A SUMMARY REPORT

RESEARCH DATA ON UPHOLSTERED FURNITURE FIRE BARRIERS

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1. INTRODUCTION

Current fire statistics report that of residential fires that result in death, upholstered furniture is the leading item to ignite. The hazards of open flame burning can be significantly reduced with the use of fire barriers and without the use of added flame retardants. Research has been conducted by key scientific and regulatory organizations on the availability and efficacy of fire barrier materials for use in the construction of upholstered furniture. These studies by the National Institutes of Standards and Technologies (NIST), Chemical Insights Research Institute (CIRI) of Underwriters Laboratories Inc. and the State of California Department of Consumer Affairs Bureau of Household Goods and Services (BHGS) are summarized below:

2. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST) FIRE BARRIER RESEARCH

STUDY 1. SMOLDERING AND FLAME RESISTANT TEXTILES VIA CONFORMAL BARRIER FORMATION[1]

Purpose of the study.

To investigate the fire barrier properties and ignition resistance of an oxidized cyclic siloxane back-coating barrier.

Key findings.

A cotton fabric back-coated with vinyl-modified aluminum-hydroxide (BCF vATH-Fabric) was found to have smolder and open flame resistant properties. This product is commercially available.

Brief description of the materials.

- Pristine cotton fabric
- Cotton fabric back-coated with vinyl-modified aluminum-hydroxide (BCF vATH-Fabric)
  - Fabric: cotton
  - Reactive fillers
    - 65% (by mass) vinyl-modified aluminum-hydroxide
    - 13% (by mass) vinyl-modified nanosilica
  - Binder: silicone elastomer crosslinked by PT-catalyzed hydrosilation
  - Back-coating applied to fabric by knife coating
  - Halogen free
- Cotton fabric back-coated with standard aluminum-hydroxide (BCF ATH-Fabric)
  - Only briefly mentioned in initial characterizations with BCF vATH-Fabric and cotton

Brief description of the methods.

- Flexural rigidity
  - Peirce' cantilever test
- Wash resistance test
  - UK SI1324
- Microscale combustion calorimetry
  - ASTM D7309 method A
  - 3 mg samples with an E factor of 15.21 kJ/g O_2 and a heating rate of 1 °C s^{-1} up to 1000 °C
- Smoldering ignition resistance
  - ASTM E1353-08a with mockup assembly of fabric and California Technical Bulletin TB 117-2013 compliant foam
  - Smoldering ignition source was a NIST SRM 1196 cigarette.

- Flame ignition resistance
  - Simulated match-flame ignition test with mockup assembly of fabric and TB 117-2013 compliant foam
  - Designed to simulate the UK fire and furnishing regulatory requirements as determined by BS5852: Source 1.
- Fire barrier properties
  - Cone calorimetry (ASTM E 1354) with mockup assembly of fabric and TB 117-2013 compliant foam
  - The foam (105 mm × 105 mm × 51 mm) and the fabric (105 mm × 105 mm) were held together with a standard retainer frame.

Results.

- Flexural rigidity
  - Pristine fabric: 82 μJ
  - BCF vATH-Fabric: 291 μJ
  - BCF ATH-Fabric: 751 μJ
- Smoldering ignition resistance
  - Pristine fabric: failed
  - BCF vATH-Fabric: did not smolder, suppressed charring in foam, extinguished the ignition source.
- Flame ignition resistance
  - Pristine fabric: flame ignition, progression, and breakthrough with first application of flame.
  - BCF vATH-Fabric: passed, no ignition after multiple attempts.
- Fire barrier properties
  - Pristine fabric: 20 s to ignite fabric, 240 s to ignite pyrolyzing foam and transition to flaming.
  - BCF vATH-Fabric: 30 s to ignite fabric, 90 s to flame out.

Which barriers pass BOTH the TB 117-2013 smolder test and an open flame test?

- Back-coated vinyl-modified aluminum hydroxide (BCF vATH)
  - Barrier:
    - Reactive filler
      - 65% (by mass) vinyl-modified aluminum-hydroxide
      - 13% (by mass) vinyl-modified nanosilica
  - Binder: silicone elastomer crosslinked by PT-catalyzed hydrosilation
  - Can be made from commercially available products:
    - Two-part component (base and curing agent) silicone Sylgard 184 (Dow Corning)
    - Vinyl-silane modified aluminum-hydroxide (Apyral 40VS1, Nabaltec)

STUDY 2. FULL-SCALE EXPERIMENTS TO DEMONSTRATE FLAMMABILITY RISK OF RESIDENTIAL UPHOLSTERED FURNITURE AND MITIGATION USING BARRIER FABRIC[2]

Purpose of the study.

To investigate fire growth in compartments furnished with three TB 117-2013 compliant couches via:

- Quantification of the effect of barrier fabrics on fire hazard.
- Determination of failure mechanisms of barrier fabrics.
- Demonstration of barrier fabrics without chemically active fire retardants can be effective.

Key findings.

A cotton blend cover fabric with a padding barrier of woven glass yarn without added flame retardants was found to extend flashover to 21 minutes compared to 6 or 7 minutes for the two couches without a barrier, the polyester cover fabric couch and cotton blend cover fabric couch, respectively.

Brief description of the materials.

- Polyester cover fabric couch
  - Cover fabric: thermoplastic polyester
  - No barrier fabric
- Cotton blend cover fabric couch
  - Cover fabric: 55% by mass cotton, 25% by mass polyester, 12% by mass viscose/rayon blend, 8% by mass linen
  - No barrier fabric
- Cotton blend cover fabric with barrier fabric couch
  - Cover fabric: 55% by mass cotton, 25% by mass polyester, 12% by mass viscose/rayon blend, 8% by mass linen
  - Barrier fabric: commercial product; layer in contact with cover fabric was nonwoven, needle-punched regenerated cellulose/polysilicic acid hybrid fibers; the other layer in contact with the padding material was constructed of a woven glass yarn; only intrinsically fire-resistant fibers, without additional chemically active fire retardants.

Brief description of the methods.

- 360° video cameras
  - Outside compartments: wide-angle high-definition video of the experiment was captured using a single-lens reflex digital camera (Canon EOS 5D Mark IV).
  - Inside compartments: high-definition video was captured using a sports action camera (GoPro Hero6) in a purpose-built enclosure located approximately 100 cm from the front opening of the compartment.
- Photoelectric smoke detector
  - On the ceiling along the centerline of the compartment, approximately 30.5 cm from the opening.
- Fire calorimetry / heat release rate (HRR) determination
  - 10 MW large-scale oxygen consumption calorimetry: using large canopy exhaust hoods to capture fire effluents for quantification of the heat release as a function of time.
- Incident heat flux
  - Three plate thermocouples were mounted on the south wall of the compartments and two were mounted on top of couch seat cushions.
  - Plate thermocouple description: 0.51 mm diameter (24 AWG) Type K thermocouple wires welded directly to the rear of an Inconel® 600 plate. The thickness of the mineral fiber blanket was 25.4 mm. A 100 nm^2 square plate of Inconel was used.
  - The incident heat flux on a plate thermocouple (q_{inc}'', in W/m^2) can be calculated using the measured temperature of the plate thermocouple ($T_{gas,}$ in K) and the gas temperature near the plate thermocouple (T_{PT}, in K).

- Temperatures
  - Gas temperature directly adjacent to each plate thermocouple was measured using an exposed junction, 2 mm diameter Type K thermocouple with an expanded uncertainty of ± 7.7 %.
  - Upper layer (Tceiling) and lower layer (Tfloor) gas temperatures were measured about 10 cm from the ceiling and the floor, respectively using Inconel-sheathed, 3.175 mm outside diameter, grounded junction Type K thermocouples with an estimated expanded uncertainty of ± 2.7 %.
  - Temperature directly behind the thermal protection for the wall-mounted microphone (Tmic) and in the outflow water for the 360° camera (Tbob) was measured using exposed junction (bare-bead) Type K thermocouples with estimated expanded uncertainties of ± 3.5 % and ± 2.1 %, respectively.
- Gas species concentrations
  - O_2, CO_2, CO sensors
    - Gas samples…were extracted from a 6 mm diameter stainless steel tube with its opening approximately 93 cm below the ceiling of the compartment. A Permapure MiniGASS sample conditioning system was used to filter and dry the sample gas. The sample gas flow rate was 1 slpm for these tests. The delay time from the room inlet port to the gas rack was approximately 45 s.
    - Oxygen concentration was measured using a paramagnetic oxygen analyzer. Carbon dioxide and carbon monoxide concentrations were measured using a nondispersive infrared (NDIR) analyzer, 600D NDIR manufactured by Cal, USA.
  - Probes for per- and poly-fluoroalkyl substances (PFAS) and hydrogen cyanide (HCN) were used, but not reported in this study.

Results.

- Photoelectric smoke detector
  - Polyester cover fabric couch: triggered at 42 s
  - Cotton blend cover fabric couch: triggered at 45 s
  - Cotton blend cover fabric with barrier fabric couch: triggered at 47 s
- Video cameras
  - Polyester cover fabric couch: flame and smoke layer at 2 min, the flame and fire increased until flashover at 7 min
  - Cotton blend cover fabric couch: flame and smoke layer at 2 min, the flame and fire increased until flashover at 6 min
  - Cotton blend cover fabric with barrier fabric couch: flame and smoke layer at 2 min, smoke dissipated by 4 minutes, smoke layer returned at 14 minutes, flashover at 21 min
- Heat release rate (HRR) reported in time to peak heat release rate (t_{PHRR}), peak heat release rate (PHRR), and total heat release rate (THR) values, respectively.
  - Polyester cover fabric couch: 8.1 ± 0.2 min, 9175 ± 548 kW, 2550 ± 160 MJ
  - Cotton blend cover fabric couch: 6.7 ± 0.2 min, 9640 ± 580 kW, 2640 ± 160 MJ
  - Cotton blend cover fabric with barrier fabric couch: 21.7 ± 0.2 min, 8420 ± 500 kW, 2250 ± 140 MJ
- Gas species concentrations
  - The leading cause of incapacitation and death during and immediately after fires is exposure to asphyxiant gases, such as carbon monoxide (CO), hydrogen cyanide (HCN), and carbon dioxide (CO2).
  - The danger of incapacitation after about 5 minutes exposure in a person engaged in light activity is about 6000 ppm to 8000 ppm. These values were never reached in the tests performed in this study due to the high ventilation factor of 0.14 m1/2 but could be easily achieved in room scenarios with more realistic ventilation values.

Which barriers pass BOTH the TB 117-2013 smolder test and an open flame test?

- This study utilized three couch assemblies that had passed the TB 117-2013 smolder test.
- The cotton blend cover fabric with barrier fabric couch reached flashover at 21 minutes compared to 6 or 7 minutes for those without a barrier, the polyester cover fabric couch and cotton blend cover fabric couch, respectively.

STUDY 3. REDUCED-SCALE TEST TO ASSESS THE EFFECT OF FIRE BARRIERS ON THE FLAMING COMBUSTION OF CORED COMPOSITES: AN UPHOLSTERY-MATERIAL CASE STUDY[3]

Purpose of the study.

To compare the fire performance of barriers (peak of heat release rates) using the ASTM E1474-14 standard test and the Cube Test.

Key findings.

Barriers that performed well in the open flame test were (in order of performance):

- B3 (nonwoven oxidized poly-acrylonitrile fibers with a 5% regenerated cellulose binder)
- B1 (nonwoven regenerated cellulose/polysilicic acid and cotton with a polyester binder)
- B5 (woven para-aramid fiber/fiberglass core with core-spun yarns)
- B2 (woven E glass with a plain weave and no sizing)

Brief description of the materials.

- Foam: flexible polyurethane foam (FPUF) (density 29.5 kg/m^3 ± 0.6 kg/m^3), compliant with TB 117-2013 requirements for standard foam
- Cover: polypropylene cover fabric (C0)
- Two sets of fire barriers (B1^0 to B4^0) and (B1 to B6)
  - B1^0 to B4^0 are barriers containing halogenated/organophosphorus fire retardants
  - B1 to B6 do not contain halogenated/organophosphorus fire retardants and are commercially available

Brief description of the methods.

- CBUF test configuration (i.e., ASTM E1474)
- Cube test configuration

Results.

- The results are the analysis of the “Cube Test” methodology, test configuration, and determination of the “wetting point.”
- Based on the values of time to the wetting point, the *best performing* fire barriers were (in order of performance):
  - B3 (nonwoven oxidized poly-acrylonitrile fibers with a 5% regenerated cellulose binder)
  - B1 (nonwoven regenerated cellulose/polysilicic acid and cotton with a polyester binder)
  - B5 (woven para-aramid fiber/fiberglass core with core-spun yarns)
  - B2 (woven E glass with a plain weave and no sizing)

Which barriers pass BOTH the TB 117-2013 smolder test and an open flame test?

This study did not test for TB 117-2013 so this information is not available. The Cube Test, as developed by NIST, was used for the open flame test.

3. CHEMICAL INSIGHTS RESEARCH INSTITUTE (CIRI) OF UNDERWRITERS LABORATORIES INC. FIRE BARRIER RESEARCH[4,5]

Purpose of the study.

This study compared the effectiveness of differing flammability reduction strategies on upholstered chairs with and without added flame retardants and the use of a barrier material using full scale furniture burns.

Key findings.

Furniture with 100% fiberglass textile barrier material (commercially available) was found to be flame resistant. The barrier textile used in this study was Hanes Companies, Inc., Uniguard #33025, 100% fiberglass, plain weave, finished weight of 3.4 oz/yd2 with an organic coating of about 7%. Dimension stability minimum 700. https://albanyfoam.com/product/uniguard-flame-guard/

Brief description of the materials.

- Upholstered chair
  - Twenty fully assembled upholstered chairs were manufactured to specifications; five chairs each of one of the fire suppression technologies.
    - No added flame retardant added to the PUF
    - Chemical flame retardant added to the PUF
    - Reactive chemical flame retardant added to the PUF
    - Fire barrier fabric added fully covering the PUF beneath the cover fabric. No flame retardant was added.
- Materials
  - Cover fabric – 100% cotton
  - Fire barrier – 100% fiberglass, Hanes Companies, Inc., Uniguard #33025, 100% fiberglass, plain weave, finished weight of 3.4 oz/yd^2 with an organic coating of approximately 7%. Dimension stability minimum 700°F. https://albanyfoam.com/product/uniguard-flame-guard
  - 70% polyurethane foam (PUF) – Type 1, density of 1.80 ± 0.05, IFD (compression) of 27-30, with an airflow (cfm) of 3.5 – 4.0 with 30% soy-based foam.
  - Other materials included recycled and regenerated fibers, metals, and engineered laminated frame with soy-based resins.

Brief description of the methods.

- TB 117-2013 smolder test and open flame tests
- Open flame tests: ISO 9705 test room and an open heat release calorimeter test for fire performance
  - The open heat release calorimeter to measure the potential or maximum flammability values.
  - The ISO 9705 test room simulates a realistic fire environment in a residential setting.

Results.

- TB 117-2013 smolder test
  - The fire barrier did not pass the smolder test in this research but had been reported to pass by the manufacturer of the chair.
- Open flame test
  - Three chair types (no flame retardant, chemical, and reactive chemical flame retardants added) were engulfed in flames at 7 minutes from ignition; with flashover at approximately 14 minutes.
  - The chair with the fire barrier never fully ignited, suppressing heat, and would not significantly contribute fuel to a residential fire.
- Study conclusion
  - The research study concluded that an effective fire barrier will reduce the peak heat release rate and delay the onset of flaming.

4. BUREAU OF HOUSEHOLD GOODS AND SERVICES (BHGS), FORMERLY THE BUREAU OF ELECTRONIC & APPLIANCE REPAIR HOME FURNISHINGS & THERMAL INSULATION (BEARHFTI) FIRE BARRIER RESEARCH[6]

Purpose of the study.

Upholstered furniture is often one of the largest fuel loads contributing to fires in residential settings. Since fire barriers are effective in delaying the involvement of filling materials in a fire, this open flame barrier study evaluates the effectiveness of a variety of barrier materials which could be used in upholstered furniture.

Key findings.

Twenty-three of 25 commercially available fire barriers passed a small scale open flame test and of the five used in full scale furniture fire studies, four were flame resistant.

Brief description of the materials.

- Polyurethane foam (PUF) substrate used in small-scale and full-scale tests
  - Type 1, density of 1.80 ± 0.05, IFD (compression) of 27-30, with an airflow (cfm) of 3.5 – 4.0 (standard for use in TB 117-2013)
- Three cover fabrics used in full-scale open flame tests
  - Polyester/acrylic blend (75%/25%), fabric weight of 12.42 oz/yd^2
  - Rayon/cotton/polyester blend (54%/24%/22%), fabric weight of 18.73 oz/yd^2
  - Cotton/polyester/olefin blend (36%/33%/31%), fabric weight of 12.34 oz/yd^2
- Twenty-five fire barrier materials were tested with the small-scale open flammability test. All were commercially available except for three. Fabric structures included:
  - Knits
  - Coated knits
  - High loft nonwovens
  - Composite nonwovens
  - Five fire barrier materials were tested with the full-scale (open flame) validation test with combinations of cover textile, all commercially available.
    - High loft nonwoven, 4.4 oz/yd^2, inherent
    - Knit, 8.8 oz/yd^2, passive
    - Composite nonwoven, 7.5 oz/yd^2, passive
    - High loft nonwoven, 9.9 oz/yd^2, passive
    - Knit, 4.5 oz/yd^2, active

Brief description of the methods.

- A small-scale open flame barrier test was used to test a variety (25) of fire barrier materials provided by the industry.
  - A barrier specimen of 10” x 10” is used in an assembly with a 5” x 5” x ½” PUF. The barrier is placed on the mounting plate with cover fabric on face side down and PUF on the top. The burner is placed 4” below the center of the bottom surface of the test specimen. Once the test begins, it is timed. Flame is turned off after 1 minute and removed. Test continues until all traces of flaming and smoldering have ceased.
  - A single test specimen fails to meet the requirements of this test if the PUF ignites, or a visible flame is observed from the foam. A barrier material passes the test if three initial specimens pass the test. If more than one initial specimen fails, the barrier material fails the test. If that occurs, then repeat with three specimens. If all three passes, the barrier passes, if one fails, the barrier fails.
- Full-scale validation tests were conducted on mock-up furniture combining various cover fabrics, barrier materials, and a polyurethane foam (PUF).
  - Five fire barrier types were used in mock-up chair samples. Three types of heavy weight fabrics were selected as cover fabrics. Each mock-up sample consists of a back cushion, a seat cushion, and two arm cushions. For comparison purposes, mock-up cushions made of the same cover fabrics and foam are constructed without barriers as control samples.

Results.

- How many of the fire barriers passed the TB 117-2013, Sec 3 smolder test?
  - Eight of the 25 fire barriers (Table 2)
- How many of the fire barriers passed the small-scale open flame test?
  - Twenty-three of the 25 fire barriers
- Of the five fire barriers tested in the full-scale open flame validation test, all four passed as noted here.
  - High loft nonwoven, 4.4 oz/yd^2
  - Knit, 8.8 oz/yd^2
  - Composite nonwoven, 7.5 oz/yd^2
  - High loft nonwoven, 9.9 oz/yd^2
  - Only #20, knit, 4.5 oz/yd^2 did not pass the validation test.
- Which fire barriers passed the smolder test and the open flame test?
  - See Table 2 for detailed list.
  - All that passed were either high loft or composite nonwovens of varying weights.

Table 2. BHGS Fire Barrier Research Fire Barrier Textiles that pass TB 117-2013 and Open Flame Tests

Structure	Weight (oz/yd^2)	Market	Open Flame Barrier Test	TB 117-2013 Sec. 3
High loft nonwoven	4.4	Mattress	Pass	Pass
High loft nonwoven	5.3	Mattress	Pass	Pass
High loft nonwoven	8.8	Mattress	Pass	Pass
Composite nonwoven	7.5	TB 133	Pass	Pass
Composite nonwoven	5.5	TB 133	Pass	Pass
High loft nonwoven	7.2	Mattress	Pass	Pass
High loft nonwoven	9.9	Mattress	Pass	Pass
High loft nonwoven	9.9	Mattress	Pass	Pass

- Limitations
  - Fabric descriptions did not include information on added flame retardants or other finishes. Only described as active, passive, or inherent.
  - Manufacturer specification information was not provided for any of the fire barriers tested.
- Study conclusion
  - The research study concluded that effective fire barriers are commercially available that reduce the peak heat release rate and delay the onset of flaming.

5. SUMMARY REVIEW

- Fire barrier textiles are effective fire suppression systems for the control of open flames that can lead to residential fires.
- The Chemical Insights research glass fiber fire barrier passed open flame testing and showed significant benefits over the alternative use of use of flame retardants or no flame retardants, the barrier did not pass TB117-2013, but the manufacturer indicated independently indicated that the chair made with this barrier did pass TB117-2013.
- The NIST research presented one fire barrier that passed an open flame test and TB117-2013.
  - A modified vinyl with aluminum hydroxide back-coating applied to the back side of the cover fabric providing a layer between the face side of the cover fabric and the PUF. This solution can be made from commercially available products.
- The NIST research also showed the benefits of numerous barriers including a nonwoven oxidized poly-acrylonitrile fiber material with a 5% regenerated cellulose binder; a nonwoven regenerated cellulose/polysilicic acid and cotton material with a polyester binder); a woven para-aramid fiber/fiberglass core material with core-spun yarns; and a woven E glass material with no sizing.
- The BHGS research compared 25 fire barrier textiles, testing for open flame and smoldering (TB117-2013).
  - Twenty-three of the 25 available barriers were found to be effective, passing a small open flame test.
  - Eight of the 25 passed the open flame test and TB117-2013. No detailed textile specification information was disclosed.
    - The material structure of the eight fire barrier textiles was either high loft or composite nonwovens.
    - These eight fire barriers represented a weight range of 4.4 to 9.9 oz/yd^2.
    - The study did not disclose if any of those passing the smoldering and open flame test contained flame retardant chemicals.
- Four of the barriers used in full scale furniture burn tests showed to be effective against open flames.

Where to find fire barriers?

- Currently, there are fire barriers available in the market that pass TB117-2013 and open flame testing.
- The materials for a fire resistant back-coating applied to the back side of the cover fabric are commercially available as identified by NIST. It is made from commercially available products including a two-part component (base and curing agent) silicone Sylgard 184 (Dow Corning) and a vinyl-silane modified aluminum hydroxide (Apyral 40VS1, Nabaltec).
- A supplier (Preferred Finishing) identified availability of two barrier fabrics that pass TB117-2013, perform well in open flame testing, and do not contain halogens.
  - K-800 is an effective green barrier. It is a cotton fiberglass knit with an intumescent coating that does not contain halogens or any CA Proposition 65 ingredients.
  - K-408 is a glass/modacrylic/rayon blend with a urethane film laminated to the fabric.
- Numerous other barriers were identified to be effective against open flames as shown in the NIST and BHGS research, but supplier names were not furnished. Their compliance with TB 117-2013 would need to be confirmed.

6. REFERENCES

1. Zammarano, M. et al. Smoldering and Flame Resistant Textiles via Conformal Barrier Formation. Advanced materials interfaces 3, http://doi:10.1002/admi.201600617 (2016).
2. Zammarano, M. et al. NIST Technical Note 2129 (ed NIST) (U. S. Department of Commerce, Gaithersburg, MD, 2020).
3. Zammarano, M. et al. Reduced-scale test to assess the effect of fire barriers on the flaming combustion of cored composites: An upholstery-material case study. Fire and Materials, http://doi:10.1002/fam.2910 (2020).
4. Davis, A., Ryan, P. B., Cohen, J. A., Harris, D. & Black, M. Chemical exposures from upholstered furniture with various flame retardant technologies. Indoor Air, doi: https://doi.org/10.1111/ina.12805 (2021).
5. Harris, D. et al. Chemical exposure and flammability risks of upholstered furniture. Fire and Materials, http://doi:10.1002/fam.2907 (2020).
6. Nurbakhsh, S. (ed State of California Department of Consumer Affairs) (Bureau of Electronic & Appliance Repair, Home Furnishings & Thermal Insulation (BEARHFTI), Sacramento, CA, 2018).

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