% of the fires started in the living room and nearly 13% in the bedroom. The first ignited material was not registered in the Norwegian statistics; however, it is reasonable to believe that soft furnishing contributed to a high degree in the start and development in many of these fires [20].

It is quite obvious that it is of crucial importance for residential fire safety to prevent these fires from starting and to mitigate or delay the fire development if an ignition should occur.

3 Regulation and Documentation of Fire Properties of Furnishing

3.1 Regulations

The probably most efficient way to control fire safety in residential buildings is to give mandatory requirements in regulations. Other requirements may be of more voluntary nature, e.g. directives given by insurance companies, by building owners, or by organizations. Different possibilities for regulation of the contents of residential buildings are shown in Fig. 10.3.

Fire safety of the construction elements and building products in a residential building is normally regulated through building codes and will not be discussed here.

Regulation of fire properties of interior textiles, armchairs, sofas and mattresses has been discussed nationally and internationally for many years, without resulting in more stringent requirements for such products, at least not on a harmonized level. All products sold on the European market, including loose furnishings, shall fulfil the General Product Safety Directive (GPSD) 2001/95/EC [21]. Although fire safety is not explicitly stated in the directive, it must be regarded as an important safety property of a product.

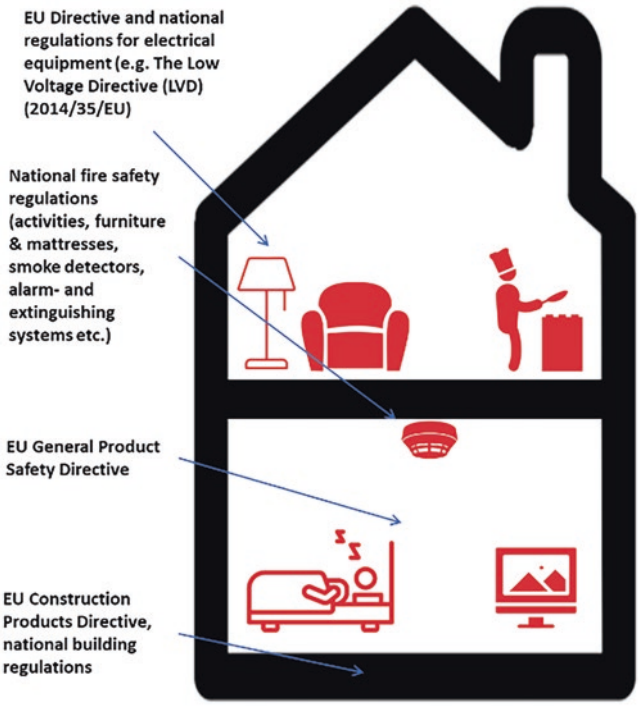

Fig. 10.3 Regulations on different levels can affect the fire safety level of the content in a home

Some European countries have regulations on this area, and there is a spread in where the regulations are applied (e.g. public buildings, private homes, hospitals etc.) and also in the level of required fire properties. Different ignition sources are used in the required tests for soft furnishing and span from a smouldering cigarette to a larger flaming source [22].

The European countries UK, Ireland, Germany, France, Portugal, Spain, Italy, Norway, Sweden and Finland have introduced fire requirements for loose furnishings. These requirements mainly cover public areas such as hospitals, prisons, hotels, theatres, etc. However, for the domestic environment, most countries lack fire requirements. In Europe, only UK, Ireland and the Nordic countries have fire requirements for private homes [23]. Both Norway and Sweden require that mattresses and upholstered furniture shall resist ignition by a smouldering cigarette.

Outside Europe, USA stands out as a country in the world with stringent requirements on loose furnishings, especially on mattresses where federal requirements apply in all states, and where a larger flaming ignition source is used in the testing for approval. For upholstered furniture, there are no federal requirements and each state is free to determine their own requirements. California is the state that places the most stringent requirements on upholstered furniture, and the ignition source applied in testing is a smouldering cigarette [24]. Ignition resistance against a smouldering cigarette is, however, the lowest level of fire requirements. This qualification gives no information about fire behaviour of the furniture item when exposed to a flaming ignition source.

The fire safety regulations on upholstered furniture and mattresses in UK were imposed in 1988 and are regarded to be rather strict, demanding that the products can withstand a relatively large flaming ignition source called *crib 5* [25]. Crib 5 is a flaming ignition source that gives a heat output approximately corresponding to half of that of a folded double-sheet of 22 g newspaper [26].

3.2 Documentation

In Europe, the fire safety properties of furnishing products are regulated by the Product Safety Directive. There are no requirements on CE marking of textiles and furniture.

For some types of buildings, like prisons, hotels and hospitals, there may be specific requirements describing fire properties of, e.g., mattresses and upholstered furniture, and do therefore also require that the products they purchase have sufficient fire safety documentation. Such documentation includes normally reports from fire testing according to recognized standards. The reports describe which standard was used, which ignition source the product was exposed to and the results from the test. Such information will also be relevant for private consumers who request fire rated furnishing products to increase the residential fire safety.

Fire safety measures do also need documentation. This is relevant for, e.g., extinguishing equipment, flame retardant chemicals, smoke alarms, fire detection

systems, stove guards, etc. The documentation shall contain information about possibly applied test methods or standards and obtained test results, any classification, applied assessment methods, scope and limitations of the product, instructions for application, mounting and use, efficiency, etc. For some products, information in a safety data sheet may also be of relevance.

4 Fire Safety of Furnishing Items

4.1 Fire Properties of Interior Textiles

Choosing textiles with good fire properties for furnishing items like curtains, blankets and pillows may be a simple way of improving the residential fire safety. In the initial phase of a fire, the fibre type and the textile construction are important factors for the fire behaviour of a textile. A denser and heavier woven textile will burn slower than a more loosely woven textile of the same material. The surface structure is also of importance; a textile with a fluffy surface will ignite more easily than the same material with a smooth surface. Factors that may have importance for the fire behaviour of textiles are:

- Chemical composition of textile fibres.
- Fibre density.
- Textile structure and surface.
- Thickness.
- Fire retardant treatment.
- Dirt (grease, dust).
- Fire properties of accessories such as ribands and tufts.

These factors may each affect the fire properties in different ways, some will have positive effect on fire behaviour, while others have negative. The fire behaviour will depend on the end-use application of the textile, e.g. if the textile is used as a curtain, carpet, or as cover textile on a sofa. The combination of materials in the interior product will also be important for the resulting fire properties, e.g. the combination of textile and upholstery foam in a piece of furniture. Different fire retardant treatments may have effect in different phases of the fire and could, for example, either prevent ignition or limit the combustion rate. Some fire retardants will act against smouldering ignition, while others are active against a flaming ignition source. A fluffy surface will generally be more easily ignitable than a smooth, dense surface, and the rate of flame spread in the textile will also be influenced by the surface structure.

This means that documentation of fire properties must be relevant for the textile product in its final use. If a textile is to be used as a curtain, the documentation must assess the fire properties in a configuration that is relevant for curtains, for example, by use of a recognized fire test method for free hanging textiles. If the textile is

Table 10.1 Fire behaviour of different furnishing textiles [27–30]

Fibre type	Fire behaviour	
Natural fibres	Cotton, linen (cellulosic fibres)	Easily ignitable. A char layer is formed during combustion. May initiate and support smouldering combustion.
	Wool, silk (protein fibres)	Less ignitable than cellulosic fibres. Contain nitrogen and can produce hydrogen cyanide during combustion.
Regenerated fibres	Viscose	Easily ignitable, burns quickly.
	Acetate, triacetate	Easily ignitable, burns quickly, melts and drips.
Synthetic fibres	Polyester	Shrinks away from the ignition source, melts and drips after ignition. Upward flame spread is often slow. Melted material increases horizontal and downwards flame spread.
	Polyamide (nylon)	As polyester, but contains nitrogen and can produce hydrogen cyanide during combustion.
	Acrylic fibre	Easily ignitable. High heat release during combustion, charring material. Contains nitrogen and can produce hydrogen cyanide during combustion.
	Modacrylic fibre	Less ignitable than acrylic fibre. Melts and withdraws from the flame. Regarded as flame-resistant fibre.
	Polyvinyl chloride (PVC)	Difficult to ignite. Melts and withdraws from the flame. Regarded as flame-resistant fibre. Contains chlorine and produces hydrochloric acid during combustion.
Inorganic fibres	Glass fibre	Non-combustible. Limited range of application since the fibre normally is brittle.

applied in upholstered furniture, the documentation must be based on a fire test method for this type of product, taking into account the other materials in that product with which a potential fire would interact.

Fire properties of some common furnishing textiles are listed in Table 10.1. All materials produce toxic smoke gases during combustion, and the type and concentration of gases and the amount of smoke will be of importance. A textile that is difficult to ignite and that burns slowly, giving off small amounts of smoke with a high degree of toxicity, may therefore be a better option than a textile that burns quickly with a high heat release and a fast flame spread.

4.2 Flame Retardants

Flame retardants are chemicals that are added to materials and products to reduce the risk of ignition and may further prevent or delay the fire development. Some flame retardants may provide a protective physical barrier between the flame and combustible material, by, e.g., formation of a char layer when exposed to heat. Other flame retardants may slow down or inhibit the combustion process by limiting the available oxygen for the combustion or by interacting with the chemical combustion reactions.

In recent years, there has been increasing awareness about the fact that some flame retardants affect health and the environment negatively, and this has caused concern about the consequences of fire safety regulations for interior products. It is feared that strict requirements to obtain a certain level of fire safety implicitly mean that harmful flame retardant chemicals need to be applied to the products in question to be able to pass the tests. Some flame retardants are no longer allowed to be used in many countries, e.g. brominated fire retardants. It is important to be aware of harmful effects and avoid use of unwanted products. However, there is also a request for fire retardant additives and chemicals that are environmentally friendly and that pose no health risk.

Most flame retardant textiles can be washed or cleaned as untreated textiles. The instructions for cleaning or washing must then be followed. The flame retardant effect can be reduced over time, through washing and wear-and-tear. There are also alternatives where the flame retardancy is built into the fibre matrix (e.g. the polyester-based Trevira CS) which make them inherently flame retardant.

Some flame retardants are added to the final material or product through impregnation or surface treatment. There are also products on the market intended to spray onto the object to increase the ignition resistance. It is important to follow the instruction manual thoroughly when such products are used and to assess if the intended application area is within the scope of the flame retardant chemical. This type of products can often not document a certain fire classification, but may improve the fire safety of highly combustible furnishing objects, textiles and decorations. The user instructions must be based on facts and relevant tests, and the manufacturers must be able to provide documentation of the efficiency of their products. It may, however, be difficult for non-fire-experts to assess the quality of the product if the fire documentation is not provided by a recognized organization (e.g. fire laboratory, research institution, university, certification body, etc.).

It should, however, be noted that fire retardant chemicals often are targeted against one type of achievement, most commonly to prevent or delay ignition. A flame retardant preventing ignition by a match flame may have little or no effect in decreasing the fire development with respect to flame spread and heat release when the object has been ignited. A flame retardant effective against flaming ignition may show no effect against smouldering ignition. Research projects indicate that there are no correlation between the ability to ignite by a smouldering cigarette and by a flaming source, and also that resistance to these small ignition sources does not reflect the fire growth properties of a furniture item [31, 32].

4.3 Upholstered Furniture and Mattresses

As mentioned in Sect. 2.2, one of the most common ignition sources in combination with upholstered furniture is a smouldering cigarette. However, other ignition sources are also possible, as a lit candle or a lamp that falls over in a sofa, sparks from a fireplace, radiant heat from an electric oven, etc.

It is a well-known fact that upholstered furniture and mattresses may ignite easily and burn rapidly with a very high heat release and a large production of toxic smoke [23, 32, 35, 36]. These fires lead to a larger percentage of fire fatalities than their percentage of fire causes would imply [12]. Fire in a single upholstered armchair may easily release enough heat energy to lead to a rapid flashover in an ordinary living room. Fire development in armchair is illustrated in Fig. 10.4.

Upholstered furniture is common as the first object ignited in residential fires, but does also have an important role as the object responsible for further fire development [19, 32, 37]. The largest part of the fire load is normally contained in the filling material and therefore it is important to prevent that a fire spreads from the cover fabric to the filling material. One way of improving the fire properties of soft furnishing is to add chemical flame retardants to the cover fabric or to the filling material or both. This could both improve the ignitability of the products and slow down the fire development. However, as described in Sect. 10.5.2, there is a large concern about flame retardants today, as many of these products may lead to harmful health and environmental effects.

However, to avoid any fire performance requirements as a means to reduce the use of flame retardants is not a good idea. As a minimum, there should be a small flame ignition resistance requirement, to ensure that furniture is not easily ignitable. Although there may still be a conflict between fire performance and the use of chemical flame retardants, it is better to have low fire safety requirements, than no requirements at all. In that way, a focus is maintained upon reaching a certain fire performance level. Fire performance requirements on individual furniture components (e.g. foam, cover) should be avoided since this may force unnecessary use of chemical flame retardants.

Considerable research has been performed to solve the fire safety problem connected to soft furnishing products over the years, and lately, the development of sustainable and environmentally friendly fire safe upholstered furniture has been

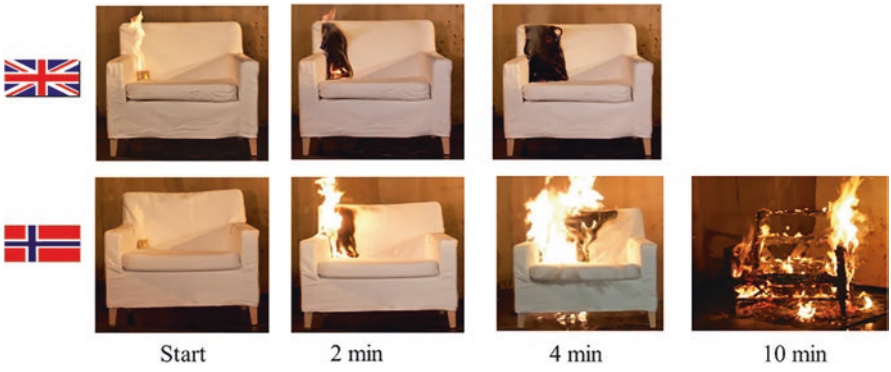

Fig. 10.4 Comparison of fire development in upholstered armchairs with identical design. The chair in the upper photos satisfies the UK fire safety requirements (resist exposure to ignition source crib 5). The chair in the lower photos satisfies the Norwegian requirements (resist ignition by a smouldering cigarette). (Photos: Thor Kr. Adolfsen, Norwegian Fire Protection Association)

brought into focus [15, 26]. Research shows that it could be possible to increase the fire safety level of such products considerably through smart combinations of materials and clever design [23, 35, 39–41]. A correct use of materials will constitute an adequate barrier against ignition in many cases, also without using flame retardant chemicals. There is promising work showing that introducing a textile as a barrier material between the upholstery foam and the cover material is efficient in reducing the fire hazard from burning upholstered furniture [31, 32, 38, 39] and that the interaction between the barrier and cover material is important for the fire growth [36].

For mattresses, the requirements might be different, since a weak ignition protection in a mattress will not be adequate if the duvet and pillow are ignited first, which represents a large start fire.

One of the challenges with fire safety of upholstered furniture and mattresses is that such products may have a long lifetime in a home and it is often not an option, or not even wanted, to replace them with new products with the required fire properties. It is therefore a need for simple, efficient safety measures that can be applied on existing furniture, with the aim of protecting the highly combustible filling material from heat and flame. There exist spray-on flame retardant chemicals on the market that could be a solution in that it prevents the cover material from ignition and further flame spread. Another solution with this effect is to cover the furniture or even replace the cover material with fabrics of better fire protective properties (e.g. a dense wool fabric). If the furniture has a detachable cover fabric, a fire barrier material could be introduced between the cover and the foam.

4.4 Curtains and Draperies

Curtains are manufactured in many different types of fibres, both natural, regenerated and synthetic. The fire load (i.e. the energy content) of a curtain is normally not very large (depending on the size of the curtain) compared to other elements of the furnishing. However, fires often start in curtains and may spread rapidly in the material itself or when the burning curtain falls down and ignites another object, like an upholstered sofa.

Larger draperies and door curtains may, however, release large amounts of heat in a fire and may lead to flashover in a smaller room [33].

4.5 Bedding Items

Duvets and pillows are composite products consisting of a cover material and a filling material. The cover material is normally a textile of cotton, polyester, a mixture of these fibres, or can be made of other types of fibres. Common filling materials are down, mixtures of feathers and down, and polyester fibres [27, 28].

Duvets and pillows will normally resist ignition from a smouldering cigarette in a standardized test, but often not ignition from a match flame.

The bedding items in use are covered with quilt covers and pillow cases, often made of cotton, linen, polyester or blends.

The combination of the cover materials and the filling materials is determining for how a fire may develop in the bedding items. A fire that starts in a duvet can become a large ignition source that would expose the mattress and other combustible objects in the vicinity. Some mattresses on the market are tested for resistance to larger fire sources and will probably resist ignition from a burning duvet. Documentation of fire properties shall then be available for these mattresses.

There are bedding items on the market that contain flame retardant chemicals or fibres. These products may be good alternatives when fire start in the bed is regarded as a risk. Flame retardant products are described briefly in Sect. 10.3.2.

4.6 Carpets

A fire may start in a carpet or it may spread to the carpet from other burning objects, like curtains, upholstered furniture or a mattress. The fire spread in the flooring material will normally be of importance at some stage after the initial phase in the fire. There may be exceptions, for example, if the initial fire exposure is larger than the type of ignition source the flooring is intended to resist, the flooring may contribute considerably to the fire development [34]. As for textiles in general, the ignition and fire spread ability of the carpet will depend on factors like fibre type, density, surface structure (fluffy or smooth), backing material, adhesives, etc. A dense wool carpet with short pile is an example of a carpet that would be expected to have relatively good fire properties. A fluffy carpet made of easily ignitable textile fibres will probably show a poor fire behaviour.

5 Other Methods for Prevention of Ignition in Dwellings

5.1 Reduced Ignition Propensity Cigarettes (RIP)

As already mentioned, a smouldering cigarette is the most common ignition source for ignition of upholstered furniture and mattresses. Seventeen percent of all fatal fires with known fire cause in Norway in the periods 1997–2008 and 2005–2014 were due to smoking [20, 42]. Likewise, smoking material is identified as the leading cause of fatal fires in many countries worldwide [12, 14, 15, 43, 44]. In November 2011, a regulation on self-extinguishing cigarettes was introduced in the EU and EC. Such cigarettes are designed so that they do not burn in all their length but

self-extinguish if they are left unattended. The purpose of the requirement was to reduce the number of fires caused by cigarettes [45].

However, it is unclear whether the regulatory requirements for self-extinguishing cigarettes have had the desired effect on fire statistics. US Consumer Product Safety Commission reported in 2012 that it was premature to conclude that use of the RIP cigarette alone will greatly reduce the threat of unintentional fires ignited by cigarettes involving mattresses or soft furnishings [46]. A Swedish study performed 3 years after the introduction of the requirement for self-extinguishing cigarettes on the market was not been able to demonstrate any effect either on the fire statistics or on the fatal fire statistics [47]. Furthermore, small-scale tests were performed on models of upholstered furniture, where it was observed that the cigarettes mainly smouldered in their full length without extinguishing. The solution with introducing RIP cigarettes must therefore be viewed with caution, as it cannot be said to be an efficient or reliable fire safety measure on its own.

5.2 Smoking Apron and Smoking Blanket

Smoking aprons and smoking blankets are made of fire-resistant textile and are used for covering the clothing of persons when they are smoking tobacco. These measures are mostly used when the smokers themselves are not able to deal with situations where embers fall from the cigarette and where they need help to be able to smoke. As it has not been demonstrated that the requirement for self-extinguishing cigarettes works as expected, one should not solely rely on these types of cigarettes, but rather use a smoking apron or smoking blanket where this type of measure is practical [5].

5.3 Protection of Electric Components

Electrical components can pose an increased risk of ignition due to negligent use or because of faulty devices, either through their heat generating function or loose currents leading to over-heating, e.g. in sockets. Electric ovens, dishwashers, washing machines and dryers are examples of electrical equipment that can generate heat and cause ignition. This type of ignition can be prevented by component protection that causes the power to such equipment to be turned off when a dangerous situation is detected. Protection can be achieved by integrating an electronic switch between the frame and the outlet or integrated as part of the fixed electrical installation. This protection technology is being used in electrical equipment in homes. On one hand, it is intended to control and monitor the parameters of electrical devices, household appliances, heating and lighting. On the other hand, it is used to disconnect the power supply when a dangerous situation is detected [5].

There are also possibilities of installing specific extinguishing systems that are integrated into the electrical installation (e.g. socket) or electronic device. The integration of component protection in electrical appliances can also relate to smoke and heat detectors and other sensors such as people presence. The integration allows the adjusting of the logic of the control unit. If, for example, these sensors detect smoke in a laundry room, the power can be disconnected from all appliances in that area [5].

In addition, these control systems can communicate via the internet and send an alarm signal to an external monitoring service. A challenge for component protection is the time required for disconnection of devices when overheating is detected. A fire may start before the network connection is cut off and fire spread may not be able to be prevented.

6 Concluding Remarks

This chapter is dealing with different ways to prevent fire from starting in dwellings and methods that will prevent a small fire from developing into a large and uncontrollable fire. The chapter's main focus is on fire properties of materials in the furnishing.

However, a key word is holistic thinking in order to obtain an optimal fire safety solution. The fire safety measures mentioned here should be used in combination with active measures for detection and mitigation, and there should also be organizational measures that ensure that the right measures are implemented for the person in question, and that the fire safety is maintained and revised regularly.

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Prof. Anne Steen-Hansen has been working as a professor in Fire Safety Engineering at the Norwegian University of Science and Technology (NTNU) since August 2019, and has also a part-time engagement as a Chief Scientist at RISE Fire Research in Trondheim. She holds a MSc in physics and mathematics from 1986 and received her PhD on the topic smoke production in 2002. Her field of interests includes materials' reaction to fire, fire investigation, fire statistics, domestic fire safety, industrial fire safety and fire terminology. Anne is the Director of the Fire Research and Innovation Centre (FRIC) in Norway, and has been President of EGOLF (European Group of Organisations for Fire Testing, Inspection and Certification) from 2016 to 2022.

Mrs. Karolina Storesund has been working as a senior scientist at RISE Fire Research in Trondheim, with particular focus on reaction-to-fire properties and fire safety for vulnerable groups. She holds an MSc in Textiles from University of Leeds. Karolina was Director of the Fire Research and Innovation Centre and is now coordinator at the Norwegian Research Center for AI Innovation at the Norwegian University of Science and Technology (NTNU).