NIST National Institute of Standards and Technology U.S. Department of Commerce

FRPM19 EUROPEAN MEETING ON FIRE RETARDANT POLYMERIC MATERIALS 26.-28.6.2019 TURKU FINLAND

engineering laboratory

Assessing the Effect of Barrier Fabrics on the Heat Release Rate of Residential Upholstered Furniture

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Introduction

- In the U.S., residential upholstered furniture (RUF) fires are the single largest cause of civilian deaths in home fires (about 25%) [1].
- The fire safety community has developed test methods and mitigation strategies to assess whether certain technologies can reduce the fire hazard of RUF by suppressing smoldering and flaming combustion.
- Recent analysis of fire losses indicates that a majority of the RUF fire deaths and other losses occur during flaming, rather than smoldering combustion, regardless of the ignition source type [2].
- We conducted a series of full-scale tests focused on quantifying the ability of 6 different commercially available barrier fabrics (BFs) (compliant with California State Assembly Bill No. 2998 [3]) to reduce the heat release rate (HRR) and delay the fire growth of full-scale chair mock-ups.

Chair Mock-ups: Chair Construction

- 7 chair types
  - 1 cover fabric (B0), polypropylene
  - 6 fire barriers (B1-B6)
- Triplicate tests = 21 chairs

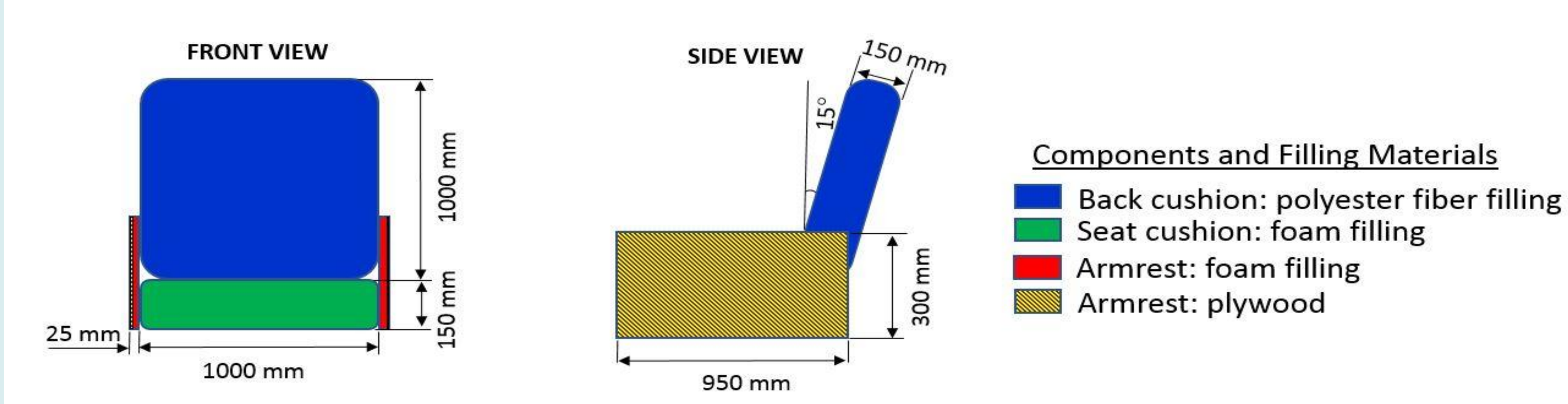
Seams (Metal Staples)

Cushion Design

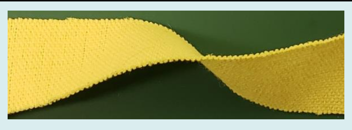
Foam or Polyester Fibers

Fire Barrier

Cover Fabric



Barrier Materials

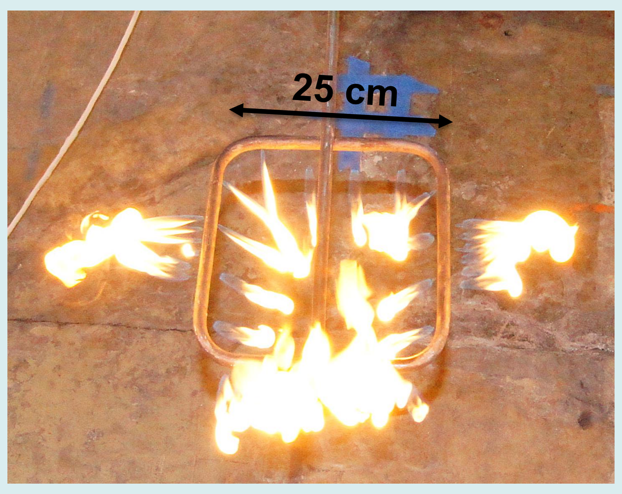
Barrier	Barrier Sample	Fabric Type	Materials	Density g·m^{-2}	Air Perm. cm^3·s^{-1}·cm^{-2}
B0		Cover fabric	Polypropylene	340 ± 7	3.9 ± 0.3
B1		Nonwoven-bonded polyester	RC**/PSA* (top), cotton (bottom)	239 ± 21	22.4 ± 1.4
B2		Woven	E glass, no sizing	109 ± 4	9.2 ± 2.2
B3		Nonwoven, 5% RC** binder	Oxidized poly-acrylonitrile fibers	240 ± 22	7.1 ± 0.5
B4		Woven	E glass, no sizing	50 ± 1	31.4 ± 4.6
B5		Woven, core spun yarns	Para-amid fiber, Fiberglass core	278 ± 3	2.7 ± 0.0
B6		Nonwoven, Needle-punched	RC**/PSA* hybrid Yarn, glass yarn	275± 4	9.7 ± 0.7

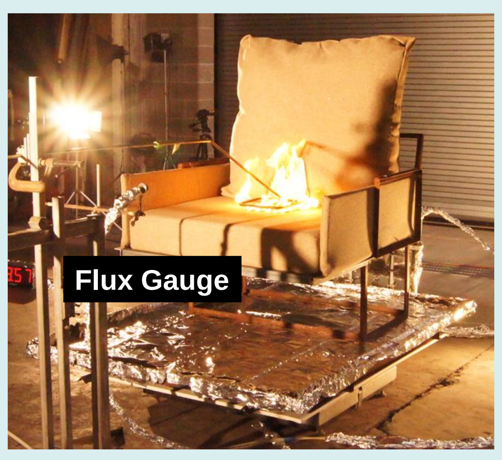
Note: RC** = Regenerated Cellulose; PSA*= Polysilicic Acid

Experiment and Results

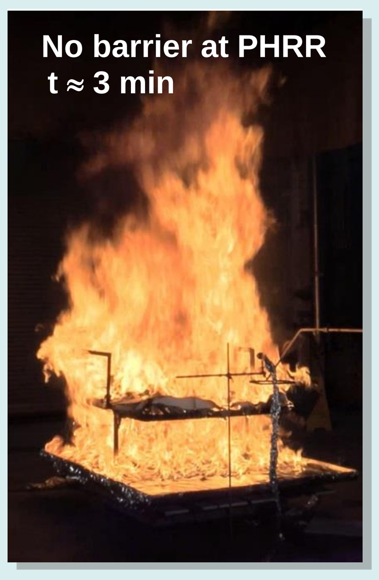
Ignition Source

- Propane burner by Cal TB 133 [4]
- Heat Flux 18 kW applied for 80s
- Located 1 inch above the seat



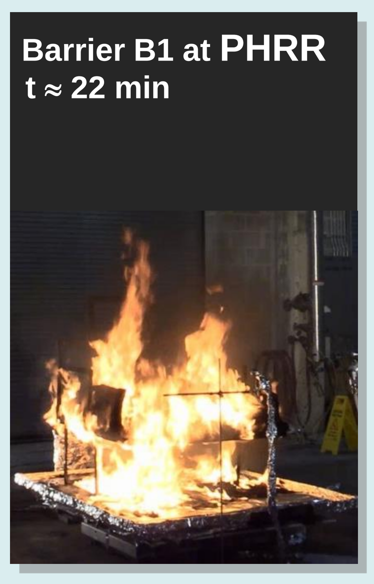


Effect of Fire Barriers

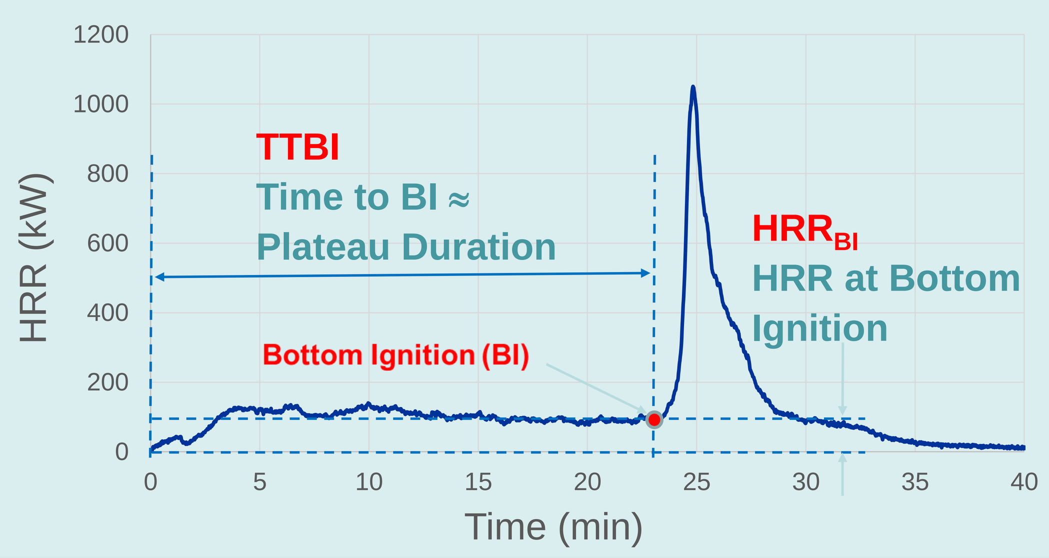


Fire barriers allow to:

- Increase time to peak from 3 mins (B0) to 22 mins (B1/B6)
- Decrease PHRR from about 3 MW to about 1 MW



Effect of Fire Barriers on HRR



Bottom of Chair Barrier Failure Mechanism

Ignition of chair (flame spread)

Foam pyrolysis to liquid polyol

Liquid percolates through the barrier

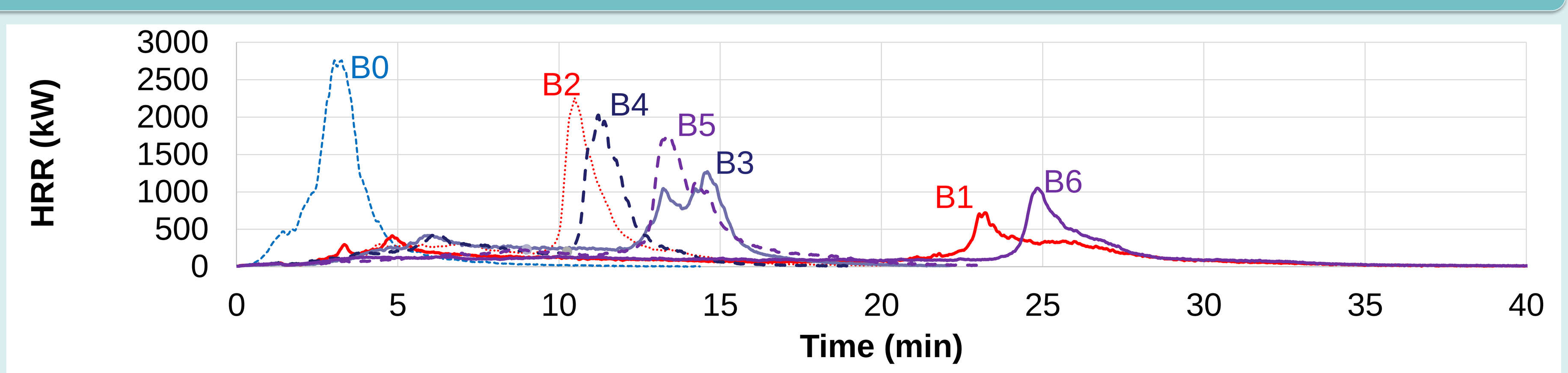
Bottom Ignition

Formation of pool fire

Pool fire at PHRR

Data Summary

Barrier	THR (MJ)	EHC (MJ/kg)	Mass Loss (%)	PHRR (kW)	TTP (min)	TBI (min)	TTP-TTBI (min)
B0	311 ± 5	24.3 ± 0.4	93 ± 3	2610 ± 154	3.3 ± 0.2	2.2 ± 0.1	1.1 ± 0.1
B1	307 ± 12	22.4 ± 0.3	87 ± 0	888 ± 157	22.2 ± 2.2	20.0 ± 2.3	2.2 ± 0.9
B2	288 ± 8	23.9 ± 0	82 ± 2	2025 ± 329	11.5 ± 1.4	9.9 ± 1.9	1.6 ± 0.5
B3	328 ± 3	23.7 ± 0.2	87 ± 2	1030 ± 341	14.1 ± 0.6	9.7 ± 2.0	4.5 ± 1.4
B4	304 ± 2	24.0 ± 0.2	89 ± 1	1817 ± 222	10.9 ± 1.0	9.2 ± 0.3	1.7 ± 0.8
B5	321 ± 3	23.8 ± 0.2	83 ± 0	1648 ± 133	12.6 ± 0.6	10.5 ± 0.7	2.1 ± 0.1
B6	297 ± 6	22.2 ± 0.3	83 ± 1	991 ± 319	22.7 ± 3.4	20.2 ± 3.3	2.6 ± 0.9



References

[1] Hall, J.R., *Estimating Fires When a Product is the Primary Fuel But Not the First Fuel, With an Application to Upholstered Furniture*, National Fire Protection Association, (2014).
[2] Gann, Richard G. *Reducing the Fire Hazard of Residential Upholstered Furniture (RUF)*, CPSC Meeting on Furniture Flammability, (2018).
[3] A.B. 2998, Bloom. Consumer products: flame retardant materials, (Cal. 2018).
[4] California Dept of Consumer Affairs. Bureau of Home Furnishings and Thermal Insulation. *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies*. [Technical Bulletin 133] (1991). Retrieved from: https://bhgs.dca.ca.gov/industry/tb133.pdf

Conclusion

- All 6 fire barriers tested (compliant with [3]) delayed the fire growth and significantly increased available time for safe egress and for firefighter response.
- B1 and B6 showed the longest time to peak (~22 mins)
- Barrier failure due to mass transfer of liquid pyrolizates percolating through the barrier and resulting in abrupt HRR increase and pool fire formation.