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European Fire Safety Alliance

Fire safety of fire safe cigarettes

International review and Dutch data

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Management summary

In order to reduce the high risk of smoking-related fire deaths, the European Union (EU) has taken measures regarding cigarettes that are sold in packs (prefabricated packed cigarettes). Since November 2011, there has been a requirement in the EU for these cigarettes to self-extinguish so that they cannot easily set fire to other materials (such as upholstered furniture, mattresses and beddings). This is called the lower ignition propensity (LIP). The envisaged fire-safe character of the current prefabricated cigarettes is an implementation of the requirement to make cigarettes less fire-prone. For reasons of clarity, this report uses the term 'fire-safe cigarette' instead of 'lower ignition propensity (LIP) cigarette'.

The Fire Service Academy, part of the Institute for Safety (IFV), acknowledges the high risk of smoking-related fire deaths; this has been substantiated by its annual study into fatal residential fires[1]. The question is whether the number of victims of residential fires can be reduced by tackling one of the known causes, i.e. burning cigarettes. The Fire Service Academy is therefore interested in the effect of fire-safe cigarettes on fire safety in people's living environment. The goal of the study is to obtain an understanding of the reduced propensity of fire-safe cigarettes to ignite specifically upholstered furniture and of their influence on fire safety in people's living environment. As regards the ignition propensity of fire-safe cigarettes, both their effect under test conditions and their effect in starting a residential fire have been studied. For the purpose of the study, a review was conducted of the available literature, consisting of scientific articles and research reports.

The study reveals that the measure of introducing fire-safe cigarettes plays a limited role in reducing the number of smoking-related fire deaths as there are several factors that influence the probability of smoking-related fire deaths:

> socio-economic factors that can lead to a fire starting[2]
> the source of ignition (the cigarette) and the object of origin (such as furniture) during the ignition phase of the fire
> the contribution of objects in the vicinity to - particularly - the smoke development in the post-ignition phase, and
> the conditions of the victim during the fire[3].

The measure of introducing fire-safe cigarettes focuses on the source of ignition during the ignition phase of the fire and not on other factors that influence the probability of smoking-related fire deaths.

Based on a field study, the Netherlands food and consumer product safety authority (NVWA) has concluded that commercially available fire-safe cigarettes are generally sufficiently safe in fire tests as specified by the Standard[4]. Another conclusion is that the measure of introducing fire-safe cigarettes focuses on a limited portion of tobacco products that can cause residential fires since the measure exclusively addresses prefabricated and legally

[1] About one in twenty fires in buildings is caused by smoking (Statistics Netherlands, see section 3.3.2), whereas about one in three fatal residential fires is a smoking-related fire (Fire Service Academy, see section 3.3.3).
[2] Smoking-related fires occur relatively more frequently in connection with people with a low income, with people of over 65 whose mobility is limited, and with people with drinking and/or drug issues.
[3] Being under the influence (or not) of narcotics (alcohol, drugs, medication), sleeping, limited mobility, etcetera.
[4] NEN-EN 16156 and EN ISO 12863.

traded cigarettes. According to the Standard, three quarters of those cigarettes have to actually be fire-safe in a fire test and one quarter is allowed to fail the test. Due to the scope of the Standard and the failure percentage permitted, a maximum of two[5] to three[6] in five cigarettes smoked is fire-safe in test conditions.

It has been found that the introduction of fire-safe cigarettes has hardly reduced the ignition propensity of cigarettes used at home. The characteristic parts of the fire test in the Standard consist of the substrate and the position of the cigarette. The substrate on which the cigarette is tested consists of layers of filter paper instead of materials in which residential fires often start, such as mattresses, beddings and upholstered furniture. The position of the cigarette in the test is horizontal and static, whereas residential fires can also be caused by falling cigarettes, whose burning end can be inclined downwards or upwards. The position of the cigarette influences the way in which the cigarette comes into contact with the substrate. Both tests where upholstery and mattresses were used as substrates and tests with falling cigarettes showed that fire-safe cigarettes are just as fire-prone as non-fire-safe cigarettes. This justifies the conclusion that the fire test in the Standard is not representative of how smoking-related residential fires start.

And finally, the effect of the introduction of fire-safe cigarettes on the number of smoking-related fire deaths cannot be established conclusively. Significant positive effects have been observed in several studies, with decreases in the number of fatalities by more than 40 %. On the other hand, no demonstrable effects have been observed in other studies. These opposing conclusions are sometimes even arrived at on the basis of one and the same dataset. Furthermore, the effect of the introduction of fire-safe cigarettes is hard to measure since other fire safety measures may also contribute to a reduction in the number of smoking-related fire deaths, such as improvements to public fire education, the use of smoke alarms, and/or improvements to the ignitibility of upholstered furniture and mattresses.

[5] In the event that 75 % of all fire-safe cigarettes pass the test.
[6] 42 % are not covered by the regime of the Standard and 15 % of all cigarettes are allowed to fail the fire test, which is one quarter of the 58 % of fire-safe cigarettes.

Contents

Introduction

Background

In order to reduce the relatively high risk of smoking-related fire deaths, the European Union (EU) has taken measures regarding cigarettes that are sold in packs (prefabricated packed cigarettes). Since November 2011, there has been a requirement in the EU for these cigarettes[7] to self-extinguish so that they cannot easily set fire to other materials (such as upholstered furniture, mattresses and beddings). This is called the *lower ignition propensity* (LIP). The term *reduced ignition propensity* (RIP) is sometimes also used outside Europe. The envisaged fire-safe character of the current prefabricated cigarettes is an implementation of the requirement to make cigarettes less fire-prone.[8] For reasons of clarity, this report therefore uses the term 'fire-safe cigarette' instead of 'lower ignition propensity (LIP) cigarette'. Since 2011, all prefabricated packed cigarettes sold in the EU and, by analogy, also in the Netherlands, have been 'fire-safe' cigarettes. These cigarettes self-extinguish when they are no longer actively smoked[9]. As a result, no fire should start in furniture or beds as a result of inattentiveness while smoking. The European Committee expects that the introduction of the LIP regulations will lower the probability of victims of smoking-related fires compared to the situation with non-fire-safe cigarettes[10].

The testing of the ignition propensity of self-extinguishing cigarettes is based on the European standards EN 16156 and EN ISO 12863. In order to reduce the number of smoking-related fires, requirements are also set on the fire safety of furniture in Great Britain and the United States. In a similar fashion, measures to make furniture fire-safe, possibly through legislation, have been discussed in the Netherlands. Manufacturers have identified the introduction of the fire-safe cigarettes as one of the arguments against the use of flame retardants in fire-safe furniture and beds. In a *policy paper* (EFIC, 2016), they claim that fire safety can be achieved in other ways and they refer to fire-safe cigarettes as one of the alternative measures.[11]

Goal and research questions

The Fire Service Academy, part of the Institute for Safety (IFV), is interested in the effect of fire-safe cigarettes on fire safety in people's living environment. The goal of the study is to obtain an understanding of the reduced propensity of fire-safe cigarettes to ignite specifically

[7] Hand-rolled cigarettes, pipe tobacco and cigars do not need to fulfil the fire safety requirements that apply to prefabricated cigarettes. It is not clear why this distinction is made, given that all types of tobacco products can cause fire.
[8] The lower ignition propensity can also be achieved by other methods.
[9] 'Active smoking' means that the smoker takes a puff.
[10] 'Non-fire-safe cigarettes' refers to prefabricated packed cigarettes that were sold prior to November 2011 (and illegally imported prefabricated packed cigarettes).
[11] Due to the Open Flame Test, which is used for testing the fire safety of furniture, manufacturers often opt for the use of flame retardants in the form of chemical additives. But such additives have been found to pose environmental and health hazards. The European Furniture Industries Confederation (EFIC) therefore claims in the *Policy paper: The case for flame retardant free furniture*, that it prepared together with other organisations, that *"*A high level of fire safety can be achieved in other ways. Smoke detectors, automatic sprinklers in buildings, self-extinguishing cigarettes and candles, reduced smoking rates, better material combinations in furniture, and improved fire safety education all increase fire safety without potential harm from flame retardant use*".*

upholstered furniture and of their influence on fire safety in people's living environment. The main question of this study is:

To what extent do fire-safe cigarettes contribute to reducing the number of smoking-related fire deaths?

Sub-questions are:

1. What is known in the literature regarding the ignition propensity of fire-safe cigarettes in test conditions?
2. What is known in the literature regarding the ignition propensity of fire-safe cigarettes used in people's living environment?
3. What is known in the literature regarding the real-life effect of the introduction of fire-safe cigarettes on smoking-related fire starting and smoking-related fire deaths?

Demarcation and study method

The study is limited to a literature review for the purpose of which several scientific articles and research reports were studied. The report on the Swedish study into the theory and reality of fire-safe cigarettes by Larsson and Bergstrand (2015) was the starting point for the collection of relevant literature. Some of the literature they used was also studied in the context of this review. In addition, the recent literature review by Baker, Coburn, Liu and McAdam (2016) on *The science behind the development and performance of reduced ignition propensity cigarettes* was also an important source for this study. Next, internet searches with search terms such as ‘LIP cigarette’ and ‘lower ignition propensity’ were used to find additional relevant literature available in digital libraries of renowned foreign research institutions[12] and international scientific journals[13]. Information was also gathered through personal contacts with fellow-researchers abroad and through ResearchGate.

[12] Such as NIST, NFPA, SP Technical Research Institute, TriData and KPMG LLP.

[13] I.e. Fire Technology, Fire Science Reviews, American Journal of Public Health, European Journal of Public Health Injury Prevention, Burns, Injury Epidemiology, Inhalation Toxicology and Tobacco Control.

1 Regulations for fire-safe cigarettes

This chapter addresses the sub-question: What is known in the literature regarding the ignition propensity of fire-safe cigarettes in test conditions?

1.1 The measure of introducing fire-safe cigarettes

Although smoking is not one of the most common causes of fires, or of residential fires, a fire due to a 'neglected' cigarette more often results in injuries and/or deaths than fires due to another cause. About one in twenty fires in buildings is caused by smoking (Statistics Netherlands, see section 3.3.2), whereas about one in three fatal residential fires is a smoking-related fire (Fire Service Academy, see section 3.3.3). Foreign statistics confirm such a high probability of smoking-related fire deaths.[14]

The relatively high risk of people falling victim to smoking-related fires was cause for the US Congress to adopt the *Cigarette Fire Safety Act* in 1984 in order to study whether cigarettes could be made fire-safe. Consequently, in 2004, the state of New York was the first state to introduce regulations for fire-safe cigarettes (Bonander, Jonsson, & Nilson, 2015). Since that time, it has only been allowed to sell cigarettes that successfully passed a fire test according to the standard *ASTM E2187 Standard Test Method for Measuring the Ignition Strength of Cigarettes*. Canada introduced similar regulations on October 1st, 2005. Australia introduced the ASTM method on March 9th, 2007, after which these regulations were also introduced in New Zealand and South Africa in 2009. The ASTM E2187 has been in effect in all American States since late 2017.

Finland was the first European country to introduce regulations on the fire safety of cigarettes. Since April 1st, 2010, only fire-safe cigarettes have been allowed to be sold there. Since November 18th, 2011, cigarettes sold in any country of the European Union have to comply with the European standards *EN 16156:2010 Cigarettes – Assessment of the ignition propensity – Safety requirement* and *EN ISO 12863:2010 Standard test method for assessing the ignition propensity of cigarettes.*[15] This test method compares to the American test method and measures whether a cigarette continues to burn while lying horizontally on one of three standard substrates (see also section 0). In order to enable them to pass the test, the design of the cigarettes has been changed.

Virtually all fire-safe cigarettes that are currently sold (Li, Pang, Xing, Wang, Liu, McAdam & Xie, 2014; Alpert, O'Connor, Spalletta & Connolly, 2010) have special paper incorporating two thicker buffer bands. In a rolled cigarette, these buffer bands form rings that

[14] In its research publication *NFPA's Latest Estimates of Home Fires Started by Smoking Materials – 2014,* the NFPA states that 5 % of fires in the US are smoking related and that 21 % of all fire deaths died as a result of smoking-related fire. An average of 6 % of all accidental residential fires in the UK in the period from 2010 to 2016 was smoking-related and 36 % of all residential fire deaths died due to smoking-related fires (source: https://www.gov.uk/government/statistical-data-sets/fire-statistics-data-tables#cause-of-fire).

[15] EN 16156:2010 Cigarettes — Assessment of the ignition propensity — Safety requirement and EN ISO 12863:2010 Standard test method for assessing the ignition propensity of cigarettes.

compartmentalise the cigarette. The rings slow down the burn rate and enable less air (air/oxygen) to flow to the lit end of the cigarette. The oxygen reduction extinguishes the cigarette when it is not actively smoked. This shortens the burning time of the cigarette, thus reducing the probability of fire starting in furniture, beds and other materials. The composition and dimensions of the buffer bands can differ for different brands of cigarette, as can the thickness of the paper and the amount of fire-accelerating additives, such as citrate, and porosity-enhancing agents, such as calcium carbonate (Alpert et al., 2010).

In the early 1990s, when the National Institute of Standards and Technology (NIST) developed the ASTM standard, several parts of the cigarette were identified that might be able to influence the ignition propensity (Baker, Coburn, Liu & McAdam, 2016; Li et al., 2014).

- The main factor in reducing the ignition propensity is to reduce the density of the tobacco (Gann, Harris Jr, Krasny, Levine, Mitler & Ohlemiller, 1987; Krasny, Harris Jr, Levine & Gann, 1989; both in: Baker et al., 2016). The reduced density leads to less fuel being available relative to the length of the cigarette. The density can be reduced by cutting the tobacco more coarsely. However, the tobacco column must have a certain density in order to shape the cigarette (Norman, 1999; Nakanishi, 1999; both in: Baker et al., 2016).
- The second important factor in reducing the ignition propensity is the air permeability of the paper (Norman, 1999 in: Baker et al., 2016), which was corrected into the diffusivity of the paper in a later study (Norman, 2005; in: Baker et al., 2016). However, reduced air permeability of paper also leads to more, unhealthy smoke being emitted, and can therefore only be applied to a limited extent.
- The third important factor is the thickness of the cigarette, since, on the one hand a thinner cigarette leads to less fuel being available and, on the other hand, to a smaller contact surface with the substrate (which may or may not ignite in the test according to the standard).
- The fourth factor, reducing the amount of fire-accelerating additives[16] (such as potassium citrate), has a varying effect on the ignition propensity (Baker et al., 2016).

It has also been found that cigarettes without filters have a greater ignition propensity than cigarettes with filters, with the length of the filter influencing the ignition propensity of the cigarette (Gann et al., 1987; Harwood et al., 1993; both in: Alpert et al., 2016).

The industry has mainly focussed on the use of special paper to achieve the lower ignition propensity (Alpert et al., 2010). On the one hand, changes have been made to the filter paper that has flame retardant and oxygen reducing effects, i.e. the thicker buffer bands, but fire-accelerating and porosity increasing additives have also been added to the filter paper. It is not known if the effects of these two changes offset each other in practice.

[16] See the website of the RIVM for a summary of additives for the different brands of cigarette: http://www.rivm.nl/toevoegingentabaksproducten/products.html

1.2 EN 16156 and test method EN ISO 12863

EN 16156 requires that cigarettes that are not actively being smoked self-extinguish before the cigarette has fully burned up. In order to test if a certain type of cigarette fulfils this condition, 40 cigarettes of that type are tested using the method established in EN ISO 12863. At least 30 of the 40 cigarettes tested (75 %) must self-extinguish before the cigarette has fully burned up. It is not clear why 25 % of all cigarettes tested do not have to pass the test. By permitting a considerable portion of approved cigarettes to keep burning until there is nothing left of them, there is still a risk of fire, also with a fire-safe cigarette.

The test measures the probability that the cigarette continues to burn and will ignite the substrate. To test this, a burning cigarette is laid horizontally onto three types of substrate. The substrates are standard heat-absorbing carriers, consisting of 3, 10 or 15 layers of filter paper. The tests are carried out in a climate-controlled environment where the relative humidity is (55 ± 5) % and the temperature is (23 ± 3) °C.

With a fire-safe cigarette that features buffer bands in the paper (indicated in blue in the figure below), there are four situations that can occur and determine the test outcomes of the fire-safe cigarette, see figure 1.1.

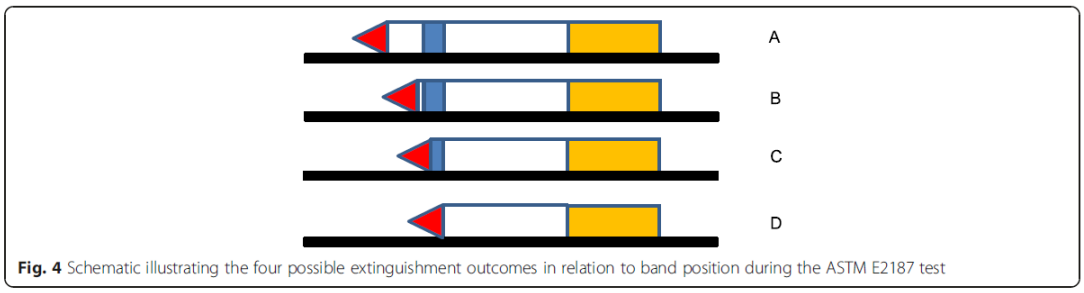


Fig. 4 Schematic illustrating the four possible extinguishment outcomes in relation to band position during the ASTM E2187 test

Figure 1.1 The four possible test outcomes of a fire-safe cigarette (Baker et al., 2016)

In situation A, the cigarette extinguishes long before the buffer band is reached. This may be caused by the fact that the smouldering tip of the cigarette only contacts the substrate. In situations B and C, the band plays a role in the extinguishing process because it creates a lack of oxygen in the compartment near or in the band, causing the cigarette to extinguish. In situation D, the cigarette extinguishes right after the fire has passed the band. It is plausible that the band also plays a role in suppressing the smouldering process in the tip of the cigarette. A cigarette designed as a fire-safe cigarette that does not pass the test, is a cigarette whose buffer band has not been constructed effectively. As a result, the cigarette cannot reach one of the four situations shown in figure 1.1. The production process of the paper, especially the fibre size, band width and air permeability checks, has been found to be decisive in order to guarantee a consistent capacity to self-extinguish (Baker et al., 2016).

In order to assess whether the producers comply with EN 16156:2010, the Dutch NVWA conducted a market study in 2013 (NVWA, 2013). The results showed that one of the 90 samples tested did not comply with the Standard since 57.5 % of the cigarettes of that one sample continued to burn, whereas a maximum of 25 % is allowed.

Results of the market study by NVWA
A total of 1140 fire-safe cigarettes were studied, 66 of which burned up completely (5.8 %).

Firstly, the 90 different brands/types of cigarette were subjected to a screening study (10 cigarettes for every sample). This showed that for:
> 71 samples all 10 cigarettes studied self-extinguished
> 13 samples 1 in 10 cigarettes studied burned up
> 4 samples 2 in 10 cigarettes studied burned up
> 2 samples 3 in 10 cigarettes studied burned up

The six samples for which more than one in 10 cigarettes burned up were subjected to a more extensive examination. This showed that for:
> 1 sample 1 in 40 cigarettes studied burned up (2.5 %)
> 1 sample 2 in 40 cigarettes studied burned up (5 %)
> 1 sample 3 in 40 cigarettes studied burned up (7.5 %)
> 2 samples 5 in 40 cigarettes studied burned up (12.5 %)
> 1 sample 23 in 40 cigarettes studied burned up (57.5 %)

The study was conducted on legally traded prefabricated packed cigarettes and shows that 94.2 % of the cigarettes tested is fire-safe in the test conditions.[17] This means that these cigarettes extinguish on the substrate as prescribed in the Standard.

1.3 Scope of the LIP regulations

In order to gain an understanding of the scope of the regulations on fire-safe cigarettes in the Netherlands, the market share of fire-safe cigarettes compared to that of illegal packs of cigarettes and of hand-rolled cigarettes was studied.
The Dutch tobacco retail sector publishes details on the internet[18] about the sale of cigarettes and loose tobacco (shag and pipe tobacco). In the period from 2012 to 2014, the number of prefabricated packed cigarettes sold decreased to an average of 10.5 billion a year, compared to an average of 12.5 billion a year in the period from 2010 to 2011. The sale of loose tobacco is measured in kilos. This has been converted into the number of hand-rolled cigarettes; see the text block below.

A study by KPMG (2016) shows that, on average, 1.7 billion cigarettes were illegally imported into the Netherlands in the period from 2010 to 2011 and 1.3 billion in the period from 2012 to 2014. In general, fewer cigarettes have been sold after the introduction of the LIP regulations; the number of legally sold and hand-rolled cigarettes has also decreased, see table 1.2.

[17] The first phase of the study consisted of 10 cigarettes each being studied for 90 brands of cigarette. That is a total of 900 cigarettes. 27 of those cigarettes burned up. The second phase of the study consisted of 40 cigarettes each being studied for 6 brands of cigarette. That is a total of 240 cigarettes. 39 of those cigarettes burned up.
[18] See the website of the Dutch tobacco retail sector:
https://www.tabaksdetailhandel.nl/assortimenten/tabak/marktcijfers/marktcijfers_kerftabak en
https://www.tabaksdetailhandel.nl/assortimenten/tabak/marktcijfers/marktcijfers_sigaretten

Determination of the number of hand-rolled cigarettes based on kilos of tobacco measured

It is estimated that some 40 cigarettes can be rolled from a 42.5-gram bag of shag tobacco. That is 941 hand-rolled cigarettes per kilo of tobacco. It is not known how much of the loose tobacco sold in the Netherlands is used for smoking cigarettes or pipes. However, similar data is known for all of Europe. According to Matrix Insight (2013), the relative market share of hand-rolled cigarettes in 2010 was 6.8 % and that of pipe tobacco was 0.3 %. This means that 96 % of the loose tobacco sold was used for cigarettes.

In the period from 2012 to 2014, 7.0 million kilos of loose tobacco were sold on average, compared to an average of 8.1 million kilos in the period from 2010 to 2011. This averages out to 6.3 billion hand-rolled cigarettes in the period from 2012 to 2014, compared to an average of 7.3 billion in the period from 2010 to 2011.

Table 1.2 Sales of prefabricated cigarettes and tobacco for hand-rolled cigarettes

	Prefabricated cigarettes		Hand-rolled cigarettes	Total
	Legal (fire-safe)	Illegal		
2010-2011	12.5 billion (58 %)	1.7 billion (8 %)	7.3 billion (34 %)	21.5 billion (100 %)
2012-2014	10.5 billion (58 %)	1.3 billion (7 %)	6.3 billion (35 %)	18.1 billion (100 %)

Illegally imported cigarettes and hand-rolled cigarettes are not covered by the regulations on the fire safety of cigarettes. Furthermore, according to the Standard, it is allowed that a quarter of all legally sold cigarettes are not fire-safe. As a result, the measure of fire-safe cigarettes concerns 44 % to 58 % of all cigarettes in the Netherlands.[19]

1.4 Reality of the test method

Coburn, Liu & McAdam (2013) question how realistic the test method (ASTM E2187) actually is. They noted that:

> The development stages of the ASTM E2187-based test methodology have, through necessity, resulted in a simplification of real world fire scenarios involving smoking materials. Each simplification represents a significant departure from reality which would need to be validated by real fire statistics over a period of time. It is also important to note the ASTM E2187-based tests are an evaluation of the extinction potential of the cigarette under carefully controlled laboratory conditions, rather than the ignition potential, as the latter would be highly dependent upon many other factors in real world situations.

Therefore, they also concluded that several measures will be needed in order to reduce the number of cigarette-related fires. An example they gave is the small number of fires starting in upholstered furniture that result in a disproportionately high number of deaths and losses.

[19] The total market share of legally sold cigarettes is 58 %. In accordance with the Standard, at least three quarters of the cigarettes sold are actually fire-safe. That is a market share of 44 % (0.75 * 58 %).

Therefore, in order to reduce fire by cigarettes, it should not only be the cause of the fire that is considered, but the *fire initiation event* (in other words: the combination of the source of ignition and the object of origin).

Baker et al. (2016) also acknowledge – based on studies by Ahrens (2011; 2013) – that the test method according to ASTM E2187 uses a simplified ignition scenario compared to the multitude of possible scenarios that occur in real life. Furthermore, laboratory research by the American Consumer Product Safety Commission (CPSC), Division of Combustion and Fire Sciences (Mehta 2012, in: Baker et al., 2016) has shown that the outcome[20] of the ASTM test is not a good basis to predict the smouldering behaviour of the substrate if the standard test paper is replaced by furniture upholstery. Baker et al. (2016) therefore also asserted that the simplified standard method-based fire-safe cigarettes should not be used as the sole or main solution for reducing cigarette-related fire risks, since the test method's technical approach does not consider the composition or the physical shape of the substrate, both of which have an important influence on the ignition propensity. Just like Coburn et al. (2013) they indicated that several measures were needed in order to reduce smoking-related fires and their consequences.

Larsson and Bergstrand (2016) concluded from a real-life study into the ignition propensity of cigarettes on combinations of upholstery that approved fire-safe cigarettes burned up completely in two thirds of all test situations (see also section 2.3). The tests were conducted in accordance with EN 1021-1, using both the standard substrate (cellulose paper) and different combinations of upholstery. It was found that the results of the standard test using the cellulose paper do not correlate with the results of the tests where the combinations of upholstery were used as the substrate.

An as yet unpublished study by Andrews of the University of Central Lancashire[21] (UK) into the ignition propensity of fire-safe cigarettes (in accordance with EN ISO 12863) in real-life fire situations also shows that the manner in which the cigarette contacts the substrate is important. Here tests with falling cigarettes, instead of with horizontally and statically placed cigarettes, were carried out. Three contact situations were tested:

> cigarettes that fall down with their burning end at an angle *below* their horizontal position (with their burning end inclined downwards)
> cigarettes that fall down with their burning end at an angle *higher than* their horizontal position (with their burning end inclined upwards)
> cigarettes that fall down in a vertical position with their burning end pointing down (with their burning end pointing down in a straight line).

It has been found that the fire-safe cigarettes burn up fully if they fall down with their burning end inclined downwards and that this tends to happen less if they fall down with their burning end inclined upwards. All tested cigarettes that fall down with their burning end pointing straight down burn up completely. If a cigarette is discarded such that its burning end lands in a waste bin or a crevice in an armchair, the cigarette can burn up completely. In fact, a smouldering fire in the armchair actually started in the tests. Fire also started in the tests with wood chips, both with the fire-safe cigarettes and with some hand-rolled cigarettes. The test results confirm the picture sketched by Coburn et al., Baker et al. and Larsson and Bergstrand, namely that the tests according to the ASTM E2187 and EN ISO 12863 are not realistic.

[20] Such as a fire-safe cigarette or not, and extinguished in time or burned up completely.
[21] Information obtained through email contact. Stephen Andrews is a Senior Lecturer in Forensic Fire Investigation at the University of Central Lancashire (United Kingdom) and a researcher.

2 Fire-safe cigarettes in people's living environment

This chapter addresses the sub-question: What is known in the literature regarding the ignition propensity of fire-safe cigarettes used in people's living environment?

2.1 Fire in upholstered furniture and mattresses

The ignition of upholstered furniture, mattresses or bedding plays an important role for the measure of fire-safe cigarettes. One in five smoking-related residential fires starts in upholstered furniture, mattresses or bedding[22] and for two-thirds of the deaths resulting from these fires, the fire started in such materials[23] (Hall, 2013). It is mainly the development of smoke and toxic gases that forms a problem in case of a fire (in upholstered furniture). Most fire deaths are caused by the victim inhaling smoke and toxic gases (Irvine & Kuligowski, 2005). This not only concerns the ignition of mattresses and upholstered furniture, but also the fire behaviour of these materials as the fire develops. This applies, for instance, in respect of 6 % of residential fire deaths where upholstered furniture was the second object to catch fire (Ahrens, 2017). [24]

A review of the literature on the fire behaviour of upholstered furniture revealed four important properties that play a role in fire in upholstered furniture (Babrauskas & Krasny, 1985), i.e.:

- the ignition by cigarettes
- the ignition by small open flames
- the effects of such ignition in terms of heat release rate[25], fire spread and the development of toxic products, and
- the contribution that upholstered furniture makes to the fire risk if it is not the first object to catch fire.

As far as fire starting in mattresses in a test setup is concerned, the stuffing of the mattress (density), the mattress ticking and the test setup were found to have a greater influence on the ignition than the type of cigarette (Matsuyama et al., 2014, in: Larsson & Bergstrand, 2015). The ignition propensity of two types of fire-safe cigarettes was found to be comparable to that of a non-fire-safe cigarette. This finding is supported by results from an extensive study into the fire behaviour of mattresses and upholstered furniture by Nazaré and Davis (2012). For instance, they stated that "an innerspring mattress filled with melamine-type foam has been shown to result in higher heat release rates than a solid core mattress of the same size filled with similar melamine-type foam" (Damant & Nurbakhsh 1992). Nazaré and Davis also stated that mattress ticking with a quilted pattern has a slightly higher heat release rate than ticking without a quilted pattern. The fire behaviour of bedding is also relevant. A study by Ohlemiller and Gann (2003, in: Nazaré & Davis, 2012) for

[22] 11 % started in beds, mattresses and bedding and 9 % started in upholstered furniture.
[23] 29 % started in beds, mattresses and bedding and 37 % started in upholstered furniture.
[24] 2 % of the residential fires started in upholstered furniture and 18 % of the residential fire deaths died in fires that started in upholstered furniture. In total, 24 % of all residential fire deaths died in fires where upholstered furniture was on fire.
[25] Heat release rate (HRR) is the energy that is released.

example shows that bedding (sheets, duvet and blanket) on a queen size (152 cm x 203 cm) or even bigger mattress can cause a flashover.

2.2 Fire behaviour of cigarettes

Baker et al. (2016) conducted a literature review in which they considered the fire behaviour of cigarettes in general besides other factors. Based on several different literary sources, the average thermophysical properties of a burning cigarette that is not actively being smoked were defined as follows: A non-actively smoked burning cigarette consists of a smouldering bar of biomatter with a peak temperature of about 600 to 700 °C, that extends along a volume of 1-2 centimetres in length with a diameter of approximately 8 mm (for a standard king-size cigarette), with a burning rate of 2-5 mm a minute when burning along a tobacco length of 58 mm. Combined with the property that the availability of oxygen can be regulated, a smouldering cigarette will produce smoke while actively being smoked and will act as a source of ignition when it comes into contact with another object. The ignition of furniture upholstery by a smouldering cigarette can be prevented by proper control of the oxygen diffusion to the burning end of the cigarette, since the oxygen diffusion has been found to be directly related to the heat flow to the direct surroundings (Baker et al., 2016).

2.3 Fire-safe versus non-fire-safe cigarettes

Larsson and Bergstrand (2016) have recently carried out real-life experiments with three brands of approved fire-safe cigarettes[26] in a test setup with different combinations of furniture upholstery. This differed from the substrate used in the test method according to EN 16156. Most experiments were carried out in accordance with EN 1021-1, but in some scenarios the cigarette was also covered by different kinds of textile, which differed from the standard test method. The experiments showed that the cigarettes were generally not fire-safe. In the tests according to EN 1021-1, 68 % of the fire-safe cigarettes used burned up fully. Several tests showed the fabric and the upholstery (combination of fabric and upholstery) to be smouldering as well. These experiments were also carried out with non-fire-safe cigarettes. The tests with the combination of cotton (320 g/m^2) and PU foam stuffing (density 20-22 kg/m^3) did not show any significant difference between non-fire-safe cigarettes and fire-safe cigarettes in respect of the damage to the stuffing caused by the fire. This means that fire-safe cigarettes are just as capable of igniting materials as non-fire-safe cigarettes are. However, at an average of 13 minutes, the burning time of fire-safe cigarettes was significantly shorter than the average burning time of 20 minutes of non-fire-safe cigarettes.

A Japanese study (Matsuyama, Uyama, Sasaki, Ogina, Nagawa & Sekizawa, 2014, in: Larsson & Bergstrand, 2015) compared the ignition propensity of two types of fire-safe cigarettes to that of a non-fire-safe cigarette. The first type of fire-safe cigarette featured buffer bands with sodium alginate and the second type had buffer bands with cellulose. Experiments were carried out in two test setups. In the first setup, a burning cigarette was laid between two mattresses after which the mattresses were pressed together from above. In the second test setup, the mattress was placed in a frame (as used for testing furniture in accordance with EN 1021) and the burning cigarette was placed in the fold between the seat and the backrest. Different combinations of cotton and polyester were tested, and the results

[26] The brands of fire-safe cigarettes used were pre-tested for their ignition propensity (in accordance with EN ISO 12863, with layers of filter paper as the substrate) and passed the test to a sufficient extent (< 25 % were not fire-safe).

were analysed by the type of mattress, location of the cigarette and type of cigarette. No significant differences were found between the fire-safe cigarettes and the non-fire-safe cigarette. This was true for both test setups.

A Chinese study (Li et al., 2014, in: Larsson & Bergstrand, 2015) into the fire behaviour of fire-safe cigarettes and non-fire-safe cigarettes showed that there is no difference in the peak temperature in the core of the cigarette (approx. 700 °C). Furthermore, it was found that the burn rate decreases as the burning part approaches a buffer band in the paper.

According to Alpert et al. (2010) small cigars and hand-rolled cigarettes are generally fire-safe. This is because no additives that accelerate burning have been added to the filter paper of small cigars and hand-rolled cigarettes, whereas these additives, combined with the buffer bands, have been added to the paper of fire-safe cigarettes (Alpert et al., 2010). No information was found in the literature about a possible influence of the fire-accelerating additives on the ignition propensity of cigarettes.

In an as yet unpublished study, Andrews[27] has found that illegal cigarettes of the Jin Ling brand that have been tested burn up very fast and, due to the weight of the tobacco in the cigarettes (0.8 gram), they have a higher HRR (heat release rate) than other non-fire-safe cigarettes. Furthermore, the tests with the illegal cigarettes resulted in fire more often than the tests with other non-fire-safe cigarettes.

[27] Information obtained through email contact. Stephen Andrews is a Senior Lecturer in Forensic Fire Investigation at the University of Central Lancashire (United Kingdom) and a researcher.

3 The effect of the introduction of fire-safe cigarettes

This chapter addresses the sub-question: What is known in the literature regarding the real-life effect of the introduction of fire-safe cigarettes on smoking-related fire starting and smoking-related fire deaths?

3.1 Using statistics to measure the effects of policy

Since the introduction of the regulations on fire-safe cigarettes, some evaluations into the effect of the regulations on fire safety have been carried out (Coburn et al., 2013; Baker et al., 2016). In general, use is made of fire statistics that compare the number of smoking-related fires and/or the number of smoking-related fire deaths in the period after the introduction of the regulations to the number in the preceding period. In order to be able to measure the effect of the policy, annual statistic fluctuations need to be taken into account. This can be done by considering the multi-year trend. If the measure was introduced gradually or in the middle of the year, the period in which the regulations were introduced should not be taken into account in the analysis.

Most studies focus on the effect of the LIP regulations on residential fires. An understanding of the degree to which smoking plays a role as a cause of residential fires can be obtained by comparing the number of smoking-related residential fires and/or the number of deaths due to such fires to the total number of residential fires. An understanding of the effect of the LIP regulations on smoking as the cause of residential fires can be obtained by comparing the percentage of smoking-related residential fires in the period after the introduction of the LIP regulations to the percentage in the period preceding the introduction. However, the effect is hard to measure if, besides the LIP regulations, other aspects may also affect changes in smoking as the cause of residential fires. Examples of positive aspects are fire-safe furniture and mattresses, smoke alarms and public fire education, and examples of negative aspects are de-institutionalisation[28], unemployment and alcohol abuse. Most evaluation studies focus on the effect in North America (Baker et al., 2016). The regulations on fire-safe cigarettes were implemented in the US through a phased process in the period from 2004 to 2011. Standards for fire-safe furniture and mattresses were implemented in the period preceding the implementation of these regulations.[29]

The most recent study into the effect of LIP regulations in North America was conducted by Bonander, Jakobsson and Nilson (2017). Other studies that are discussed are those conducted by Ahrens (2016), Yau and Marshall (2014), Hall (2013) and by Frazier,

[28] A social trend to have vulnerable people, such as the elderly and people with mental problems, live in their own home environment on their own and with limited assistance.

[29] Regulations on the fire safety of mattresses, i.e. *Standard 16 CFR part 1632* were introduced in 1973, and a non-statutory standard for the fire safety of upholstered furniture, i.e. the *Upholstered Furniture Action Council (UFAC) standard* was introduced in the final years of the 1970s.

Schaenman and Jones (2011). The regulations have been in effect in Europe since 2011 (in Finland since 2010). The evaluations of the effect in Europe and European countries found were performed by Sondik and Schaenman (2016), Haikonen, Lillsunde, Lunetta and Kokki, (2016), Kokki (2016), London Fire Brigade (2015) and Bonander et al. (2015).

The different studies found significant positive effects, with decreases of more than 40 %, to no demonstrable effects at all (Bonander et al., 2017; Baker et al., 2016). These opposing conclusions were sometimes arrived at on the basis of one and the same database.

3.2 Foreign statistics

3.2.1 North America

In their most recently published policy evaluation, Bonander et al. (2017) studied the average effect of the LIP regulations in the period in which they were gradually introduced in different American states. They came to the conclusion that previous statements on the alleged positive effect of LIP regulations in the Unites States were premature. Their study mainly revealed that no statistically significant effects were identified for the number of fire deaths, the number of residential fire deaths and the number of cigarette induced fires. Although a significant effect was found for part of the estimates of the number of cigarette fire deaths, this effect appeared not to be robust when also taking state-specific trends into account or when making a comparison with the effects of fires due to other causes.

Ahrens (2016) arrived at a comparable conclusion. According to her, the proportion of smoking-related residential fire deaths in the periods before and after the introduction of fire-safe cigarettes was almost equal, i.e. approximately one quarter of the total number of residential fire deaths.[30] See the text block below as well.

Residential fire deaths related to the total number of residential fires

The graph on the left in figure 3.1 shows the number of residential fires (in thousands) a year in the US. The graph on the right shows the number of residential fire deaths (in thousands) and the number of smoking-related residential fire deaths (in thousands).

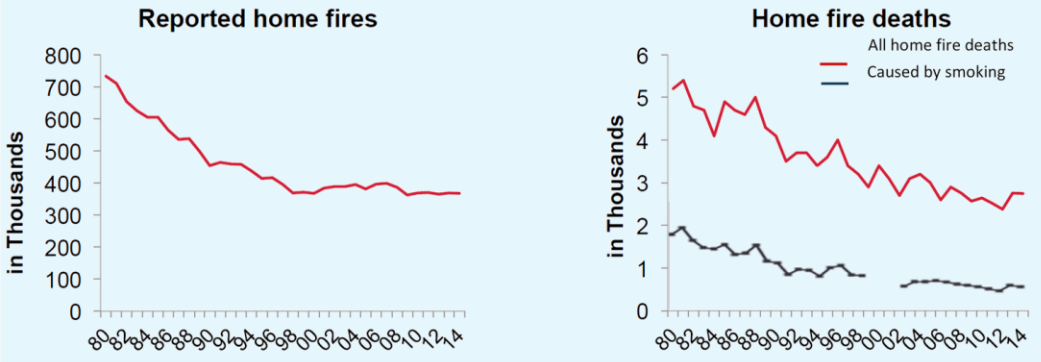


Figure 3.1 Total number of residential fires (left) and residential fire deaths (rights) in the US (Ahrens, 2016)

[30] The number of smoking-related fire deaths related to the total number of fire deaths. Not only the number of smoking-related fire deaths, but also the total number of residential fire deaths decreased in the period from 1980 to 2014, i.e. by 47 %. The total number of residential fires dropped by 50 %.

The graph on the left shows that there was a sharp decrease in the number of residential fires in the period until 1999, i.e. from approximately 740,000 in 1980 to approximately 380,000 in 1998. This number remained rather stable after 1999: in the period from 1999 to 2014, it fluctuated between 380,000 and 410,000 residential fires a year. The graph on the right shows both the total number of residential fire deaths and the number of smoking-related residential fire deaths. This shows that the number of smoking-related residential fire deaths decreased in the period from 1980 to 1999, as well as the total number of residential fire deaths. The number of smoking-related fire deaths remained quite stable in the period from 2002 to 2014.
According to Ahrens, the number of smoking-related residential fire deaths decreased by 68 % in the period from 1980 to 2013. The number decreased the most in the period from 1980 to 1984, i.e. by 35 %, and it decreased by 23 % in the period from 2009 to 2013. This shows that this decrease had already started before the introduction of the fire-safe cigarettes. Ahrens also stated that some 5 % of all residential fires in the period from 2009 to 2013 were caused by smoking and that 23 % of fire deaths concerned smoking-related residential fires. On closer scrutiny, the graph on the right shows that the percentage of smoking-related residential fire deaths relative to the total number of residential fire deaths in the period before the introduction of the fire-safe cigarette (1992-1999) was comparable to the period after the introduction of the fire-safe cigarettes.

An earlier evaluation by Yau and Marshall (2014) showed a decrease of 19 % in the total number of residential fire deaths after the introduction of the regulations for fire-safe cigarettes compared to the period before the introduction. Yau and Marshall identified the limitations of the data source they used as a first point to consider for the interpretation of the study results since this data source did not give any information on the number of smoking-related fire deaths. They also stated that it was possible that the decrease had not been caused, or not only been caused, by the introduction of fire-safe cigarettes, but also by lots of other factors.[31]

Hall (2013) used the same database as Ahrens (2016) and found a 30 % decrease in the number of smoking-related fire deaths during the period in which the regulations were implemented in all states (2003-2011). He considered the absolute number of smoking-related residential fires and the absolute number of victims of these fires. In particular, the number of smoking-related residential fires that started in mattresses, duvets and upholstered furniture decreased.[32] According to Hall, the introduction of the regulations on the fire safety of cigarettes in Canada and the US had been the main reason for the decrease in the number of smoking-related fire deaths. He thought that the Standards for fire-safe mattresses and upholstered furniture, that also applied during the period under consideration, had been less influential. According to Hall, in 2003, efforts to improve the ignitibility of upholstered furniture and mattresses had already been ongoing for more than twenty years, whereas the lifecycle of such products is 10 to 15 years.

According to Larsson and Bergstrand (2015), there may still be furniture in homes that is not fire-safe. They found that smoking-related fires in the US were more common among people

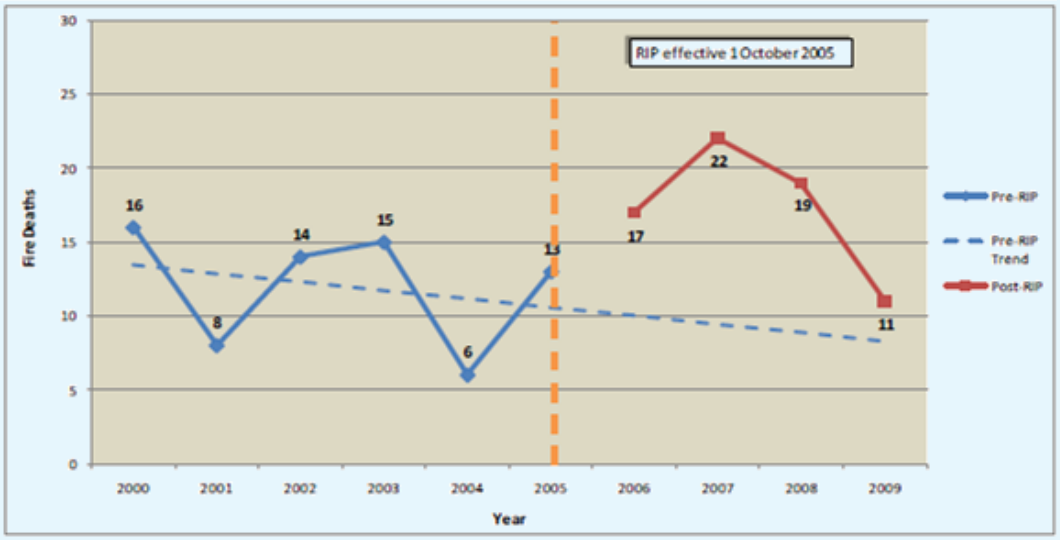
[31] Examples of such factors are the consumption of cigarettes that decreased by 41 % in the period from 1980 to 2006 (Hall, 2013), the development of standards for the fire safety of mattresses and upholstered furniture, technical developments in housing construction, the increase of smoke alarms and sprinklers in homes, changes in the number of households that permit smoking in the home and improvements in healthcare and in the treatment of burns.

[32] In the period from 1980 to 2011, the absolute number of smoking-related fires that started in mattresses, duvets and upholstered furniture decreased by 93 %. The absolute number of smoking-related residential fires that started in waste bins decreased by 65 %. The share of smoking-related residential fires that started in mattresses, duvets and upholstered furniture decreased from 64 % of the total number of residential fires in 1980 to 17 % of the total number of residential fires in 2011. The share of fire deaths decreased from 85 % of the total to 72 % of the total.

with low incomes. They explained this by the generalisation that the furniture of this group is often older or of a poorer quality than that of people with higher incomes. Old or inferior furniture poses a greater fire hazard than new furniture that has to comply with stricter fire safety requirements (Larsson & Bergstrand, 2015).

Frazier et al. (2011) looked at the effect of the introduction of fire-safe cigarettes on the number of smoking-related fires and the number of smoking-related fire deaths in the Canadian provinces of Alberta and Ontario and the state of New York in the US. See the text block below for an example.

Example of statistics on the effect of fire-safe cigarettes in Ontario
The fire-safe cigarettes regulations were introduced in Ontario in 2005. There was already a decreasing trend as regards the number of fires and fire deaths in the period before the introduction. This was true for both the total number and the number of smoking-related fires and fire deaths After the introduction of the LIP regulations, the number of smoking-related fires and fire deaths was initially higher than before the introduction; a decreasing trend was found again afterwards. This also holds true for the total number of fires and fire deaths. Figure 3.2 shows the data for the number of smoking-related fire deaths.



Source: Lit Smoking Material Fire Data from the Ontario Fire Marshal's Office, December 2010.

Figure 3.2 Ontario fire statistics: 2000-2009 (Frazier et al., 2011)

The various analyses that were carried out[33] do not show any significant effect of the introduction of fire-safe cigarettes in Canada and New York. Frazier et al. (2011) identified the earlier effect of the introduction of fire-safe mattresses and upholstered furniture as an important explanation for the absence of an effect from the introduction of the fire-safe cigarette. According to them, the decrease in the number of people who smoke also played an important role in the decrease in the number of smoking-related fires and fire deaths. They saw a connection between the reduction in tobacco consumption and the decrease in the number of smoking-related fires.

[33] This includes a trend analysis, a comparison of the number of smoking-related fires relative to the total number of fires, with corrective analyses for changes to the ratio of the smoking and the non-smoking population and for changes to the consumption of tobacco.

All in all, the conclusion can be drawn that different researchers handle statistics differently, due to which conflicting conclusions are sometimes drawn from one and the same dataset. Opinions also vary as to the influence of the measure of fire-safe mattresses and upholstered furniture on the number of smoking-related fires and fire deaths.

3.2.2 Europe

According to the European Commission, the number of smoking-related fire deaths in Finland has decreased by 43 % after the introduction van the regulations.[34] It calculated this on the basis of the absolute number of deaths, using the data of the full year in which the regulations were introduced with effect from 1 April compared to the data of the three preceding years.

In the year when the regulations were introduced (2010), the absolute number of smoking-related fire deaths dropped to 16, compared to an average of 28 in the period from 2007 to 2009 (Kokki, 2011). This is a 43 % reduction. When calculating on the basis of the relative number of fire deaths, this number has decreased by one third, since the number of smoking-related fire deaths relative to all fire deaths in 2007-2009 was 35 % on average and in 2010 it was 23 % on average (Haikonen et al., 2016). This has decreased the percentage by 12 %.
Haikonen et al. (2016) attribute the decrease to the introduction of the regulations on fire-safe cigarettes in April 2010. They consider smoking-related fire deaths to be a socio-economic problem since the number of smoking-related fire deaths in low income groups has increased: "Very recent trends in fire-related deaths have shown that preventive measures can be successful. However, the problem is not straightforward and has been shown to be partially a social issue, as the majority of victims are socioeconomically deprived and often intoxicated".
The decrease was measured in the year after the introduction of the regulations. In the following year, 2011, the number continued to decrease to 13 victims of smoking-related fires, after which the number increased to 27 in 2012 (FEP-UK, 2014) to decrease to 15 in 2013 (Sondik & Schaenman, 2016).
Another study by Kokki (2016) showed that the average number of fire deaths in Finland decreased by a quarter in 2010-2014 compared to the period from 2007 to 2009. According to Kokki, this decrease was mainly influenced by the introduction of regulations on fire-safe cigarettes, changing legislation on smoke alarms, the obligations concerning safety risks for service providers, and targeted actions by fire brigades, including public fire education.

No effects of fire-safe cigarettes on fire safety had been observed in Sweden two years after the introduction of the regulations (Bonander et al., 2015). According to data from fire studies in the period from 2010 to 2013, smoking-related fires in Sweden occurred relatively more frequently in connection with people of over 65 with limited mobility, and with people with drinking and/or drug issues (MSB, 2014, in: Larsson & Bergstrand, 2015).

The London Fire Brigade (2015) saw a decrease from approximately 21 fires caused by smoking per month in London in 2010 to 16 a month in 2014. The number of smoking-related fire deaths decreased from 20 in 2010 to 8 in 2014. It is suspected that the decreases are the effect of the regulations on fire-safe cigarettes that were introduced in 2011. However, the London Fire Brigade expressed its concern as to the fact that the decrease was not more than this and as to the large number of smoking-related fires.

[34] See http://europa.eu/rapid/press-release_IP-11-1342_en.htm?locale=en

3.3 Dutch statistics

There are no known evaluations of the effect of fire-safe cigarettes in the Netherlands.[35] However, some statistics on smoking-related fires in buildings and smoking-related fatal residential fires have been published. These statistics are described below.

3.3.1 Fires in residential buildings

Statistics Netherlands (CBS) publishes data on fires and fire causes via Statline[36]. Statline does not provide any information on the causes of fires in residential buildings, but it does give information on the causes of all fires in buildings. On average, fires in buildings make up 32 % (a minimum of 26 %, a maximum of 40 %) of all fires recorded by Statline since 2000.

Figure 3.3 shows a summary of the fires in buildings broken down into types of building. This distinguishes between residential buildings, non-residential buildings and other buildings. The latter category also includes the fires where the type of building is unknown (or was not recorded). This may also include fires in residential buildings that were not reported as such to Statistics Netherlands. Due to the large number of fires in buildings in the category of 'other buildings (including unknown)', there is significant uncertainty as regards the other categories.

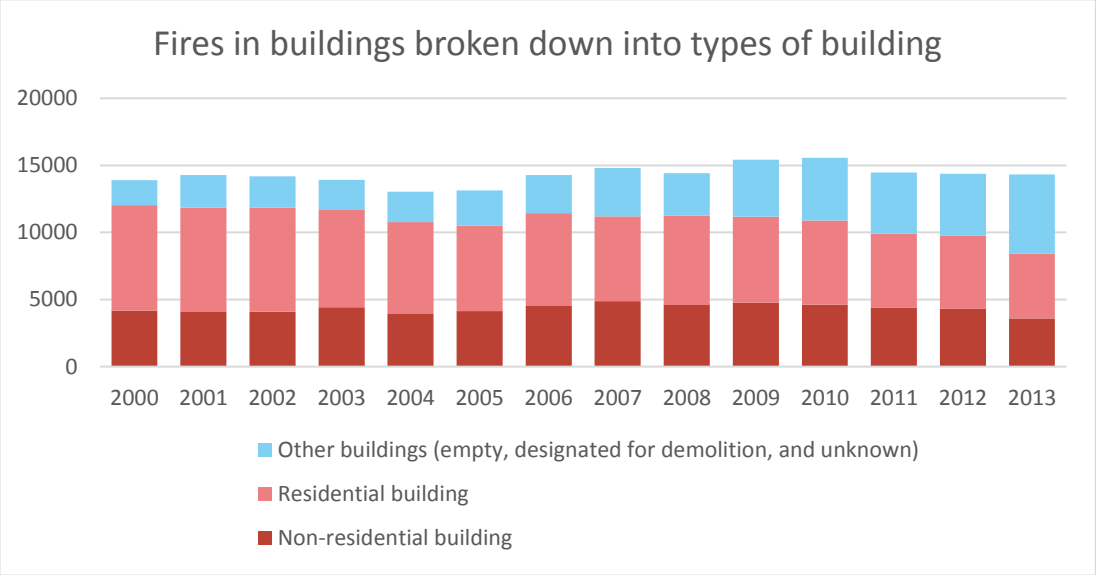


Figure 3.3 Fires in buildings in the Netherlands, per year, broken down into types of building

When considering the ratio between fires in residential buildings and fires in non-residential buildings, the first category decreased from 65 % in 2000 to 58 % in 2010, and the ratio remained reasonably constant since 2007. In 2012 and 2013, this was 56 % and 57 % respectively. No significant difference in the share of fires in residential buildings compared to the preceding period can be found after the introduction of the fire-safe cigarettes in 2011.

[35] The *Fatale woningbranden 2008 t/m 2012: een vergelijking* study report (IFV, 2013) identified that the percentage of fatal smoking-related residential fires had not decreased in 2012, one year after the introduction of the fire-safe cigarette. This study only considered fatal residential fires of a known cause.
[36] www.statline.cbs.nl, consulted on 16-05-2017.

3.3.2 Causes of fires in buildings

Figure 3.4 shows the causes of fires in buildings. It distinguishes between fires in buildings of unknown cause, fires in buildings caused by smoking, and fires in buildings not caused by smoking. In 2000, the causes of 79 % of all fires in buildings were known, compared to 60 % in 2010 and 52 % in 2013. Here again, there is a high degree of uncertainty about the other categories due to the large number of fires in buildings whose causes are not known.

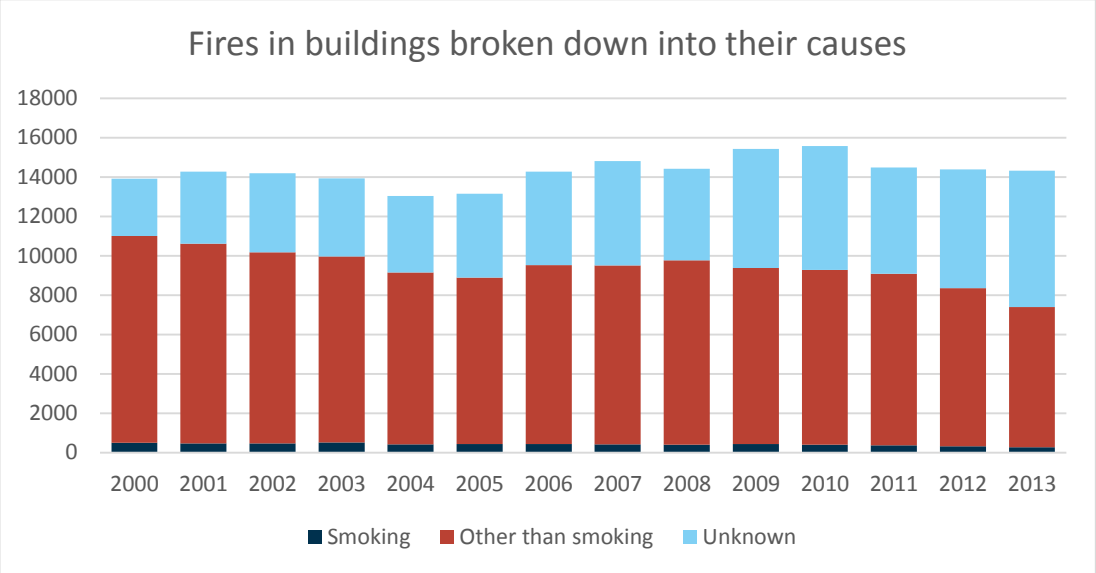


Figure 3.4 Fires in buildings in the Netherlands, per year, broken down into their causes

Smoking caused 5 % of all fires in buildings whose cause was known in the period from 2000 to 2011. In 2012 and 2013 this was 4 %. This means that there is no significant difference in the proportion of fires in buildings in the periods before and after the introduction of the fire-safe cigarettes.

3.3.3 Fatal residential fires

The Fire Service Academy has been gathering data on fatal residential fires since 2008. This database features data on fires in homes and other residential use-related buildings, where residents died as a consequence of the fire and were there was no association with murder or suicide. Analysed data was published until 2016.[37] On average, there were 29 fatal residential fires a year throughout this period; this number varied between 22 and 39 a year. The average annual number of fatal victims was 34 and varied between 25 and 44.

[37] See the website of the IFV: https://www.ifv.nl/advieseninnovatie/Paginas/Fatale-woningbranden.aspx#tab2

Table 3.5 Fatal residential fires in the Netherlands, for individual years

	Before the LIP regulations				After the introduction of the LIP regulations				
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of fatal residential fires	39	22	29	26	25	30	30	27	32
by smoking	*10*	*3*	*9*	*10*	*6*	*5*	*9*	*8*	*6*
not by smoking	*20*	*11*	*14*	*14*	*13*	*17*	*18*	*13*	*15*
unknown	*9*	*8*	*6*	*2*	*6*	*8*	*3*	*6*	*11*
Number of deaths	44	25	29	28	26	33	30	31	37

The proportion of smoking-related fires in the total number of fatal residential fires whose causes are known varied between 21 % (in 2009) and 39 % (in 2010). It was 42 % in the year when the LIP regulations were introduced. A repeating wave pattern can be seen over the entire period; this already started before the introduction of the fire-safe cigarette. See Figure 3.6.

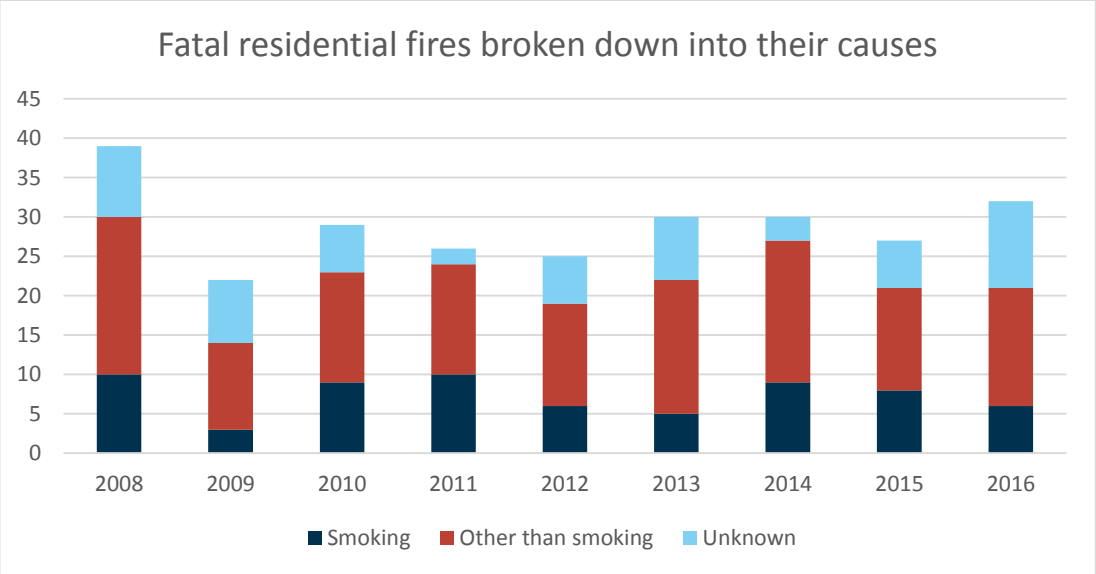


Figure 3.6 Causes of fatal residential fires in the Netherlands, for individual years

On average, 31 % of all fatal residential fires whose cause was known, was caused by smoking in the period ending in 2011. This is also true for the period after 2011. This means that there is no difference in the proportion of fatal smoking-related residential fires in the periods before and after the introduction of the fire-safe cigarettes.

3.4 Study requirement for effect evaluation of LIP[38] regulations

In their most recent *Report on the scientific basis of tobacco product regulations* (2015), the World Health Organisation (WHO) Study Group on Tobacco Product Regulation identified a number of topics that require further study in order to be able to forecast the effect of the LIP regulations.

- Factors that contribute to a general decrease in the number of fires, particularly studies into the effect of public fire education campaigns, sprinkler systems and into reducing the flammability of substrates (such as upholstery and mattresses).
- Behaviour-related matters, such as the impact of changes in smoking behaviour, the impact of bans on smoking in locations where people (do) smoke, the number of cigarettes smoked and people throwing cigarettes away.
- New design technologies for paper in order to improve its lower ignition propensity, standards and possible changes regarding emissions and toxicity.
- Fires started by cigarettes in conditions not covered by the Standard (outdoor fires, forest fires, fires in waste bins outside).
- The applicability of the Standard to new fire-safe cigarettes that have not been rolled using paper.

Baker et al. (2016) claim that more fundamental research into the thermophysical interaction between fire-safe cigarettes and different substrate materials is needed in order to get an insight into the effectiveness of the ignition propensity, or the lack thereof. This should lead to other substrates in the test method that better match the materials in which fires start in real life, such as stuffing and upholstery of mattresses and upholstered furniture. Aspects such as the airiness (presence of oxygen) and the flammability of the substrate play a decisive role in the ignition process. The outcomes of the fundamental research should also help in exploring whether improved or alternative technologies are available for reducing smoking-related fires. They also think that the use of computer modelling should be feasible, particularly in order to simulate the main situations where fires occur.

[38] LIP is short for the Lower Ignition Propensity.

4 Conclusions

4.1 The ignition propensity in test conditions

Based on a field study, the NVWA has concluded that fire tests according to the Standard[39] show that commonly available fire-safe cigarettes are generally sufficiently fire safe. The main findings from the literature as to the fire-safe character of cigarettes are as follows.

> The current design of fire-safe cigarettes mainly concerns the burning time of cigarettes that are not actively being smoked. In order to reduce this burning time, the current design of fire-safe cigarettes features barriers (bands) in the paper that reduce the air/oxygen supply. This will extinguish the cigarette when it is not actively being smoked so that it will not be able to ignite the surface on which the cigarette is lying. Fire-accelerating additives have been added to fire-safe cigarettes in order to lift the barrier effect when they are actively being smoked. This study does not reveal the extent to which the fire accelerating additives contribute to the start and/or the development of fire in upholstered furniture, mattresses and beddings.
> Both the burning time and the temperature of the source of ignition (the cigarette) are important. If this temperature is higher than the ignition temperature of objects in the vicinity of the source of ignition, a fire can start. The peak temperature of fire-safe cigarettes has been found to be comparable to that of non-fire-safe cigarettes.
> Other aspects of cigarettes that might influence their ignition propensity are reducing the density of the tobacco, making the cigarettes thinner, reducing the amount of fire accelerating additives, and applying or lengthening filters.

Another conclusion is that the measure of introducing fire-safe cigarettes focuses on a limited portion of tobacco products that can cause residential fires as, due to the scope of the Standard and the failure percentage permitted, a maximum of two[40] to three[41] in five cigarettes smoked in test conditions is fire safe.

> The measure of fire-safe cigarettes exclusively addresses prefabricated and legally traded cigarettes. Hand-rolled cigarettes, illegally traded cigarettes and other tobacco products are not covered by the regime of the Standard.
> In order to test the self-extinguishing, i.e. fire-safe, and lower ignition effects, a burning cigarette is placed in a horizontal and static position, on a substrate that consists of layers of filter paper. This has to be carried out in accordance with the EN 16156 and EN ISO 12863 standards. At least three quarters of the cigarettes tested should self-extinguish; one quarter is allowed to fail the test.

4.2 The ignition propensity in the living environment

It has been found that the introduction of fire-safe cigarettes has hardly reduced the ignition propensity of cigarettes used at home. This is mainly because the fire test in the Standard is not representative of how smoking-related residential fires start. The current fire-safe

[39] NEN-EN 16156 and EN ISO 12863.
[40] In the event that 75 % of all fire-safe cigarettes pass the test.
[41] 42 % are not covered by the regime of the Standard and 15 % of all cigarettes are allowed to fail the fire test, which is one quarter of the 58 % of fire-safe cigarettes.

cigarettes have been designed to fulfil the Standard. This means that a fire-safe cigarette does not carry a lower risk of fire starting than non-fire-safe cigarettes do.

The following findings from the literature review indicate that the fire test in the Standard does not compare to the actual real-life situation of smoking-related fires:

- The characteristic parts of the fire test in the Standard consist of the substrate and the position of the cigarette.
    - The substrate consists of layers of filter paper instead of the materials in which residential fires often start, such as mattresses, beddings and upholstered furniture. If, as part of the fire test, the substrate is replaced by furniture upholstery or a mattress, no significant difference is found as regards the ignition propensity of fire-safe cigarettes compared to that of non-fire-safe cigarettes.
    - The position of the cigarette in the test is horizontal and static, whereas residential fires can also be caused by falling cigarettes, whose burning end can be inclined downwards or upwards. This influences the way in which the cigarette comes into contact with the substrate. In particular, fire-safe cigarettes that fall down with their burning end pointing down in a straight line or inclined downwards continue to burn up completely. But, in practice, when fire-safe cigarettes fall down with their burning end inclined upwards, they can also burn until there is nothing left of them.
- Smoking-related residential fires often start in upholstered furniture, mattresses or beddings. Furthermore, smoking-related fires and fires in upholstered furniture, and often the combination of these two types of fire, tend to cause deaths more often than fires due to a different cause or in other materials. It is mainly the development of smoke and toxic gases that forms a problem in case of a fire (in upholstered furniture). The fire-safe aspect of cigarettes, i.e. their self-extinguishing effect, should therefore mainly aim to prevent upholstered furniture, mattresses and beddings igniting.
- The measure of introducing fire-safe cigarettes focuses on the source of ignition and thus on the ignition phase, but not on the material that is ignited and the post-ignition phase. Smoking-related fires often involve upholstered furniture. Some characteristics play a role in fire in upholstered furniture:
    - the ignition by cigarettes
    - the ignition by small flames
    - the effects of an ignition in terms of heat release rate, fire spread and the development of toxic products, and
    - the contribution that upholstered furniture makes to the fire risk if it is not the first object to catch fire.

4.3 The effect of the introduction of fire-safe cigarettes

The literature review does not provide a sufficient basis to enable the effect of the introduction of fire-safe cigarettes on the number of smoking-related fire deaths to be established conclusively. This is related to how the policy effect was measured on the one hand and, on the other, to the influence of other measures on fire safety during the actual measuring periods used.

The main findings regarding the measurement method are as follows:

> Some evaluations involved measurements during a brief period after the introduction of the LIP regulations and other evaluations involved measurements during a longer period after the introduction.
> The calculations for some evaluations were based on absolute numbers, whereas other evaluations used the percentage of smoking-related fires and/or deaths due to such fires relative to the total number of fires.
> In particular, the evaluations covering a short period after the introduction and the evaluations based on absolute numbers show a decrease. Evaluations covering a longer period after the introduction and based on the percentage of smoking-related fires and/or deaths due to such fires relative to the total number of fires do not indicate any significant effect.

The main findings regarding other fire safety measures are as follows:

> Besides the measure of introducing fire-safe cigarettes, other fire safety measures may also contribute to a reduction of the number of smoking-related fire deaths, such as improvements to public fire education, the use of smoke alarms, and/or improvements to the ignitibility of upholstered furniture and mattresses.
> It has been found that smoking-related fires (in the US and in Finland) occur relatively more frequently in connection with people with a low income and (in Sweden) with people of over 65 whose mobility is limited, and with people with drinking and/or drug issues. This means that socio-economic factors should also be factored in when selecting appropriate measures.

4.4 Contribution of fire-safe cigarettes to reducing the number of fire deaths

The study reveals that the measure of introducing fire-safe cigarettes plays a limited role in reducing the number of smoking-related fire deaths as there are several factors that influence the probability of smoking-related fire deaths:

> socio-economic factors that can lead to a fire starting[42]
> the source of ignition (the cigarette) and the object of origin (such as furniture) during the ignition phase of the fire
> the contribution of objects in the vicinity to - particularly - the smoke development in the post-ignition phase, and
> the conditions of the victim during the fire.[43]

Several measures are required in order to reduce the number of smoking-related fires and the number of deaths due to such fires. These measures should focus on the combination of

[42] Smoking-related fires occur relatively more frequently in connection with people with a low income, with people of over 65 whose mobility is limited, and with people with drinking and/or drug issues.
[43] Being under the influence (or not) of narcotics (alcohol, drugs, medication), sleeping, limited mobility, etcetera.

the source of ignition (the cigarette) and the object of origin (such as furniture). The following areas of attention are important when selecting appropriate measures.

> Smoking-related fires occur relatively more often in connection with people of over 65 whose mobility is limited, with people with a low income, or with people with drinking and/or drug issues.
> Smoking-related fires and/or fires where upholstered furniture catches fire cause more deaths than fires with another cause or in other objects.
> In some fatal fires in upholstered furniture, the furniture does not get involved in the fire until after the ignition phase of the fire.
> In particular, the mattress stuffing (density), the mattress ticking and the test set-up influence the ignition by cigarettes.
> The position of the cigarette and the way in which it comes into contact with the substrate appear to be decisive for the cigarette's ignition propensity.
> Cigarettes that are illegally available on the market have been found to cause a higher fire risk than other cigarettes.

4.5 Final comments

The currently available literature has provided sufficient information about the fire-safe cigarettes' reduced propensity to ignite furniture and specifically upholstered furniture. The information found also applies to the situation in the Netherlands.

However, the literature review that was conducted does not provide a sufficient understanding of how the causes and effects of smoking-related fires can be reduced and of what the causes and effects of fire in upholstered furniture are. This understanding is necessary since smoking-related fires and/or fires in upholstered furniture cause more deaths than fires with another cause and/or in other objects.

In order to be able to improve fire safety, further studies should be undertaken into factors that have a decisive influence on the fatal character of smoking-related fires and measures that influence such factors.

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