Executive Summary

The upholstered furniture fire problem

Upholstered furniture accounts for the largest share of fire deaths of any first item ignited in US home fires.
In 2006-2010 US home structure fires, upholstered furniture as first item ignited accounted for
- 480 civilian deaths per year (19% of all home fire deaths),
- 6,700 structure fires per year (2%),
- 840 civilian injuries per year (7%), and
- $427 million in direct property damage per year (6%).

Estimates of the upholstered furniture home fire problem increase when the traditional estimates based on item first ignited are supplemented by estimates of fires involving upholstered furniture as the principal item contributing to fire spread but not item first ignited.
In 2006-2010 US home structure fires, upholstered furniture as first item ignited or principal item contributing to fire spread accounted for
- 610 civilian deaths per year (24% of all home fire deaths),
- 8,900 structure fires per year,
- 1,120 civilian injuries per year, and
- $566 million in direct property damage per year.

There are five major upholstered furniture home fire scenarios plus a sixth scenario with little or no detail that accounts for few fires and losses.
- **Cigarette-ignition scenario.** Smoldering ignition by lighted tobacco product, principally cigarette (45% of total upholstered furniture home fire deaths),
- **Open flame ignition by another fire,** where upholstered furniture is the principal item contributing to fire spread but not the first item ignited (21%),
- Ignition by arcing or heat from operating equipment (12%),
- **Small-open-flame ignition** by candle, match or lighter (10%),
- Smoldering ignition by ember, ash or other or unclassified hot or smoldering object (10%),
- Unclassified, other or multiple heat source (3%).

The relevance of existing requirements to the major upholstered furniture fire scenarios

The **cigarette-ignition scenario** was the first upholstered furniture fire scenario to be addressed by formal fire test requirements, beginning in 1975 in California with **Technical Bulletin (TB) 117, Requirements, test procedure and apparatus for testing the flame retardance of resilient filling materials used in upholstered furniture,** and in 1980 in the UK with requirements (e.g., “The Furniture and Furnishings (Fire) (Safety) Regulations 1988,” Statutory Instruments 1988, No. 1324, Her Majesty’s Stationary...

The small-open-flame scenario was also first addressed by TB 117 in California in 1975 and by the UK in 1980 using tests based on BS 5852. A simulated match was used as the ignition source, replacing the cigarette ignition source in the cigarette-ignition tests in these same two standards.

The scenario of ignition by another fire, as when a piece of upholstered furniture is the primary item contributing to fire spread but not the item first ignited, has never been the explicit basis for requirements. Some requirements use a larger open-flame igniting heat source, such as the wood crib fire used in one part of the UK requirements. Some requirements – for furniture used in public occupancies not in homes, such as California Technical Bulletin (TB) 133, *Flammability test procedure for seating furniture for use in public occupancies* – use a larger igniting heat source and evaluate performance not on ignition resistance but on speed of fire growth and peak severity. These test conditions and criteria could be used as a starting point for design of a standard test method, with evaluation criteria, which would be appropriate for the severity of this scenario and the safety goals appropriate to the scenario.

**Changes to upholstered furniture fabrics and filling materials**

Improved resistance to cigarette ignition has been achieved through the selection of covering fabrics (e.g., thermoplastic fabrics rather than cellulosic fabrics) and filling materials (e.g., polyurethane foam rather than cotton batting). These fabric and filling material choices not only pass the cigarette-ignition tests but have also been shown through experiments to sharply increase measured cigarette-ignition resistance.

**Fire retardants and their effects on fire performance, health and the environment**

Fire retardants applied to polyurethane foam filling materials have been used to pass tests for small-open-flame resistance of filling materials since the introduction of such tests in 1975.

The small-open-flame ignitions that motivated the introduction of fire retardants constitute a modest share of total upholstered furniture fatal fire deaths (about 10-15%) and always have. For other fire scenarios – notably the large open flame ignitions involving fire spread from another burning item – available test evidence has not shown a significant effect, and one would not expect an effect because the treatments were never designed to resist such large ignition heat sources. Either way, the evidence suggests the past impact of historically favored fire retardant treatments on fire deaths could not have been very large, even if they reliably performed as intended in all fires.
Based on studies linking fire-retardant chemicals to toxic health effects, the two principal chemicals (penta- and octa-brominated diphenyl ethers) that were used as fire retardants for furniture were phased out of production nearly a decade ago. Other fire retardants, including deca-BDE and chlorinated organic phosphates, are reportedly now being used to pass TB 117, but they also are being challenged on grounds of health effects.

California is actively exploring the possibility of removing the small-open-flame ignition test from TB 117, which would remove the only US regulation that has induced the use of fire retardants in upholstered furniture.

**Fire barrier systems**

Fire barrier systems are combinations of fabric layers or coatings that prevent ignition of the protected filling material or delay the involvement of filling material in fire, thereby slowing the growth of fire and lowering the peak heat release rate (fire intensity).

Experiments on fire barriers have been very encouraging, suggesting that they can achieve improved flammability and compliance with existing and proposed requirements, often better than defined fire-retardant treatment options. At the same time, real-scale experiments to date have shown too much variation to permit a standard test and associated requirements to be written on the basis of current knowledge.
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Introduction

Why a White Paper on this topic?

Regulations intended to reduce furniture flammability have been around for nearly 40 years. Evidence began building perhaps two decades ago of serious health effects attributable to the chemicals (polybrominated diphenyl ethers or PBDEs) that are used as fire retardant treatments of upholstered furniture filling materials, to comply with the open flame test portions of these existing regulations. About a decade ago, manufacturers began phasing out the PBDEs used as filling material fire retardants.

In late 2012, California began work on revising its state regulation to remove the only open flame test requirement for domestic upholstered furniture in the US. Meanwhile, CPSC is continuing work toward a possible federal regulation for upholstered furniture but one that is only intended to address cigarette ignitions.¹

Also potentially relevant is growing concern over the threats to occupants and firefighters of faster-growing, more severe fires.

This situation adds timeliness and urgency to several questions:

- What is the size of the upholstered furniture fire problem?
- What are the different parts of that fire problem that involve different aspects of upholstered furniture fire performance, and what is the relative size of these different parts?
- Which parts of the upholstered furniture fire problem are addressed by existing regulations, and what is the evidence on how well those regulations have worked?
- What are the different engineered options used to comply with existing regulations and intended to reduce furniture flammability, and what are the pros and cons of those options (e.g., effectiveness in reducing flammability, other effects such as health effects, cost)?

A short note on terminology

“Flammability” is understood to mean the fire performance of furniture – everything from ease of ignition to speed of fire growth and peak intensity of fire.

“Furniture” is understood to mean upholstered furniture specifically. In the national fire incident data base, upholstered furniture accounts for eight times as many civilian fire

deaths as all types of non-upholstered furniture combined. The non-upholstered furniture that is thereby excluded from the scope includes the following:

- Non-upholstered chairs, which account for very few fires and deaths per year,
- Cabinetry, including desks, tables, bookcases, chests, dressers, filing cabinets, pianos, and other pieces collectively referred to as case goods,
- “Other” furniture or utensils (household utensils and appliance housings or casings), which may include some upholstered furniture fires where the item first ignited was not fully specified in the report.

Other furnishings that might be considered furniture, such as mattresses, are not listed under “furniture” in the national fire data base and are not included in this White Paper.

The White Paper uses the term “engineered option” to refer to any technology or design approach to improving furniture flammability. This includes but is not limited to the use of fire retardants or fire barrier systems.
Section 1
Overview of Upholstered Furniture Flammability
How Big is the Fire Problem? What Are the Largest Parts?

Size of upholstered furniture fire problem

Upholstered furniture accounts for the largest share of fire deaths of any first item ignited in US home fires.2

In 2006-2010 US home structure fires, upholstered furniture as first item ignited accounted for

- 480 civilian deaths per year (19% of all home fire deaths),
- 6,700 structure fires per year (2%),
- 840 civilian injuries per year (7%, the fourth largest share, after cooking materials, mattress or bedding, and flammable or combustible gas or liquid), and
- $427 million in direct property damage per year (6%, the fourth largest share, after structural member or framing, exterior wall covering, and cooking materials).

As can be seen above, the upholstered furniture share of civilian fire deaths (19%) and injuries (7%) and direct property damage due to fire (6%) are all larger than the upholstered furniture share of fire incidents (2%). Therefore, when considering the relative importance of upholstered furniture fires versus other parts of the home fire problem, it is important to focus on shares of losses, especially fire deaths, and not on shares of fires alone.

Over the past three decades, there has been a downward trend in fires beginning with ignition of upholstered furniture, in associated losses and in the upholstered furniture shares of home structure fires and losses.

From 1980-1984 to 2006-2010, estimated annual average upholstered furniture home fires and losses have declined as follows:

- Civilian deaths have declined by 61%, from 1,220 (25% of total home fire deaths) to 480 (19%).

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Fires have declined by 77%, from 29,400 (4% of the total) to 6,700 (2%).
Civilian injuries have declined by 68%, from 2,630 (13% of the total) to 840 (7%).
Direct property damage, after adjustment for inflation to 2010 dollars, has declined by 17%, from $522 million (7% of the total) to $434 million (6%).

In 1980-1984, there was an average of one death for every 24 home upholstered furniture fires. By 2006-2010, there was an average of one death for every 14 home upholstered furniture fires. This may be seen in Figure 1, where fires are divided by ten for ease of comparison with deaths. For example, 6,700 fires in 2010 are plotted as 670.
Figure 2 shows that upholstered furniture home fires and associated deaths have also declined as a share of the totals for all home fires. This suggests that the decline in upholstered furniture home fires and losses has been a combination of:

- *an overall declining trend in total home structure fires and losses* (e.g., due to the increase in usage of home smoke alarms from 50% of homes in 1980 to more than 95% in 2010), and
- *an additional declining trend in the upholstered furniture share of home structure fires and losses* (due to changes in upholstered furniture that affect only those fires, such as reductions in furniture flammability).

**Would better or more complete fire incident (NFIRS) data significantly add to or change these estimates?**

More specifically, are there fires coded as “upholstered furniture” that do not belong or do not burn the way typical pieces of upholstered furniture burn? Are there fires not coded as “upholstered furniture” that are in fact upholstered furniture?

- Throw pillows and decorative fabrics are examples of accessories normally used with upholstered furniture but not technically part of the furniture. Would a fire starting on these items be coded as upholstered furniture or as something else, such as “soft goods, wearing apparel, other”?

- What is being identified as “furniture, utensil, other”? Is this category used only for well-defined items in the furniture and utensil group that are not specifically listed by name? Or, is this category being used as a partial unknown, including items that fall within the furniture and utensil group but have not more specifically identified? If so, then some of these items are probably additional upholstered furniture fires.

If upholstered furniture accounts for *all* of the fires identified as “furniture, utensil, other,” that would add 25% to estimated deaths in fires with upholstered furniture as first item ignited or 20% to estimated deaths in fires with upholstered furniture as either first item ignited or primary item involved in fire spread.

If upholstered furniture accounts for *a proportional share* of the fires identified as “furniture, utensil, other,” that would add 21% to estimated deaths in fires with upholstered furniture as first item ignited or 16% to estimated deaths in fires with upholstered furniture as either first item ignited or primary item involved in fire spread.

If all of the fires identified as “furniture, utensil, other” are items not specifically listed, that would add nothing to the upholstered furniture fire estimates.

These are the kinds of questions that could be explored in a special data collection research project with fire departments participating in NFIRS. The answers could indicate that the upholstered furniture fire problem is even larger than has been estimated.
Major parts of the upholstered furniture fire problem

Most fires and losses from home structure fires starting with ignition of upholstered furniture involve smoldering ignition.\(^3\)

In 2006-2010, home structure fires and losses involving upholstered furniture as item first ignited can be divided among four major scenarios and an “other” group:

- **Cigarettes and other lighted tobacco products**, which cause smoldering ignitions, accounted for 28% of upholstered furniture fires and 57% of associated deaths, down from 62% of fires in 1980-1984 and down from 68% of these deaths in 1980-1984. The decline in share of fire deaths for this scenario may reflect not only the fact that it has been the focus of furniture flammability requirements throughout this period but also continued declines in the percentage of the population who smoke. The recent advent of requirements for reduced-ignition-strength cigarettes is also likely to become a contributing factor to prevention of these fire deaths in the future.

- **Ignitations due to arcing or heat from operating equipment** (principally space heaters and cords or plugs), which are an unknown mix of smoldering and flaming ignitions, accounted for 22% of these fires and 15% of these deaths, up from 14% of fires in 1980-1984 and up from 11% of these deaths in 1980-1984.

- **Candles, matches, lighters, and other open-flame heat sources**, which cause flaming ignitions, accounted for 22% of these fires and 13% of these deaths, up from 19% of fires in 1980-1984 and down from 19% of these deaths in 1980-1984.

- **Embers, ashes and other or unclassified hot or smoldering heat sources**\(^4\), which cause ignitions that should also be smoldering ignitions, accounted for 20% of upholstered furniture fires and 12% of associated deaths, up from 3% of fires in 1980-1984 and up from 2% of deaths in 1980-1984.

- **Unclassified, multiple or other heat sources** accounted for 8% of these fires and 3% of these deaths, up from 3% of fires in 1980-1984 and up from 1% of these deaths in 1980-1984.

Note that the combined smoldering-ignition share of upholstered furniture home structure fire deaths has changed relatively little (from 70% in 1980-1984 to 69% in 2006-2010), but there has been a dramatic shift in the shares for lighted tobacco products (from 68% to 57%) and for embers and ashes (from 2% to 12%).

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\(^3\) “Smoldering-ignition” fires are not the same as “smoldering,” a term which could be understood to mean only fires that never transition to flaming. Smoldering-only fires account for a very small share (about 1%) of total home fire deaths, whereas smoldering-ignition fires account for roughly 40% of home fire deaths. Nearly all of the deaths and property damage caused by smoldering-ignition fires are caused by fires that transition to flaming at some point and have most of their growth after that transition.

\(^4\) Embers and ashes are typically too small to ignite upholstered furniture. However, people familiar with NFIRS coding believe that a cigarette – which produces embers and ash and can ignite upholstered furniture – might be coded as an ember or ash. There is also the possibility of fireplace embers, but it is unlikely that such ignitions could be as common as the statistics suggest.
This shift could reflect changes in how fires start, or changes in how the same fire starts are being reported, possibly induced by changes in the coding used in NFIRS. Figures 3 and 4 show this dramatic shift in the two smoldering-ignition scenarios as well as the smaller shifts in size of the other scenarios.

![Figure 3. 1980-1984 upholstered furniture fire deaths, by type of heat source](image1)

![Figure 4. 2006-2010 upholstered furniture fire deaths, by type of heat source](image2)

If they represent a real shift in how fires start, the shift in the components of smoldering ignitions could have implications for standardized tests of smoldering-ignition resistance. The test conditions may not do well to represent ignitions by ember or ash, even if all or nearly all the embers and ashes are from cigarettes.

Very few open-flame ignitions involve torches, road flares, or lighting torches, the larger open flames identified in the fire incident reporting categories.
Roughly one-quarter of the flaming ignitions are intentionally set fires, and roughly one-third of the flaming ignitions are caused by someone, usually a child, playing with fire. There is considerable overlap between the intentional and fireplay ignitions, and the combination accounts for nearly half of flaming ignitions. Ignitions of the exposed side or front vertical surfaces or even the bottom of the furniture may be common when fires are set, especially when young children are involved. This also could have implications for standard tests of furniture flammability.

We do not know enough about the details of ignitions by operating equipment to know how many of those fires can be prevented by engineered cigarette ignition resistance or by engineered small open flame ignition resistance.

If the estimates are expanded to include fires where upholstered furniture is the primary contributor to fire or flame spread but not the item first ignited, the estimates of upholstered furniture fires and losses increase substantially, and the flaming ignition shares increase even more dramatically.\(^5\)

See *Estimating Fires When a product is the Primary Fuel But Not the First Fuel, With an Application to Upholstered Furniture* by John R. Hall, Jr. for more details.

**Table 1.** Upholstered furniture fire problem with and without the inclusion of flaming-ignition fires with upholstered furniture as primary item contributing to fire spread

<table>
<thead>
<tr>
<th>Annual average for 2006-2010 home structure fires</th>
<th>Fires</th>
<th>Civilian Deaths</th>
<th>Civilian Injuries</th>
<th>Direct Damage (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upholstered furniture as item first ignited (A)</td>
<td>6,700</td>
<td>480</td>
<td>840</td>
<td>$427</td>
</tr>
<tr>
<td>Upholstered furniture as item first ignited by flaming ignition (B)</td>
<td>1,500</td>
<td>60</td>
<td>220</td>
<td>$73</td>
</tr>
<tr>
<td>Upholstered furniture as primary contributor to fire or flame spread but NOT first item ignited (C)</td>
<td>2,200</td>
<td>130</td>
<td>280</td>
<td>$138</td>
</tr>
<tr>
<td>Combined upholstered furniture fires with flaming ignition (B+C)</td>
<td>3,700</td>
<td>190</td>
<td>500</td>
<td>$210</td>
</tr>
<tr>
<td>Combined upholstered furniture fires (A+C)</td>
<td>8,900</td>
<td>610</td>
<td>1,120</td>
<td>$566</td>
</tr>
<tr>
<td>Combined upholstered furniture fires as percent of home total</td>
<td>2%</td>
<td>24%</td>
<td>9%</td>
<td>8%</td>
</tr>
</tbody>
</table>

With the inclusion of fires where upholstered furniture is the most important fuel package but not the first fuel package, the upholstered-furniture share of home fire deaths rises from one-fifth (19%) to one-fourth (24%).

To get a sense of how fires start when upholstered furniture is the primary item contributing to fire spread, it is useful to look at the leading items first ignited (other than upholstered furniture) in those fires:

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\(^5\) Analysis taken from John R. Hall, Jr., “Fires with upholstered furniture as the primary item contributing to fire spread,” undated memorandum to Bill Pitts, NIST Fire Research Division, 2012.
The upholstered furniture fire problem is considerably larger than past estimates have indicated, but it is also a different kind of fire problem.

Of the expanded number of upholstered furniture fire deaths, only 55% occurred in fires started by lighted tobacco products (45%) or small open flames (10%), the two types of igniting heat sources that accounted for nearly all (87%) of upholstered furniture fire deaths as they were being estimated in the early 1980s. These two scenarios are also the only two fire scenarios to be explicitly and intentionally addressed by furniture flammability requirements for domestic upholstered furniture.

Summary of overview

After incorporating the scenario of upholstered furniture as the principal but not the first item ignited, there are five major upholstered furniture home fire scenarios plus a sixth scenario with little or no detail that accounts for few fires and losses.

The combined upholstered furniture fire problem is shown in Table 2; scenarios are defined by igniting heat source and listed in order of estimated average annual deaths.

<table>
<thead>
<tr>
<th></th>
<th>Fires</th>
<th>Civilian Deaths</th>
<th>Civilian Injuries</th>
<th>Direct Damage (in Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighted tobacco product</td>
<td>1,900 (21%)</td>
<td>270 (45%)</td>
<td>320 (29%)</td>
<td>$97 (17%)</td>
</tr>
<tr>
<td>Open flame from other fire</td>
<td>2,200 (25%)</td>
<td>130 (21%)</td>
<td>280 (25%)</td>
<td>$138 (24%)</td>
</tr>
<tr>
<td>Operating equipment</td>
<td>1,500 (17%)</td>
<td>70 (12%)</td>
<td>140 (13%)</td>
<td>$81 (14%)</td>
</tr>
<tr>
<td>Small open flame</td>
<td>1,400 (16%)</td>
<td>60 (10%)</td>
<td>220 (20%)</td>
<td>$69 (12%)</td>
</tr>
<tr>
<td>Ember, ash or other or unclassified hot or smoldering object</td>
<td>1,300 (15%)</td>
<td>60 (10%)</td>
<td>130 (11%)</td>
<td>$150 (27%)</td>
</tr>
<tr>
<td>Unclassified,</td>
<td>600 (7%)</td>
<td>20 (3%)</td>
<td>30 (3%)</td>
<td>$31 (5%)</td>
</tr>
</tbody>
</table>
Figure 5 focuses on fire deaths and spotlights that:

- Lighted tobacco products account for the largest share of fire deaths, or nearly half (45%). If ash, ember or unclassified hot or smoldering object is principally embers and ashes from lighted tobacco products, then the total for that heat source could rise to more than half (55%).

- Small open flames account for only 10% of the total, but when fires spreading to upholstered furniture as the principal item ultimately involved in fire, flaming heat sources combined rise to roughly one-third (31%).

- Ignitions by operating equipment could add an unknown fraction of their 12% of deaths to the smoldering, small-open-flaming, or large flame from other fire shares.

<table>
<thead>
<tr>
<th>other or multiple heat source</th>
<th>Total</th>
<th>8,900 (100%)</th>
<th>610 (100%)</th>
<th>1,120 (100%)</th>
<th>$566 (100%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>8,900</td>
<td>610</td>
<td>1,120</td>
<td>$566</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5. 2006-2010 home upholstered furniture fire deaths (first or principal item ignited), by type of igniting heat source

- Small open flame
- Spread from other fire
- Multiple, unclassified, or other
- Operating equipment
- Lighted tobacco product
- Ember, ash, or unclassified hot or smoldering
Section 2
What Parts of the Upholstered Furniture Fire Problem Are Addressed by Existing or Proposed Regulations?

Three of the five major fire scenarios identified at the end of Section 1 have been the basis for fire safety requirements somewhere in the world:

Table 3.
Fire scenarios addressed and not addressed by existing or proposed upholstered furniture flammability requirements

<table>
<thead>
<tr>
<th>Fire scenario</th>
<th>Is this fire scenario addressed by any existing requirement?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition by lighted tobacco products and other smokeable products, principally cigarettes (45% of deaths) (Smoldering)</td>
<td>Addressed by cigarette ignition resistance test applied separately to components (e.g., covering fabric, filling material) or to real-scale furniture pieces or mock-ups. Voluntary standards or requirements exist in the US, the UK, Finland, Sweden, and Norway, and possibly other countries.6</td>
</tr>
<tr>
<td>Ignition by open flame spreading from other burning item (21%) (Flaming)</td>
<td>Not directly identified as a design scenario but <strong>could be addressed by tests that measure rate of heat release and time to flashover</strong> (i.e., rate of growth and peak severity of fire). No requirements for home furniture but requirements exist for furniture in public occupancies in the US. (California). Also the UK requirements include tests using a wood-crib fire,</td>
</tr>
<tr>
<td>Ignition by arcing or heat from operating equipment (12%) (Smoldering or Flaming)</td>
<td>Not directly discussed or addressed in any requirements. Relative importance may not be recognized. May be assumed to be covered by other tests but has not been tested directly.</td>
</tr>
<tr>
<td>Ignition by small open flame (10%) (Flaming)</td>
<td>Addressed by small open flame (match or simulated match) ignition resistance test applied separately to components (e.g., covering fabric, filling material) or to real-scale furniture pieces or mock-ups. Standards or requirements exist or existed in the US (California, currently being reconsidered) and the UK.</td>
</tr>
<tr>
<td>Ember, ash or other or unclassified hot or smoldering object (10%) (Smoldering)</td>
<td>Not directly discussed or addressed in any requirements. Share of problem has grown markedly in recent years and may not yet be widely recognized. Ember or ash from cigarette is a weaker ignition heat source than a cigarette and would be resisted by anything able to resist a cigarette. Ember or ash from fireplace could be a stronger ignition source than a cigarette, and if the ember is flaming, it would not be a smoldering heat source. It is possible that “unclassified hot or smoldering object” includes some heat sources not yet identified. Therefore, <strong>could be addressed by cigarette ignition resistance tests</strong>.</td>
</tr>
</tbody>
</table>

Requirements addressing the three scenarios – ignition by cigarette or other lighted tobacco product or smokeable product, ignition by open flame spreading from other burning item, and ignition by small open flame – are described in the following sections,

---

which are presented in order of the introduction of the requirements, not in order of the size of the scenario fire problem, which means small open flame fires are discussed before large open flame ignitions.

**Cigarette ignition**

**History of requirements**

In 1967, the Flammable Fabrics Act was amended to include home textiles other than the wearing apparel it has originally been created to address. The Act mandated action on fabrics that constitute an unreasonable flammability risk. The National Bureau of Standards (NBS), which had responsibility for test method development for the Flammable Fabrics Act, began funding laboratory research on the flammability of the newly incorporated home textiles in 1968.

In 1973, the US Consumer Product Safety Commission (CPSC) was created and the Flammable Fabrics Act became its responsibility, although NBS retained responsibility for test method development.

The first formal requirement was **California Technical Bulletin 117, Requirements, test procedure and apparatus for testing the flame retardance of resilient filling materials used in upholstered furniture**, first issued in 1975. TB 117 required cigarette ignition testing of filling materials under a specified fabric. It did not require tests on upholstered-furniture covering fabrics\(^7\) or of as-used upholstered furniture pieces or mock-ups.

In 1976, the NBS submitted to CPSC a draft cigarette-ignition-resistance standard for upholstered furniture. CPSC did not address the proposal until 1978, when CPSC staff modified the NBS proposal and recommended publication of the requirement to the CPSC commissioners.

In 1979, the industry’s **Upholstered Furniture Action Council** (UFAC) introduced a voluntary standard that was a cigarette ignition test of covering fabrics over a specified filling material and of filling materials under a specified fabric. In essence, it tested the parts of an upholstered furniture piece separately, each paired with a standard reference component for the other part. Barrier materials were allowed as a solution for covering fabrics that would not otherwise pass the test.

**California Technical Bulletin 116, Requirements, test procedure and apparatus for testing the flame retardance of upholstered furniture**, first issued in 1980, is a voluntary test of resistance to cigarette ignition, performed on a variety of surfaces of a complete piece of upholstered furniture.

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\(^7\) In this White Paper, “covering fabric” refers to the fabric that covers the upholstered furniture, also called the upholstery. It does not refer to the fabric used in some test methods to cover the lit cigarette in a test of direct cigarette-to-filling-material ignition resistance.
Also in 1980, the United Kingdom issued its first requirements, largely based on British Standard (BS) 5852, *Methods of test for assessment of the ignitability of upholstered seating by smouldering and flaming ignition sources*. After some significant modifications in the 1988 edition (“The Furniture and Furnishings (Fire) (Safety) Regulations 1988,” Statutory Instruments 1988, No. 1324, Her Majesty’s Stationary Office, London, UK, 1988), the requirements have remained fairly stable. Like the US standards, the UK requirement uses a cigarette test. Unlike TB 117, it tests mock-up assemblies as well as components. This responded to a growing realization that tests of components do not reliably predict the real-scale performance of complete upholstered furniture pieces.

Picking up on the NBS work, NFPA’s Fire Test Committee began developing versions of the proposal as standards within its process.

In 1983, NFPA first issued two standards, both based in large part on the NBS work and proposal. NFPA 260 (first numbered as 260A), *Standard methods of tests and classification system for cigarette ignition resistance of components of upholstered furniture*, was also based on the UFAC test method and has been modified over the years to make it even more consistent with UFAC. NFPA 261 (first numbered as 260B), *Standard method of test for determining resistance of mock-up upholstered furniture material assemblies to ignition by smoldering cigarettes*, unlike UFAC, tests mock-up assemblies.


Testing for cigarette ignition resistance has been complicated by the advent of requirements that cigarettes sold in all 50 states and the District of Columbia must comply with tests for reduced ignition strength. Discussions have been underway in recent years to identify what ignition heat source should now be used in cigarette ignition resistance tests.

**Small-open-flame ignition**

**History of requirements**

The first formal requirement was *California Technical Bulletin 117*, first issued in 1975.\(^8\) TB 117 required small open flame ignition testing of bare filling materials directly. It did

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\(^8\) TB 117 cites an older US Department of Commerce flaming ignition test for upholstered furniture covering fabrics (designation 191-53). It is not clear when or how this test was required or what effect it might have had on fabrics in use.
not require tests on covering fabrics or on as-used upholstered furniture pieces or mock-ups.


In 1992-1993, the National Association of State Fire Marshals petitioned CPSC to establish new requirements for both small open flame ignitions and large open flame ignitions. CPSC agreed to pursue a small open flame test and looked at TB 117 as the only US test providing a starting point.

In 1997, CPSC staff concluded that the TB 117 component test results did not do a sufficiently good job of predicting the performance of real-scale upholstered furniture and that TB 117, if adopted, would not ensure a substantial reduction in risk of small open flame ignitions. More generally, researchers were discovering that tests of components did not accurately predict fire performance of mock-ups or complete pieces of furniture.

CPSC next turned to the UK requirements and focused specifically on a small-open-flame mock-up test as their starting point. CPSC’s draft method was published in 1997 for comment.

CPSC also identified a distinct hazard in the flammable dust covers, typically located on the underside of upholstered furniture and designed to conceal webbing and springs. The dust covers could be ignited during fireplay.

Before CPSC could conclude this work, they were directed by Congress, based on industry concerns, to investigate the toxic hazard presented by fire retardant chemicals during manufacture of upholstered furniture. Because CPSC was focused on prevention and small-open-flame tests, they interpreted this mandate as applying to fire retardant treatments of covering fabrics, not filling materials.

A US National Research Council review of literature related to fire retardant treatments for covering fabrics found that of the 16 chemicals examined, eight were clearly not harmful and the other eight could not be definitively judged harmful or not.  

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Around the year 2000, CPSC felt free to return to their goal of developing cigarette resistance and small open flame resistance tests. However, at about the same time, CPSC was directed by the US Government Accounting Office (GAO) to change the way that they analyzed national fire incident data to determine the size of the fire problem targeted by a candidate rule. Specifically, CPSC was directed to exclude certain fires – those involving some deliberate fire-setting action, such as intentional fires – as “not addressable” by product requirements.

Before making the modifications directed by GAO, CPSC had found a ratio of 4- or 5-to-1 between upholstered furniture fires started by lighted tobacco products and those started by small open flames. After excluding small open flame ignitions deemed to be not addressable, that ratio grew to 6-to-1 or higher, and there was no longer a sufficient basis for continuing to work on a small-open-flame ignition resistance test.

There is another rationale for including a small-open-flame ignition resistance test for upholstered furniture filling material, and it relates to the requirement for cigarette ignition resistance. Specifically, if the covering fabric fails to prevent smoldering ignition, the smoldering covering fabric may transition to flaming and expose the filling material – or the filling material surrounded by a barrier – to an open flame challenge. Any engineered option that prevents ignition of the filling material by a small open flame applied directly may also prevent ignition of the filling material by a small open flame arising from an initial smoldering ignition of the covering material.

**Ignition by large open flame spreading from other burning item (with upholstered furniture as primary item contributing to fire spread)**

**History of requirements**


The UK regulations using the British BS 5852 wood-crib fire ignition source (called their level 5 ignition source) are the only requirement for home upholstered furniture that uses fire test conditions that might be severe enough to represent this fire scenario. This wood crib provides a more severe test than do any of the small open flame tests.

In addition to more severe fire test conditions, a standard test for this scenario would need different evaluation criteria, specifically, evaluation in terms of fire growth, including speed of fire growth (e.g., rate of rise in rate of heat release) and peak fire severity (e.g.,
peak rate of heat release). It does not appear that the UK test requirements, designed for
ignition-resistance purposes, include any fire growth criteria.

In 1991, California issued Technical Bulletin 133, a test of rate of heat release (fire
growth and intensity) following a large flaming ignition. This test was designed only for
furniture used in public occupancies, where large numbers of upholstered furniture pieces
may create a very large combined fuel load in a single room. TB 133 uses a square gas-
fueled burner to create a large open flame exposure.

In 1993, ASTM issued its version of this test – now informally referred to as the furniture
calorimeter – as ASTM E1537, Test method for fire testing of upholstered seating
furniture.

NFPA issued its version in 1994 as NFPA 266, Standard method of test for fire
characteristics of upholstered furniture exposed to flaming ignition source. The standard
was withdrawn in 2001 as part of the harmonization project among NFPA, ASTM and
UL, where the three organizations sought (and still seek) to reduce unnecessarily
redundant standards addressing the same need.

In 1992-1993, the National Association of State Fire Marshals petitioned CPSC to
establish new requirements for both small open flame ignitions and large open flame
ignitions. CPSC agreed only to pursue the small open flame test.

This scenario has received little attention in the many forums devoted to furniture
flammability strategies, with the notable exception of the 2012 NIST Furniture
Flammability Workshop.11

It is through this scenario that the furniture flammability issue connects to the concern
over a modern trend toward faster, more severe fires, leading to compressed fire growth
timelines. That concern has been spotlighted in the NIST Dunes II project12 because of
its relevance to modern measures of home smoke alarm performance and in work at
Underwriters Laboratories, NIST, USFA, and other places where the concern is with
threats to the lives and health of firefighters in situations that can deteriorate far more
rapidly than in decades past.

These different threats – as well as the statistical calculation that roughly one out of four
upholstered furniture fires and associated losses involve this scenario – combine to put a
high priority on better strategies to mitigate upholstered furniture fires that are ignited by
heat sources too large to allow prevention. The twin-burner test used in the 16 CFR 1633

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11 William M. Pitts, Summary and Conclusions of a Workshop on “Quantifying the Contribution of
Flaming Residential Upholstered Furniture to Fire Losses in the United States,” NIST Technical Note
1757, National Institute of Standards and Technology, Gaithersburg, MD, 2012
12 See Tables 30 and 32 in Richard W. Bukowski et al., Performance of Home Smoke Alarms – Analysis of
the Response of Several Available Technologies in Residential Fire Settings, NIST Technical Note 1455,
mattress flammability test appears to be one example of a test providing exposure severity comparable to that produced by a fire spreading from another burning item.

### Summary of Regulations

The **cigarette-ignition scenario** was the first upholstered furniture fire scenario to be addressed by formal requirements, beginning in 1975 in California with **TB 117** and in 1980 in the UK with requirements built around **BS 5852**. The earliest requirements depended solely on fire tests of upholstered furniture components. At some point, the UK added tests of mock-ups. Component tests do not reliably predict the fire performance of complete pieces of furniture.

The Upholstered Furniture Action Council test method, NFPA 260 and 261, and ASTM E1352 and E1353, all were developed from the base of TB 117 and BS 5852, and all are designed solely to address the cigarette-ignition scenario.

Currently, CPSC is attempting to develop a national requirement built around some combination of real-scale tests of mock-ups or complete pieces of furniture and bench-scale tests of furniture components that have been validated as predictive of the performance of complete pieces of furniture.

The **small-open-flame scenario** was also first addressed by TB 117 in California in 1975 and by the UK in 1980 using tests based on BS 5852.

The **scenario of ignition by another fire**, as when a piece of upholstered furniture is the primary item contributing to fire spread but not the item first ignited, has never been the explicit basis for requirements. Some requirements use a larger open-flame igniting heat source, such as the wood crib fire used in one part of the UK requirements. Some requirements – for furniture used in public occupancies not in homes, such as TB 133 – use a larger igniting heat source and evaluate performance not on ignition resistance but on speed of fire growth and peak severity. These test conditions and criteria could be used as a starting point for design of a standard test method, with evaluation criteria, which would be appropriate for the severity of this scenario and the safety goals appropriate to the scenario.
Section 3.
What Are the Engineered Options for Reducing Upholstered Furniture Flammability? What Are the Pros and Cons of These Options?

Engineered options can be broadly grouped as follows:

- Choice of covering fabric (so as to resist ignition itself and protect the filling material from ignition)
- Choice of filling material(s) for what are often multiple layers under the covering upholstery fabric (so as to resist ignition and/or burn slowly with a low peak intensity)
- Fire retardant treatment of fabric or filling materials (to reduce flammability)
- Use of fire barrier (between covering fabric and filling materials to further protect the filling materials from ignition and/or slow growth of fire for the upholstered furniture)

In addition to the above primary options, there are others, for example:

- Design to prevent dripping of burning material onto the floor
- Design to prevent formation of openings in furniture that increase fuel/air mixing during the fire

Only primary options are discussed further here. Also not discussed further are options that address the ability of heat sources to ignite upholstered furniture, such as reduced ignition-strength cigarette, child-resistant lighter, space heater designs to alert occupants when burnable items are too close, or electrical cords more resistant to damage.

Choice of (upholstery) covering fabric or filling materials

History of product change due to requirements, and relative ignitability of different covering fabrics and filling materials

When UFAC and California TB 117 and TB 116 were introduced, the principal engineered options involved changes to the covering fabrics and filling materials. In particular, there was pressure to move away from untreated (by fire retardants) cotton and other cellulosic covering materials and away from untreated cotton batting as filling material because of their tendency to smolder.

The relative ignitability of different types of fabric and filling materials was estimated in the mid-1980s by NFPA, based on tests performed by CPSC and the National Institute of Standards and Technology (NIST, then known as the National Bureau of Standards) between 1975 and 1986, with data formatting by CPSC.
The results were organized into four fabric groups and two filling-material groups. These are the four fabric groups, in order from most likely to ignite to least likely to ignite:

- Cellulosic fabrics excluding prints (specifically including velvet, corduroy, jacquard, flock and doby)
- Cellulosic or thermoplastic print, or thermoplastic flock or doby
- Thermoplastic velvet, corduroy or jacquard
- Vinyl (a specific group of thermoplastic fabrics)

The two filling-material groups were as follows:

- Untreated (i.e., no fire retardant treatment) cotton batting
- Anything else, including polyurethane foam with or without fire retardant treatment, cotton batting with fire retardant treatment, mixed fibers, and polyester, as well as more exotic filling materials such as horsehair.

Tests of ignitability were conducted with cigarettes placed on a flat surface (such as a seat) and with cigarettes placed in a crevice between two seat cushions or between a seat cushion and the arm/side or back of the furniture. Not every combination was tested, but for those that were, ignition was always more likely in a crevice than on a flat surface and almost always as likely or more likely with untreated cotton batting than with the combined results for the other materials tested.

Vinyl covering fabrics were not tested with untreated cotton batting but allowed no ignitions in any of 18 tests (12 on flat surface, 6 in crevice) with other materials. Therefore, Table 4 does not show results for any of vinyl materials.

Table 4. Propensity of different covering fabrics and filling materials to be ignited by cigarette, at various locations on upholstered furniture (based on tests from 1975-1986)\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Untreated cotton batting</th>
<th>Any other filling material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% tests with ignitions</td>
<td># of tests</td>
</tr>
<tr>
<td>Flat surface</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulosics except prints</td>
<td>91%</td>
<td>19</td>
</tr>
<tr>
<td>Cellulosic or thermoplastic print, or thermoplastic flock or doby</td>
<td>30%</td>
<td>40</td>
</tr>
<tr>
<td>Thermoplastic velvet, corduroy or jacquard</td>
<td>0%</td>
<td>3</td>
</tr>
<tr>
<td>Crevic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cellulosics except prints</td>
<td>99%</td>
<td>16</td>
</tr>
<tr>
<td>Cellulosic or thermoplastic print, or thermoplastic flock or doby</td>
<td>No data</td>
<td>0</td>
</tr>
<tr>
<td>Thermoplastic velvet, corduroy or jacquard</td>
<td>No data</td>
<td>0</td>
</tr>
</tbody>
</table>

Test data were made available from the UFAC program but were not included in the mid-1980s NFPA analysis because the UFAC data differed so markedly from the results of the other tests – in the direction of predicting much better performance. (For example,

there were no ignitions in 16 tests on flat surface, untreated cotton batting, cellulosic fabrics other than prints, compared to 91% ignitions in the dataset used.

It is unclear why the UFAC test data, taken from the first full year of the UFAC program, differed so much from the other data available from that period. These data may not have been representative of the kinds of results UFAC itself obtained in succeeding years, when testing should have settled into a stable routine. It is also possible that the special test conditions used in UFAC testing produced results more favorable and less accurate than would be produced by TB 116, BS 5852, or NFPA 260 or 261. In any event, as noted in section 2, component tests like those in UFAC have not proven to provide good predictions of the fire behavior of composite mock-ups or complete furniture pieces.

Using data on the characteristics of upholstered furniture sold in the US and an economic product-life model, CPSC provided estimates of the dramatic shift in usage of the different covering fabrics and filling materials, from 1975 (before UFAC began) to 1982 (four years after UFAC began):

| Table 5. Percentage of upholstered furniture in use in homes, by covering fabric and filling material, 1975 versus 1982 |
|--------------------------------------------------|-----|-----|
| Covering fabric                                 | 1975 | 1982 |
| Cellulosics excluding prints                    | 64%  | 44%  |
| Cellulosic prints                               | 13%  | 14%  |
| Thermoplastic except vinyl                      | 15%  | 32%  |
| Vinyl                                            | 8%   | 9%   |
| Filling material by location                    |      |      |
| % untreated cotton batting, in seat             | 53%  | 23%  |
| % untreated cotton batting, in arm              | 80%  | 47%  |

Note that there is a slight mismatch between the groups of covering fabrics in the percent-of-inventory table compared with the groups of covering fabrics in the relative-ignitability table. However, the most ignitable group of covering fabrics provided the largest decline (cellulosics excluding prints, down from 64% to 44%) and the least ignitable groups provided the largest increase (thermoplastics including vinyl, up from 23% to 41%). The shift in filling material was even more dramatic.

CPSC analysis in the mid-1990s indicated that the inventory continued to shift in the desired direction.\textsuperscript{14} CPSC found 86% of all upholstered furniture in the retail marketplace met all UFAC requirements, and the cigarette ignition likelihood averaged about 15% of all pieces of upholstered furniture sold, whether known to be compliant or not.

A piece of upholstered furniture is expected to last about 16 years. Based on that estimate of turnover US home upholstered furniture has turned over twice since the 1982 data was collected and once since the mid-1990s updated analysis by CPSC. There does not appear to be any reasonably current but comparably detailed upholstered furniture fabric and filling material usage data available.

Potential of better or more complete fire incident (NFIRS) data to add significantly to our understanding of the fabrics involved in upholstered furniture fires

National fire incident reporting has never provided much detail on the type of material first ignited. In particular, cellulosic and thermoplastic fabrics cannot be distinguished with confidence. The leading types of material first ignited for 2006-2010 home structure fires where upholstered furniture was first item ignited were as follows, ranked by percentage share of fire deaths:

- Fabric, fiber, cotton, blends, rayon or wool (73% of fire deaths; appears to refer to cellulosic materials, but categories like fabric, fiber, and blend could refer to anything)
- “Other” fabric, textile or fur (17% of fire deaths; could be a place to record thermoplastic materials that do not look like plastic or could be used for fabrics and textiles of unknown composition, in which case, the category might be mostly more cellulosics)
- Multiple types of material (4% of fire deaths)
- Unclassified type of material (2% of fire deaths)
- Wood or paper (1% of fire deaths; ignition of parts of the upholstered furniture that are neither covering fabric nor filling material)
- Plastic or plastic-coated fabric (1% of fire deaths; could capture any type of thermoplastic or might be used only for fabrics that look like plastic, such as vinyl)
- “Other” natural product (1% of fire deaths)
- Leather (0.2% of fire deaths)

These are the kinds of questions that could be explored in a special data collection research project with fire departments participating in NFIRS, but accurate identification of fabrics and filling materials (or rather, each of the layers of filling material) would probably require fire departments to collect samples for examination by specialists.

Fire retardant treatments

History of product change due to requirements

Industry sources have indicated that they found polyurethane (PU) foam would pass the TB 117 small-open-flame test if treated with fire retardants to a necessary level and

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would not pass otherwise. This helped drive the use of fire retardants in home upholstered furniture, and although the legal requirement existed only in California, industry experts say the standard affected upholstered furniture across the country.

The UK requirements also had a wider impact than the place where the requirements began, influencing or upholstered furniture across the European common market countries. Figure 6 shows the results of studies of data collected in 1994 on percentage of upholstered furniture passing either or both of the cigarette and small-open-flame (match) tests.¹⁶

Just over half of the pieces tested passed the small open flame test. Of the 26% of pieces that passed only the cigarette test, only 38% had fire retardant treatments in either covering fabric or filling material (PU foam), and only 28% had fire retardant treatments specifically in the filling material, which tends to be type of fire retardant that inspires the greatest concerns and objections.

![Figure 6. Percentages of European upholstered furniture pieces passing cigarette and/or small open flame (match) test in 1994](image)

Of the 32% of pieces that passed both cigarette and match test, 62% had fire retardant treatments in either covering fabric or filling material. Only 39% had fire retardant treatments specifically in the filling material.

**Chemicals used as fire retardants**

Fire retardant treatments can be applied to covering fabric or filling material, including but not limited to different types of polyurethane foam. Most of the concerns raised over health effects from fire retardants have been raised specifically over the use of polybrominated diphenyl ethers (PBDEs) as fire retardant treatments for polyurethane foam used as filling material in upholstered furniture.

Different fire retardant chemicals mitigate fire in different ways. PBDEs work by disrupting the chemical reactions that sustain flaming, focusing on the step in the sequence where the greatest amount of heat is produced.

Of at least 10 different PBDEs, three accounted for nearly all of the manufacture and sales until recently:
- Penta-brominated diphenyl ether (penta or penta-BDE for short), the principal PBDE used in upholstered furniture filling materials,
- Octa-brominated diphenyl ether (octa or octa-BDE for short), the other PBDE used in upholstered furniture filling materials, and
- Deca-brominated diphenyl ether (deca or deca-BDE for short), principally used in the plastic housings of electronic devices.

Due to concerns regarding health effects, Penta-BDE and Octa-BDE were voluntarily phased out of production in 2004. Also in 2004, the sale of penta and octa in concentrations higher than 0.1% by mass were banned in the European Union. In 2006, EPA required that any new manufacture or use of penta or octa would constitute a new use and require prior evaluation before approval.17

It appears that upholstered furniture manufacturers are now using Deca-PBE, previously associated primarily with electronic device housings, and other alternative fire retardants, such as chlorinated organic phosphates, to meet the requirements of TB 117.

**Fire prevention and mitigation effects of fire retardants**

Fire retardants have been used to pass small-open-flame tests of filling material. It is not clear how effective these treatments are in resisting small-open-flame ignition of a complete piece of upholstered furniture or in resisting the kind of flaming heat source created when smoldering ignition of the covering fabric is not prevented.

Recent experiments by CPSC and UL have not shown a consistent or significant effect of fire retardants on measures of fire growth, such as peak heat release rate or time to reach peak heat release rate. For example, a memo on tests conducted in 2012 by CPSC concluded “a relative difference was noticed in the foams, but the fire-retardant foams did not offer a practically significantly greater level of open-flame safety than did the untreated foams.”18 If the fire-retardant treatment tested was applied in order to pass a test like TB 117, however, then it was not designed for that kind of fire performance.

In other words, the small-open-flame ignitions that motivated the introduction of fire retardants constitute a modest share of total upholstered furniture fatal fire deaths (about 10-15%) and always have. For other fire scenarios – notably the large open flame ignitions involving fire spread from another burning item – available test evidence has

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17 “Polybrominated diphenyl ethers (PBDEs) significant new use rules (SNUR),” US Environmental Protection Agency, [http://www.epa.gov/oppt/existingchemicals/pubs/qanda.html](http://www.epa.gov/oppt/existingchemicals/pubs/qanda.html).

not shown a significant effect, and one would not expect an effect because the treatments were never designed to resist such large ignition heat sources. Either way, the evidence suggests the past impact of historically favored fire retardant treatments on fire deaths could not have been very large, even if they reliably performed as intended in all fires.

**Next generation fire retardants**

The recent replacement fire retardants used in upholstered furniture have not been new chemicals so much as existing chemicals repurposed for use as upholstered furniture fire retardants. This may serve as a stopgap strategy but is less likely to provide a long-term solution. There are long-term efforts focusing on the possibility of next-generation fire retardants that might be effective for fire safety and free of adverse health effects.

EPA’s Design for the Environment Program, created in 1992, is a partnership that currently includes CPSC, the American Fire Safety Council (formed in 2003 as the successor organization to the Fire Retardant Chemicals Association), the American Furniture Manufacturers Association, the Business and Institutional Furniture Manufacturers Association, and GreenBlue (a non-profit association formed in 2002 to promote improved life-cycle sustainability in products).

In 2005, EPA published a two-volume review of alternative chemicals for use as fire retardants in polyurethane foam.19 This kind of review provides the technical details and judgments required to determine acceptability of candidate replacements for existing fire retardant chemicals, as well as a process to determine acceptability of the next generation of candidate fire retardant treatments.

**Fire-barriers**

**Use of fire-barriers as an engineered option to reduce upholstered furniture flammability**

In the realm of fire safety, "barrier" is a catch-all term for a material layer that significantly reduces the fire contribution of a product. (One can consider drywall as a barrier protecting against the fire contribution of combustible thermal or sound insulation in the wall cavities.) For soft furnishings (upholstered furniture and mattresses) a barrier material could be a woven cloth, a non-woven fabric, a felt, etc. Some upholstery fabrics are back-coated with the coating designed to act as a barrier; in such designs, there is no need for an extra layer of fabric in the furniture assembly.

Mechanisms by which a barrier material might reduce furnishing flammability are:

- **Thermal resistance.** This keeps the rate at which filling materials are heated below temperatures at which they generate flammable vapors.

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> **Inhibition of vapor transport.** The barrier reduces the rate at which the combustible vapors from the filling materials reach the oxygen needed for burning.

> **Dilution and heat absorption.** The barrier can degrade to generate inert gases, such as water vapor, that decrease the flammability limits of the vapors in air.

> **Chemical interaction.** The barrier can degrade to release gases that retard the degradation of the filling materials or inhibit the combustion of the generated vapors.

These mechanisms can have contradictory properties. For instance, a barrier that unduly restricts the flow of degradation gases also restricts the flow of air in and out of the cushions during normal use. This reduces the resiliency of a cushion. A barrier that has a lot of fiber surface areas might be prone to smoldering ignition.

The installation of a barrier can have a major effect on fire performance, but to be fully effective, the barrier must block every path flame might take to the interior padding materials and so must surround those materials.

It may be possible – and less expensive – to install the barrier only in the location(s) needed to pass the regulatory test. For cigarette ignition resistance, this might mean protecting the top of the seat and the inside of the arms and back. This would not provide protection against thermal ignition by a space heater, for example.

Seams and zippers are potential installation weaknesses. If the seam fails, then there will be a gap where the barrier is not present.

Barriers have been recognized at least as far back as the introduction of the UFAC tests in 1979, where barriers were offered as an alternative way to comply with a smoldering-ignition-resistance requirement if the covering fabric did not perform well enough by itself.

More recently, barrier materials have drawn increased attention as an alternative to fire retardants. The 2008 version of the draft CPSC requirement resembles the original 1979 UFAC protocol in its use of a fire-barrier option as an alternative route to compliance for upholstered furniture that does not pass the cigarette-ignition-resistance test. Also, the recently revised CPSC mattress flammability standard (16 CFR 1633) achieves compliance through the use of barriers.

**Recent experimental work at CPSC and at Underwriters Laboratories (UL) provides the best estimate of the effectiveness of fire barriers.**

The fire-barrier system studied by CPSC in a round of tests in 2012 was described as follows:²⁰

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The system consisted of polyester batting over a commercially available fire-barrier
The fire-barrier was composed of a fiberglass base needle-punched with polyester and modacrylic fibers
The polyester batting was 100% polyester fiber (nominally 4 oz/yd²) in non-woven construction, 0.375” thick.

The conclusions from the 2012 CPSC tests on barriers were quite favorable: “Overall, the results demonstrated that the addition of a fire barrier markedly increased the fire safety of the furniture. The data indicated that the fire sizes were smaller and the time to reach the peak fire size was slower with fire barriers, regardless of the fabric or foams used.”

A second memo provided further definition of fire-barriers and further quantification of their performance:21
“A qualified fire barrier … must be smolder resistant and open-flame resistant…” because “…if the cover material is not smolder-resistant and can transition to flaming, then the fire barrier would be called upon to protect filling materials from flaming combustion.” This is a more precise restatement of the UFAC rules in which the barrier material is treated as a back-up for smoldering resistance by the covering fabric.

- Chairs with fire barriers had a peak heat release rate more than 50% lower than the peak heat release rate for chairs without barriers.
- Chairs with fire barriers took more than three times as long to reach peak heat release rate than chairs without barriers.

When CPSC moved on to full-scale tests later last year, the results were not so favorable:22 “…staff expected that the chairs constructed with the fire barrier would not result in any smoldering ignitions and would limit combustion in an open-flame exposure scenario. However, when tested, the fire barrier did not consistently provide a clear result on protection against smoldering ignitions. The chairs constructed with fire barriers demonstrated a considerable amount of smoldering.

“During testing, it was found that the construction of the chairs was not uniform. For example, in some cases, the plastic that wraps the foam prior to use was included in the final chair, and the seams may not have been at the exact edge of the cushions. Despite these irregularities, staff determined that they did not affect considerably the actual result of the tests. The performance of the fire barriers, when exposed to an open-flame ignition source, did indicate that the fire barrier was somewhat successful in reducing fire severity.”

Additional work remains before CPSC can say that they have a valid standard test of performance, suitable for use in a national requirement.

The work at UL was described by Tom Fabian of UL in a presentation at a 2012 NIST workshop on furniture flammability.23

A series of experiments performed on mock-ups and complete pieces of furniture showed that use of an appropriate barrier significantly slowed fire growth and reduced peak heat release rates. Among the experiments was a series comparing contemporary furniture with non-retarded foam, polyester covering fabric, and polyester wrap to contemporary furniture with added cotton-based fire barrier. Flashover was observed in 4 minutes for the contemporary furniture without fire barrier but not until 21 minutes for the contemporary furniture with fire barrier.

A second series of experiments measured time to untenability (defined as a temperature of 150° C at a location 1.5 meters above the floor) in an upstairs bedroom as affected by a living room fire in upholstered furniture. Time to untenability was 5 minutes 3 seconds with no barrier and 32 minutes 39 seconds with an added fire barrier.

**Summary of Engineered Options**

Improved resistance to cigarette ignition has been achieved through the selection of covering fabrics (e.g., thermoplastic fabrics rather than heavy cellulosic fabrics) and filling materials (e.g., polyurethane foam rather than cotton batting). These fabric and filling material choices can not only pass the cigarette-ignition tests but have also been shown through experiments to sharply increase measured cigarette-ignition resistance.

**Fire retardants** have been used to pass tests for small-open-flame resistance of filling materials since the introduction of such tests in 1975.

In fires where a smoldering ignition progresses far enough to transition to an open flame fire on the covering fabric, fire retardants in the filling material might be able to have an impact, but it is not clear what fraction of such smoldering-to-flaming fires are small enough to be affected by the type and level of fire-retardant treatment currently used in filling materials.

Fire retardants are also used in some covering fabrics to pass the tests of covering fabrics. These are different types and levels of fire retardants than are used to treat filling materials, and there has been little or no expressed public concern about the health effects of these fire retardants.

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23 Taken from notes on presentation by William M. Pitts, *Summary and Conclusions of a Workshop on “Quantifying the Contribution of Flaming Residential Upholstered Furniture to Fire Losses in the United States,”* NIST Technical Note 1757, National Institute of Standards and Technology, Gaithersburg, MD, 2012, pp. 4-5.
Polyurethane foams fire-retarded to pass TB 117, have also been tested for their ability to slow fire growth and reduce peak heat release rate. Recent tests by CPSC and UL have shown some effect but not enough to make a significant practical difference.

In other words, the small-open-flame ignitions that motivated the introduction of fire retardants constitute a modest share of total upholstered furniture fatal fire deaths (about 10-15%) and always have. For other fire scenarios – notably the large open flame ignitions involving fire spread from another burning item – available test evidence has not shown a significant effect, and one would not expect an effect because the treatments were never designed to resist such large ignition heat sources. Either way, the evidence suggests the past impact of historically favored fire retardant treatments on fire deaths could not have been very large, even if they reliably performed as intended in all fires.

Due to concerns regarding health effects, the two principal chemicals (penta- and octa-brominated diphenyl ethers) used as fire retardants were phased out of production nearly a decade ago. Other fire retardants, including deca-BDE and chlorinated organic phosphates, are reportedly being used to pass TB 117, but they also are being challenged on grounds of health effects.

California is actively exploring the possibility of removing the small-open-flame ignition test from TB 117, which would remove the only US regulation that has induced the use of fire retardants in upholstered furniture.

**Fire barrier systems** are combinations of fabric layers or coatings that prevent ignition of the protected filling material or delay the involvement of filling material in fire, thereby slowing the growth of fire and lowering the peak heat release rate (fire intensity).

Fire barriers have long been recognized in regulations as an engineered option to provide ignition resistance when the covering fabric and filling material choices are not sufficient.

More recently, fire barriers have been explored as options for a wide range of fire safety goals, but particularly for the flaming scenarios.

Experiments on fire barriers have been very encouraging, suggesting that they can achieve improved flammability and compliance with existing and proposed requirements, often better than defined fire-retardant treatment options. At the same time, real-scale experiments to date have shown too much variation to permit a standard test and associated requirements to be written on the basis of current knowledge.

**An overview of the match between engineered options and major upholstered furniture fire scenarios**

While the past 30 years have seen large reductions in the upholstered furniture fire problem, it remains one of the largest parts of the US home fire problem, with an estimated 610 fire deaths a year. This includes 130 fire deaths a year involving
upholstered furniture as the principal item contributing to fire spread but not as the item first ignited.

The **cigarette-ignition scenario** still accounts for by far the largest share of fire deaths (45%). Current research is focused on development of a new test standard to be administered by CPSC, demonstrated to predict real-scale fire performance of complete upholstered furniture pieces, with compliance to be achieved by **choices of covering fabrics and filling materials**, possibly supported by fire-barrier systems or acceptable fire retardants.

The **small open flame ignition scenario** is the other scenario traditionally addressed by regulation. It accounts for a small share of fire deaths (10%). Current research is focused on shifting the basis for compliance with any test standard from traditional fire retardants to fire-barrier systems or next-generation fire retardants.

The **scenario of large open flame ignitions due to fire spreading from another burning item** has only recently been quantified and accounts for 21% of fire deaths. Current research has not yet focused on this leading scenario or on the potential for fire-barrier systems or next-generation fire retardants to address the scenario.

The **operating equipment ignition scenario** accounts for 12% of fire deaths and has had a similar share of upholstered furniture fire deaths for as long as we have had good data. Current research is not focused on this scenario.

The **scenario of embers, ash, or other hot or smoldering ignition** accounts for 10% of fire deaths but did not account for a significant share in the 1970s and 1980s when current regulations were developed. Current research is not focused on this scenario. It is assumed that this scenario may be equivalent to the cigarette-ignition scenario – either a different coding of actual cigarette ignitions or ignition heat sources that are mostly weaker than but similar to cigarettes – and so may not require separate testing or separate safety strategies.
Section 4.
Summary of Current Status of Regulations and Research Related to the Upholstered Furniture Fire Problem

Review of current global regulatory situation for furniture flammability

- Beginning in 1975, the US, the UK, and parts of Europe have been covered by some type of cigarette-ignition-resistance standard for upholstered furniture.

- In the past, California and the UK have supplemented the cigarette-ignition-resistance standard with a second standard covering small open flame ignition resistance for the filling material or the entire piece of upholstered furniture. This second standard induced the widespread use of polybrominated biphenyl ethers (PBDEs), principally penta-BDE, as a fire retardant treatment for polyurethane foam filling materials.

- Rising health concerns regarding PBDEs led to increasingly comprehensive bans on manufacturing and sale of penta-BDE in particular. Both penta-BDE and octa-BDE were largely phased out almost a decade ago. There is pressure to ban or phase out other fire retardants, including deca-BDE and chlorinated organic phosphates, which are reportedly the fire retardants used by manufacturers to replace the phased-out penta and octa.

- In 2012, California began considering a proposal to rescind the small-open-flame ignition-resistance test part of TB 117, which is the only requirement in the US inducing use of fire retardants in filling materials of home upholstered furniture.

- The UK has maintained both their existing small-open-flame ignition resistance test requirement and a larger open-flame (wood crib fire) test requirement, while also moving away from the use of traditional fire retardants to comply with those tests. It is likely that compliance in the UK will depend increasingly on the use of fire barriers, but the technical literature is currently quite thin on fire-barrier fire performance data to support this shift.

Assessment of impact of regulatory change on fire loss in the United States

- Cigarette ignition-resistance requirements induced substantial shifts in covering fabrics (from cellulosic to thermoplastic) and in filling materials (from cotton batting not treated with fire retardants to any other filling material). Both shifts have been associated with sharp improvements in measured cigarette ignition resistance of upholstered furniture in use and sharp declines in upholstered furniture fires and associated losses.
California has the only US legal requirement for cigarette-ignition resistance, as part of TB 117 and TB 116, but its requirements are very similar to those of the UFAC program, which has been adopted across the country despite being a voluntary program.

Fire retardants have been the principal engineered option used to comply with small-open-flame ignition-resistance requirements in TB 117. Fire retardants in filling materials have been used solely to address this part of the requirements.

Small-open-flame ignition-resistance requirements targeted a much smaller part of the upholstered furniture fire problem. Because the targeted fire problem was relatively small, the estimated benefits from this part of the requirements have also been small. This does not mean it was ineffective, only that it was designed for a comparatively small fire problem.

Shifts in materials used in upholstered furniture, in part induced by flammability requirements, have resulted in far fewer fires but fires with a higher average severity. Recent studies have drawn attention to the sharp decline in time to escape in some typical home fire scenarios over the past several decades. These declines also compress the time for effective action by firefighters, reducing their chances of success and increasing their own risks of injury or death.

Fires that grow quickly when not prevented require a different engineered option than do fires where prevention through ignition resistance is a realistic goal. Options that slow fire growth or reduce peak heat release rates would be fire barriers or fire retardants, where the latter would need to be next-generation fire retardants that are shown to be effective for fire safety goals and acceptably free of serious health effects.

Overview of global research and development activities

There is considerable research underway to identify and qualify a next generation of fire retardant treatments that will be effective for fire safety and safe for environmental health. The Environmental Protection Agency’s Design for Environment (DfE) initiative is a major leader in this work and a major source of systematic evaluation protocols to be applied to candidate new materials.

There is some research underway to refine test procedures and standards for assessment of cigarette-ignition resistance of upholstered furniture. In the US, the Consumer Product Safety Commission is the entity most likely to act on this work if it is successful and is also a principal researcher.
There is some research underway (e.g., CPSC and Underwriters Laboratories) to evaluate the performance of fire-barrier systems against various ignition scenarios and for various fire performance goals.

NIST, NFPA and the US Fire Administration have contributed to recent awareness of the size of the fire problem associated with upholstered furniture as the principal item contributing to fire spread. There is not yet any significant research underway to identify technologies capable of significantly mitigating these challenging fires or to develop a standard test for this fire scenario.

There does not appear to be any active research on the opportunities for improved ignition resistance through selection or design of covering fabrics and filling materials from among those that are compliant with current requirements.

There does not appear to be any active research on tests for ignition-resistance effectiveness with respect to smoldering ignition heat sources other than cigarettes (e.g., ember or ash), even though they now account for a large share of upholstered furniture fires and losses. This may be as simple as verifying that these reported fires are primarily cigarette ignitions reported under a different name.

There does not appear to be any active research on a test for ignition-resistance with respect to ignitions due to arcing or heat from operating equipment, even though they account for a large share of upholstered furniture fires and losses. It is likely that the relative importance of this scenario has not been widely recognized.

There has been a little thinking, but no major projects, on ways to supplement the data collected in NFIRS and/or better understand what details typically lie behind some of the less well-defined reporting categories. For example, how many upholstered furniture fires are coded as “other” furniture or utensil? Are cellulosic and thermoplastic fabrics being coded into the same reporting groups, or are they being reported in different groups?