

MATERIALS AND FIRE PERFORMANCE TESTING OF BARRIER FABRICS IN MATTRESS AND UPHOLSTERED FURNITURE¹

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BACKGROUND

Fire blocking barrier fabrics have been, or will likely be, heavily used in mattresses and upholstered furniture in order to comply with current or proposed fire performance regulations, such as Consumer Product Safety Commission (CPSC) 16 CFR 1633 (Standard for the Flammability (Open Flame) of Mattress Sets) and 16 CFR 1634 (Standard for the Flammability of Residential Upholstered Furniture – Proposed Rule). Over the last 30 years the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST) has provided significant contributions to the current understanding of mattress and upholstered furniture flammability.^{2,3,4,5} We are continuing to provide technical information on these topics with our most recent activities focused on fire block barrier fabrics used and/or intended for mattresses and upholstered furniture.

The subject of material, technology, and measurement science needs for the development and utilization of barrier fabrics in the mattress and upholstered furniture industries will be the focus of a BFRL sponsored workshop on March 18th-19th 2009.⁶ This paper contains recent data illustrating why barrier fabrics may be required for upholstered furniture, a problem in barrier fabrics which could provide insufficient protection of the foam, and how a High Throughput approach to measure fiber shrinkage could be used to develop superior performing barrier fabrics.

EXPERIMENTAL

Cushions (46 cm by 46 cm by 7.5 cm) were made of a polyurethane foam (Table 1) covered with a 100% polypropylene cover fabric (373 g/m², 11 oz/yd²). Some cushions had a polyester fiber wrap (680 g/m², 20 oz/yd²) placed between the cover fabric and foam. A modified four cushion California Technical Bulletin 133 mock-up (Figure 1) was used to evaluate the fire performance of the cushions as a function of polyurethane foam type and presence of a polyester wrap. For more information on the mock-up and data from evaluating other foams, please review Ohlemiller, et al.⁷

Table 1. Polyurethane foam properties. Fire Retardant quantities reported as mass fraction (%).⁸

Identification	Density kg/m ³ (lb/ft ³)	Comment
Cl/P-M	26.9 (1.68)	3.5 % Chlorine/Phosphorous flame retardant; 11.1 % melamine (M)
Graphite	54.4 (3.4)	Expandable graphite; positive for halogens
Cl/P-M2	42.2 (2.64)	2.9 mass Cl/P flame retardant; 28.4 % M

RESULTS AND DISCUSSION

The peak heat release from these experiments is shown in Figure 2. The black bars are the cushions without the polyester fiber wrap (foam and cover fabric only). Commercial upholstered

furniture will normally contain fiber wraps for a variety of reasons, such as end-product cosmetics and softness. However, for these studies cushions without the polyester fiber wrap serve as a control for understanding the contribution of the polyester fiber wrap to the cushion fire performance. This figure clearly shows that the cushion containing the chlorine/phosphorous–melamine flame retardant (FR) package (Cl/P-M2) has a lower peak heat release compared to the cushion containing the same FR package but at a lower concentration, Cl/P-M. The graphite foam cushion fire performance is similar to the Cl/P-M cushion.

The addition of the polyester fiber wrap (gray bars) had two consequences. One consequence was that all the peak heat release values increased. Another was that all the cushions, regardless of the foam type (FR type), had the same high peak heat release values. This suggests the polyester fiber wrap in addition to the polypropylene cover fabric dominates the fire behavior of the mock-up and in essence forces the polymer in the foam to burn in spite of the presence of the flame retardant.

There are potentially two approaches to resolve the poor Cal 133 performance of the polyurethane foam, polyester fiber wrap, and polypropylene cover fabric cushions. One solution is the development and/or utilization of a fiber wrap with superior fire performance; i.e., use inherently low flammability fibers⁹ or flame retardants in the fibers. Another solution is to use fire blocking barrier fabrics in much the same way the mattress industries have used barrier fabrics to comply with CPSC 16 CFR 1633. In the cushion construction described here, the suggestion would be to place the barrier fabric between the cover fabric and the fiber wrap.

The Cone Calorimeter was used to evaluate the impact of different barrier fabrics over a polyurethane foam slab. The foams were Cal 117 compliant containing a low level of a halogen flame retardant (density: 31 kg/m³, 1.9 lb/ft³). The three barriers were Barrier A (nonwoven aramid fiber; 68 g/m², 2.0 oz/yd²), Barrier B (knitted glass charring fiber; 250 g/m², 7.3 oz/yd²), and Barrier C (woven glass fiber; 120 g/m², 3.5 oz/yd²). The Cone Calorimeter experiments were operated with the samples horizontal to the cone. The samples were exposed to an incident flux of 35 kW/m². If the sample self extinguished after a peak in the heat release rate, then the spark igniter was re-inserted. In some cases, the sample reignited when the igniter was reintroduced. For more details about this study and a discussion of the uncertainty please review Ohlemiller, et al.¹⁰

Figure 3 is Cone Calorimeter data from samples with the three barriers covering the Cal 117 compliant foam. All three experiments had the spark igniter reintroduced after the sample self extinguished (post first peak in the heat release rate). However, only the Barrier B sample reignited to give a second peak. Visual inspection of these samples before reignition revealed only Barrier B had cracks and holes in the barrier where as Barrier A and C both sealed the Cal 117 compliant foam from the heat flux environment; therefore preventing foam ignition. During other large and bench scale tests (not reported), BFRL scientists have observed failure of barrier fabrics to protect the foam due cracks or holes developing in the barrier fabric. We propose that a potential problem with barrier fabrics is that some fiber materials may shrink in a high heat flux environment, thus creating holes and rendering the underlying foam poorly protected. In other words, once the holes appear, the flames can get inside the barrier and result in a significant fire.

The purpose of the barrier fabric workshop at NIST (March 2009) is to help BFRL focus our research activities on the critical material, technology, and measurement science problems facing barrier fabrics in the mattress and upholstered furniture industries. This information will come from presentations and discussions with stakeholders in these industries. Our research suggests that a critical problem with barrier fabrics is some materials shrink sufficiently to cause the barrier fabric to shrink and create cracks and holes in the charred barrier fabric. The exposed and unprotected foam can then ignite and become involved in the fire. Other fiber-based barrier fabrics typically perform well with no visual cracks.

To help accelerate the development of low shrinking fibers for superior performing barrier fabrics, we developed a High Throughput (HT) tool to either evaluate the shrinkage of multiple fibers of the same composition at multiple fluxes simultaneously (Figure 4), or evaluate fibers of multiple compositions at the same heat flux simultaneously. The current focus has been on methods and tools development and not new technology experimentation. The range of materials tested and the number of replicates is very small, but we believe these initial results are promising. Specifically, an all cotton barrier fabric failed and a synthetic polymer fiber barrier performed well in a large scale mattress fire tests. We observed cracks and holes in the cotton barrier, which were not present in the synthetic barrier. Using the HT tool we measured a 16% shrinkage at 18 kW with a 15 mg tension weight for a cotton fiber, where as we measured only a 5% shrinkage for the synthetic polymer fiber at the same testing conditions. The HT tests suggest that the cotton barrier may experience a factor of 3 times greater shrinkage, which may result in the observed cracks in the cotton barrier. The linear density of both specimens was the same.

SUMMARY

In summary, for 30 years BFRL has been actively involved in mattress and upholstered furniture fire performance studies. Our research has led us to believe that barrier fabrics have great fire safety promise, which is aligned with anecdotal comments from stakeholders and agencies associated with fire safety issues. In addition to shrinkage, the fire blocking performance of the barrier depends on other properties as well, such as oxidation resistance, heat transfer resistance, and air permeability. Hopefully, the HT approach that we are developing can provide another piece of the puzzle to developing high performance fire blocking barriers for mattresses and upholstered furniture. Another approach to generating a superior barrier fabric may be the development of materials or the utilization of fillers, such as carbon nanotubes and clays, in fibers¹¹ or as a coating¹² to decrease fiber shrinkage in barrier fabric. Through BFRL sponsored Fire Grants, we are working with researchers in academia to concurrently explore novel filler types and coating technologies.

Figure 1. Four cushion mock-up in Cal 133 mock-up frame, showing placement of Tee burner igniter. The heat release rate properties of these mock-ups were measured using standard oxygen consumption calorimetry in a 2 meter furniture calorimeter in the large-fire facility at NIST.



Figure 2. Peak Heat Release from Cal 133 tests of PU foams with or without polyester fiber wrap between the polypropylene cover fabric and the PU foam. The inserted peak Heat Release values are an average of the two tests of each specimen type. Standard uncertainty is 10% of the reported peak heat release value.

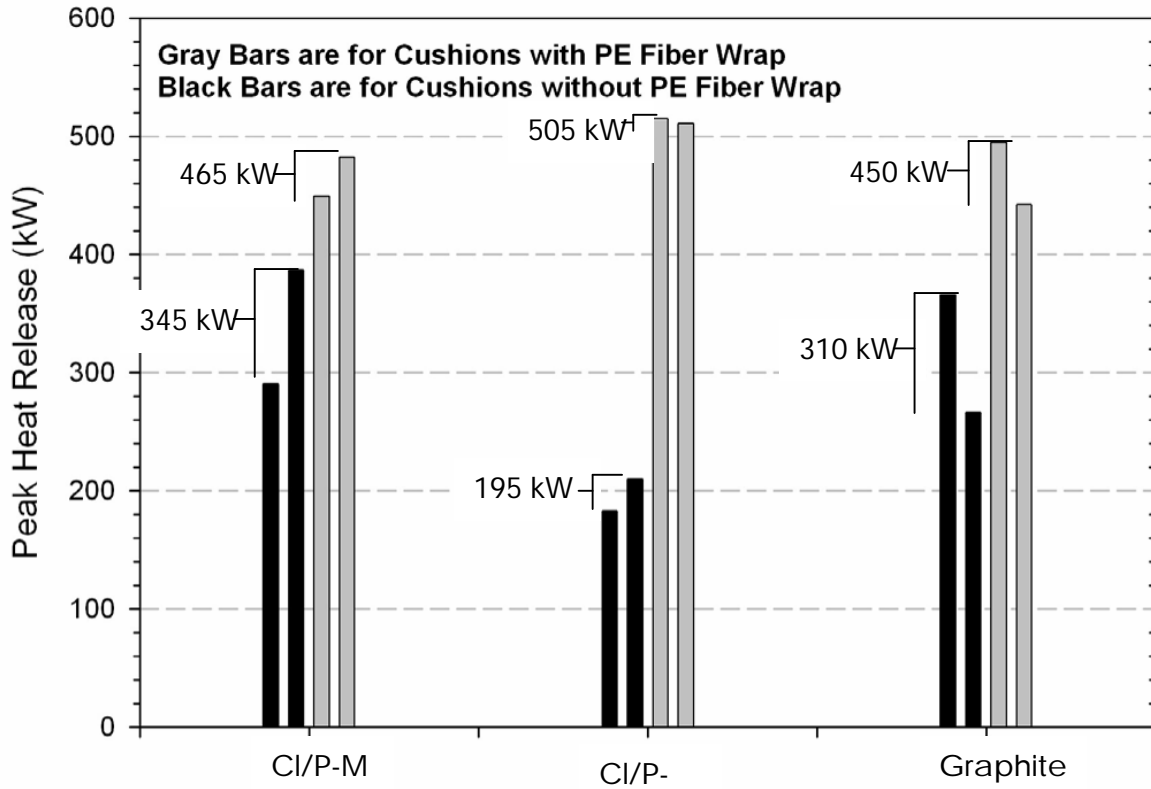


Figure 3. Cone Calorimeter of three fire block barrier fabrics covering a PU foam. The material in Barrier B shrank sufficiently to create holes in the barrier fabric. Upon reapplying an ignition source, the foam exposed by the holes in the barrier fabric ignited, which lead to the second pHRR in the Barrier B plot.¹⁰

The dotted and solid lines are replicate tests. The standard uncertainty is 10% of the heat release rate value, except for Barrier B where the uncertainty is 15%.

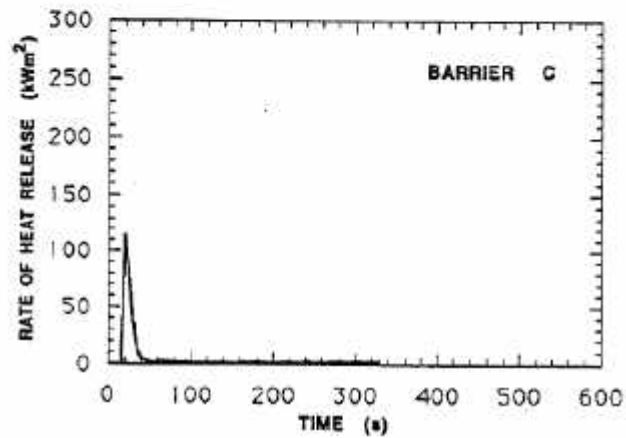
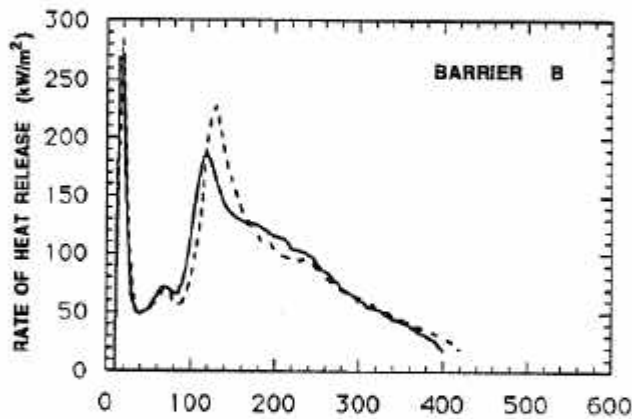
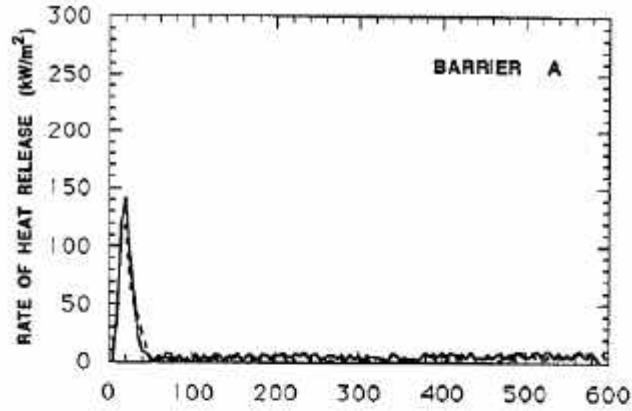
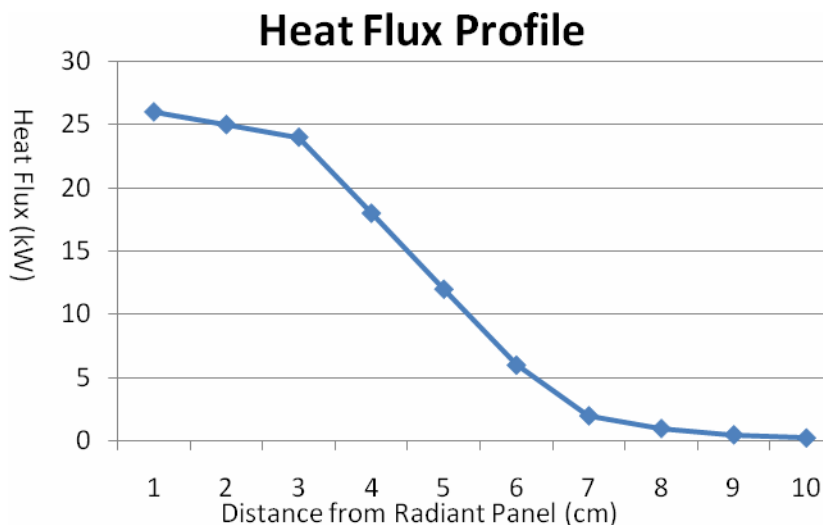


Figure 4. Heat flux decreases as a function of distance from the radiant heat source. This multi-flux environment on the same fiber composition is a High Throughput approach to accelerate our measurement of fiber shrinkage in barrier fabrics.



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- ¹ This work was carried out by the National Institute of Standards and Technology (NIST), an agency of the U. S. government and by statute is not subject to copyright in the United States. Certain commercial equipment, instruments, materials or companies are identified in this paper in order to adequately specify the experimental procedure. This in no way implies endorsement or recommendation by NIST.
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