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Reduced-Scale Test to Assess the Effect of Fire Barriers on the Combustion Behavior of Core Flammable Materials: an Upholstery–Material Case Study

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Some of the data in this presentation hasn't been through the NIST review process and should be considered experimental / draft results.

Outline

- **Fire Barriers** as alternative to Chemical FRs

- **Cube Test**: reduced scale test to assess the effect of Fire Barriers

- **Case Study**: Upholstered Furniture
  - Full-scale test (Chair Mock-ups)
  - Bench-scale to Full-scale Correlation

Why Fire Barriers? Severe Restrictions on FRs in USA

FEDERAL LEVEL [CPSC Docket No. CPSC–2015–0022, Sept’17]

- **CPSC** recommends to refrain from intentionally adding nonpolymeric, organo-halogen FRs in:
  - children’s products
  - upholstered furniture (UF) sold for use in residences
  - mattresses (and mattress pads)
  - plastic casings surrounding electronics.

STATE LEVEL:

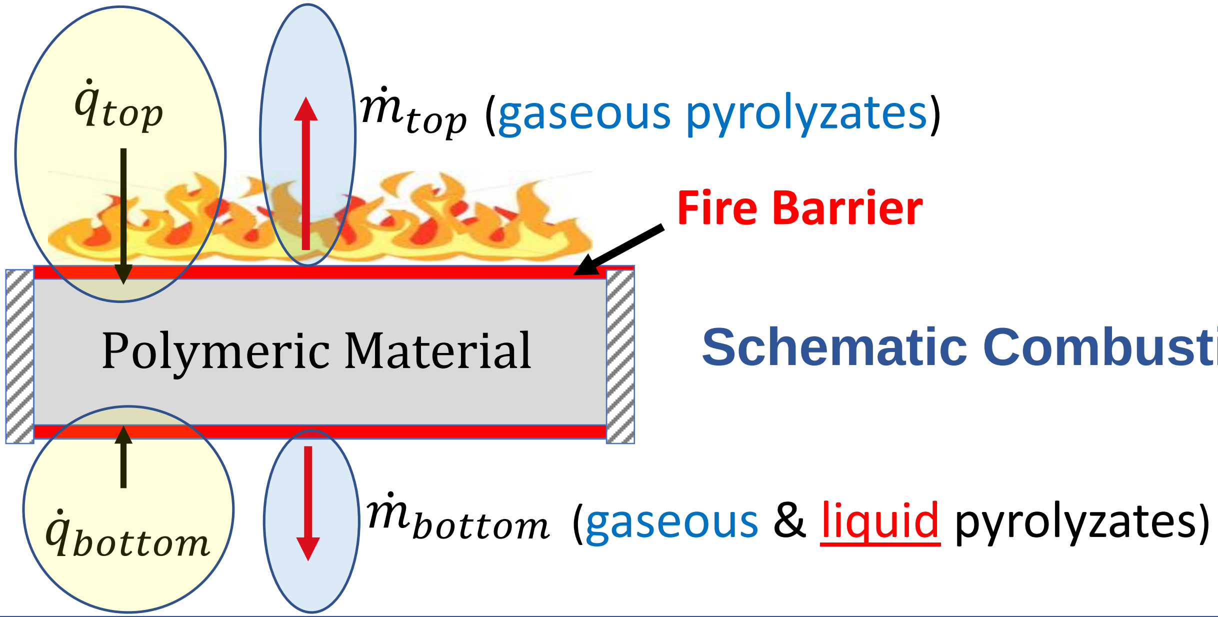
- **California State** [Assembly Bill No 2998, Sep 29, 2018]

bans the use of FR based on halogenated, organo-phosphorous, organo-nitrogen, nanoscale chemical, chemicals of high concern in children’s products, mattresses, or upholstered furniture

- **State of Maine** first State banning all flame retardants in residential UF

https://www.mainelegislature.org/legis/bills/bills_128th/billtexts/HP013801.asp

Fire Barriers: a Physical Approach to Flame Retardancy



Schematic Combustion Process

POLYMER PYROLYSIS

POLYMER → Gaseous products + Liquid products

Two-fold mechanisms of action of Fire Barriers:

(1) Limiting generation rate of flammable pyrolyzate (**Heat Transfer**)

(2) Limiting or controlling the rate and location at which pyrolyzates are released and able to burn (**Mass Transfer**)

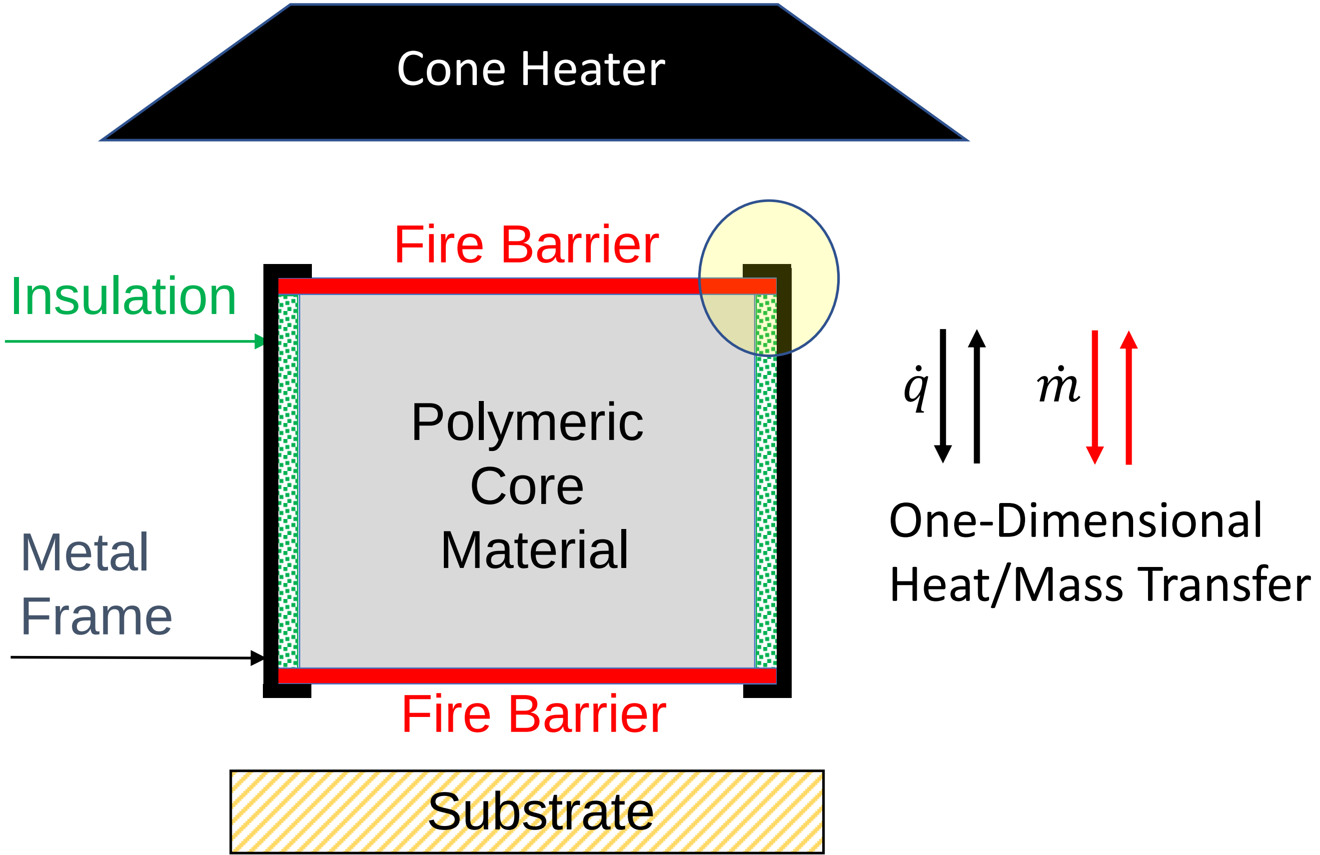
NIST Cube Test (ASTM WK65005)

What is it? Tool for the Cone Calorimeter to capture Mass Transfer and Heat Transfer phenomena through the top and <u>bottom</u> of the sample.

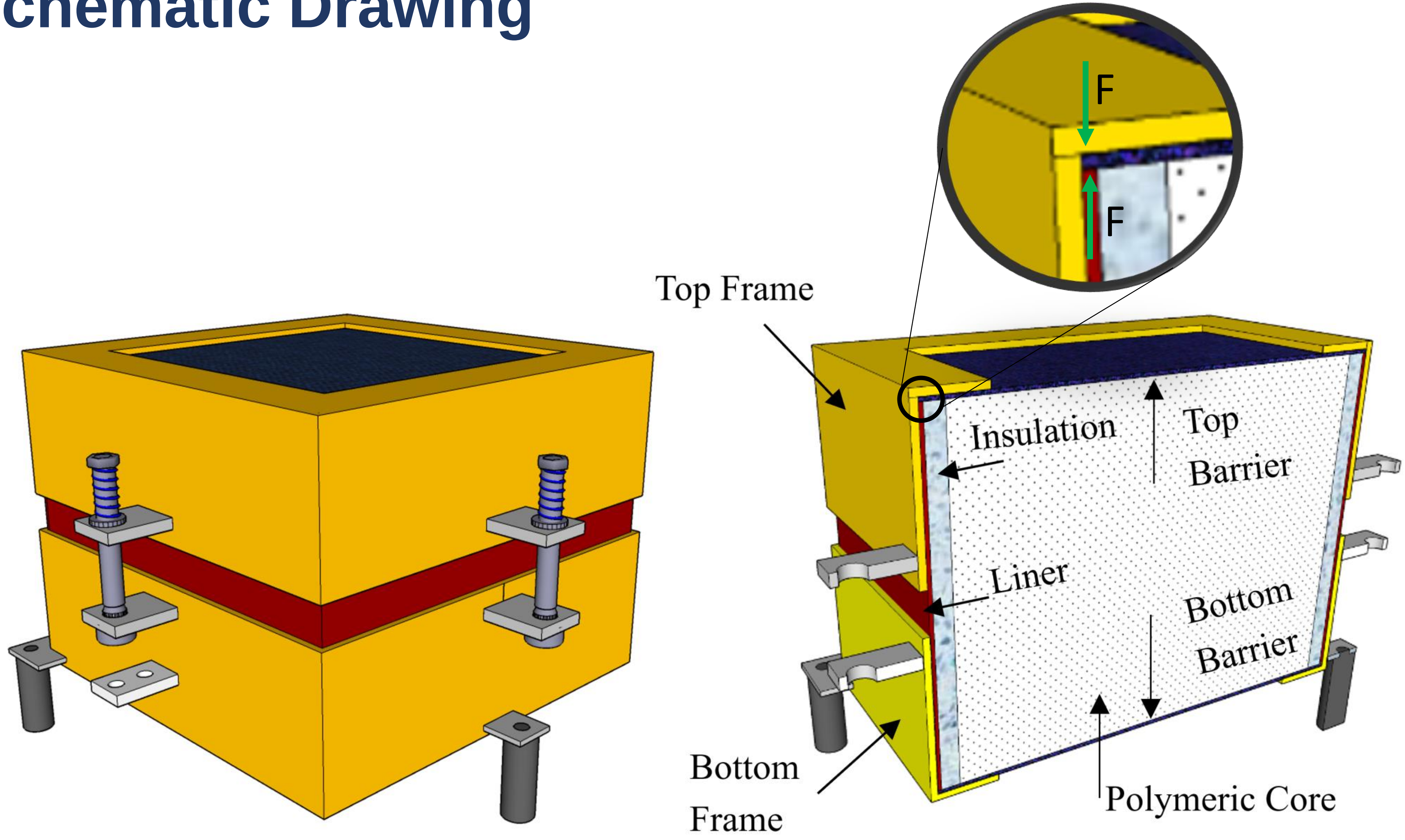
What is used for? Characterize the combustion behavior of a flammable core material in presence of fire barriers.

The sample is intended to be a representative cross-section of an item

Sample dimensions:
100 mm × 100 mm × product thickness



Schematic Drawing

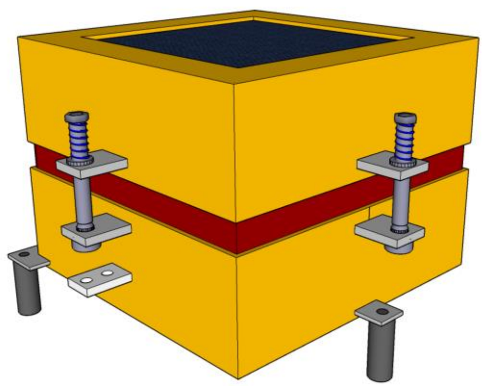


Case Study: Upholstered Furniture (UF)

Materials

- 1 Polyurethane Foam (TB117-2013)
- 1 Cover Fabric (Polypropylene)
- 6 Fire Barriers compliant with California Assembly Bill No 2998

Reduced Scale Test (Cube Test)



Correlation

Full-scale Test (Chair Mock-ups)

Barrier Materials

Materials compliant with California Bill AB 2998

	Fabric Type	Materials	Density $g\cdot m^{-2}$	Air Perm. $cm^3\cdot s^{-1}\cdot cm^{-2}$
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 polyacrylonitrile 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

***PSA** : Polysilicic acid

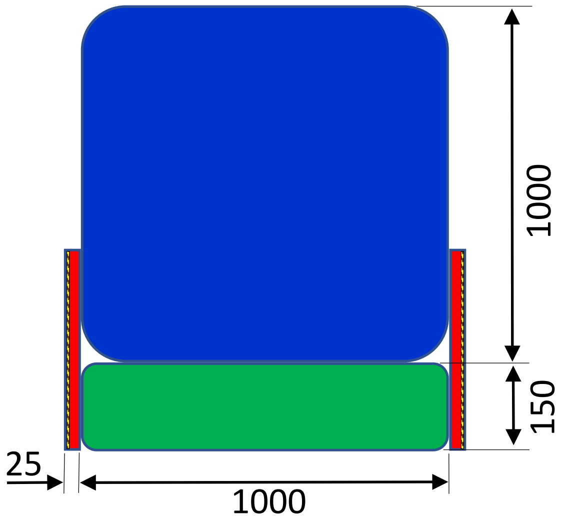
****RC** : Regenerated cellulose

B1, B5, B6: UF Commercial Barriers

B2, B3, B4: Experimental Barriers

Chair Mock-ups

FRONT VIEW

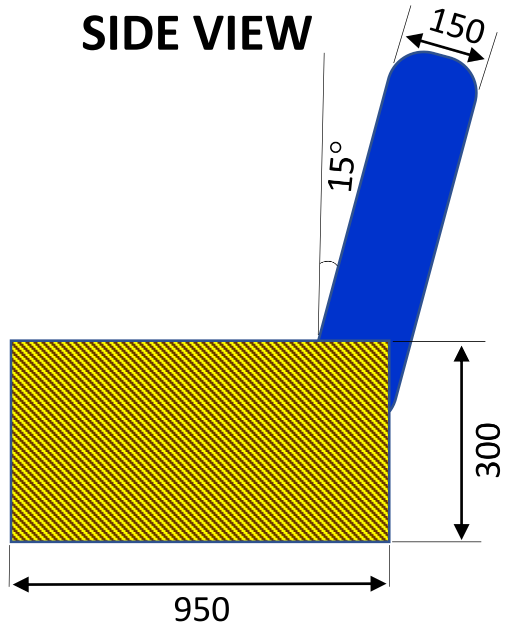


Back cushion (polyester fibers)
Seat cushion (TB117-2013 foam)
Armrest padding (TB117-2013 foam)
Armrest support (5 mm plywood)

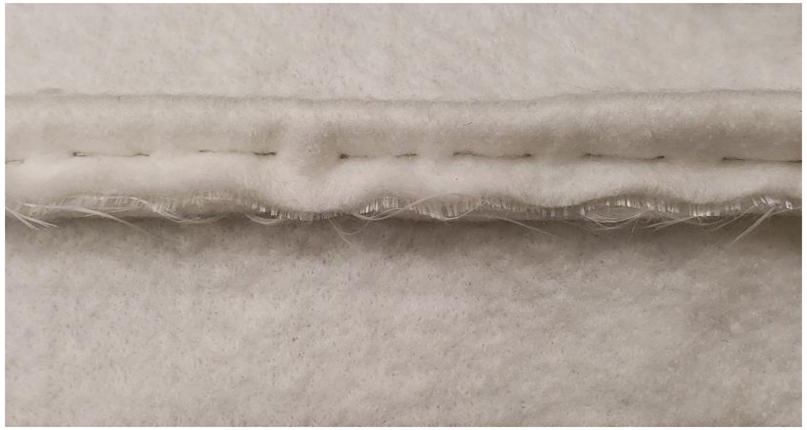
Dimensions in mm

All chair components protected by FB

SIDE VIEW



Seams (Metal Staples)

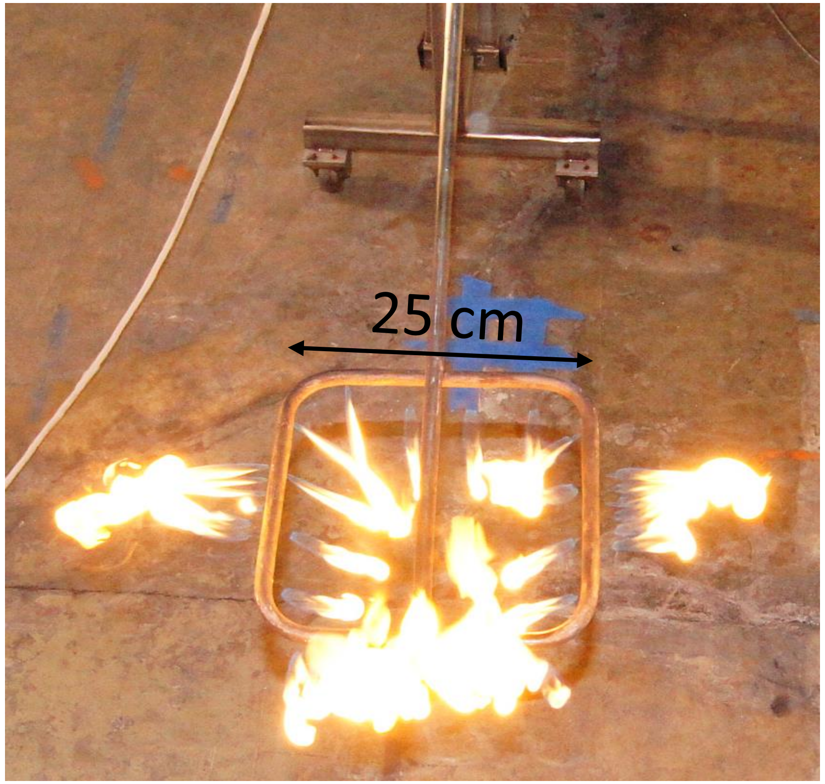


7 chair types (C0 to C6):
C0: cover fabric (B0) only
C1 to C6: cover (B0) +1 fire barrier (B1 to B6)

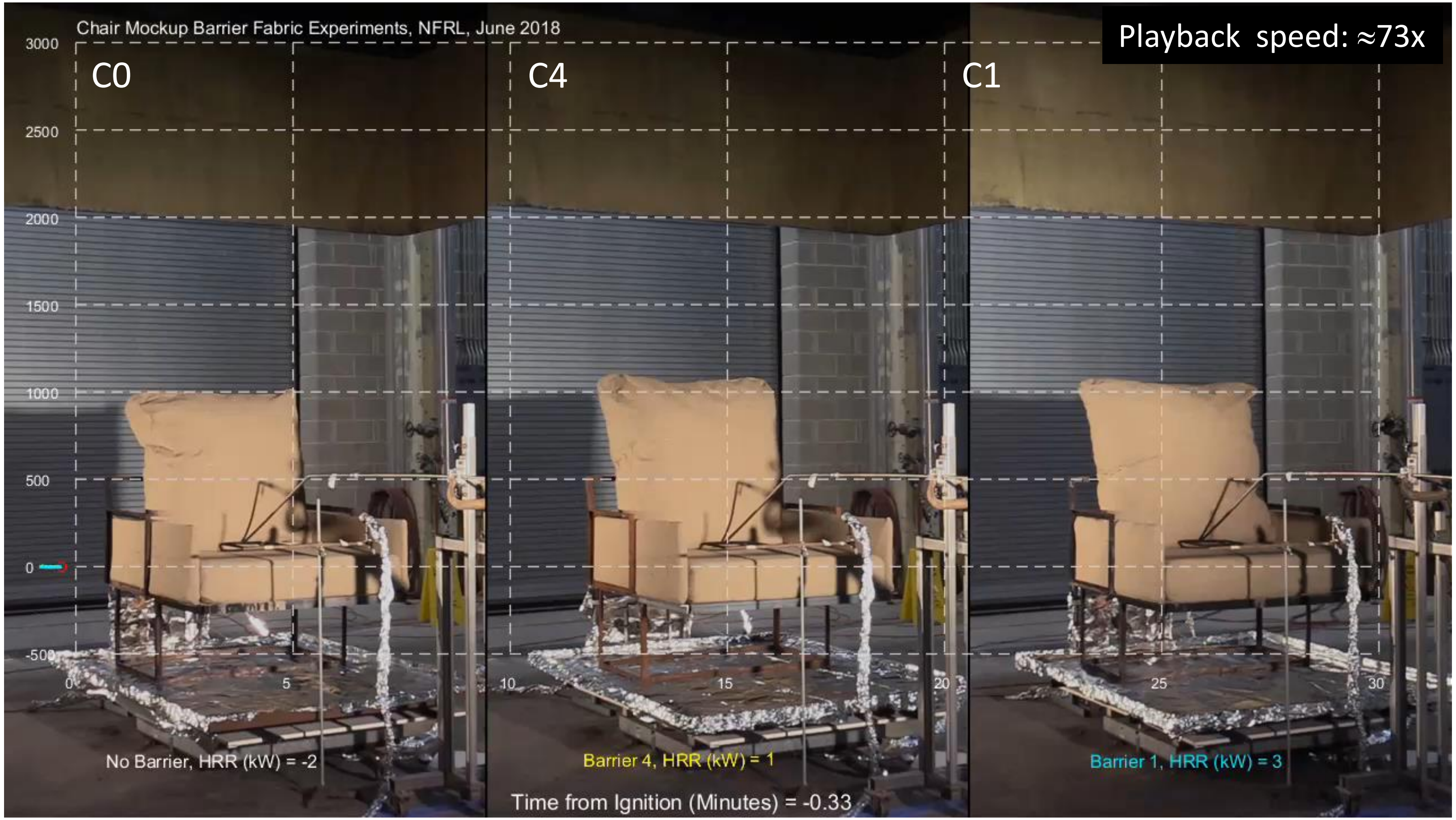
7 chair types in triplicate tests: tot. of 21 chairs

Ignition Source

- Square Burner (18 kW for 80s)



Effect of Fire Barriers: Videos



Fire barriers allows to:

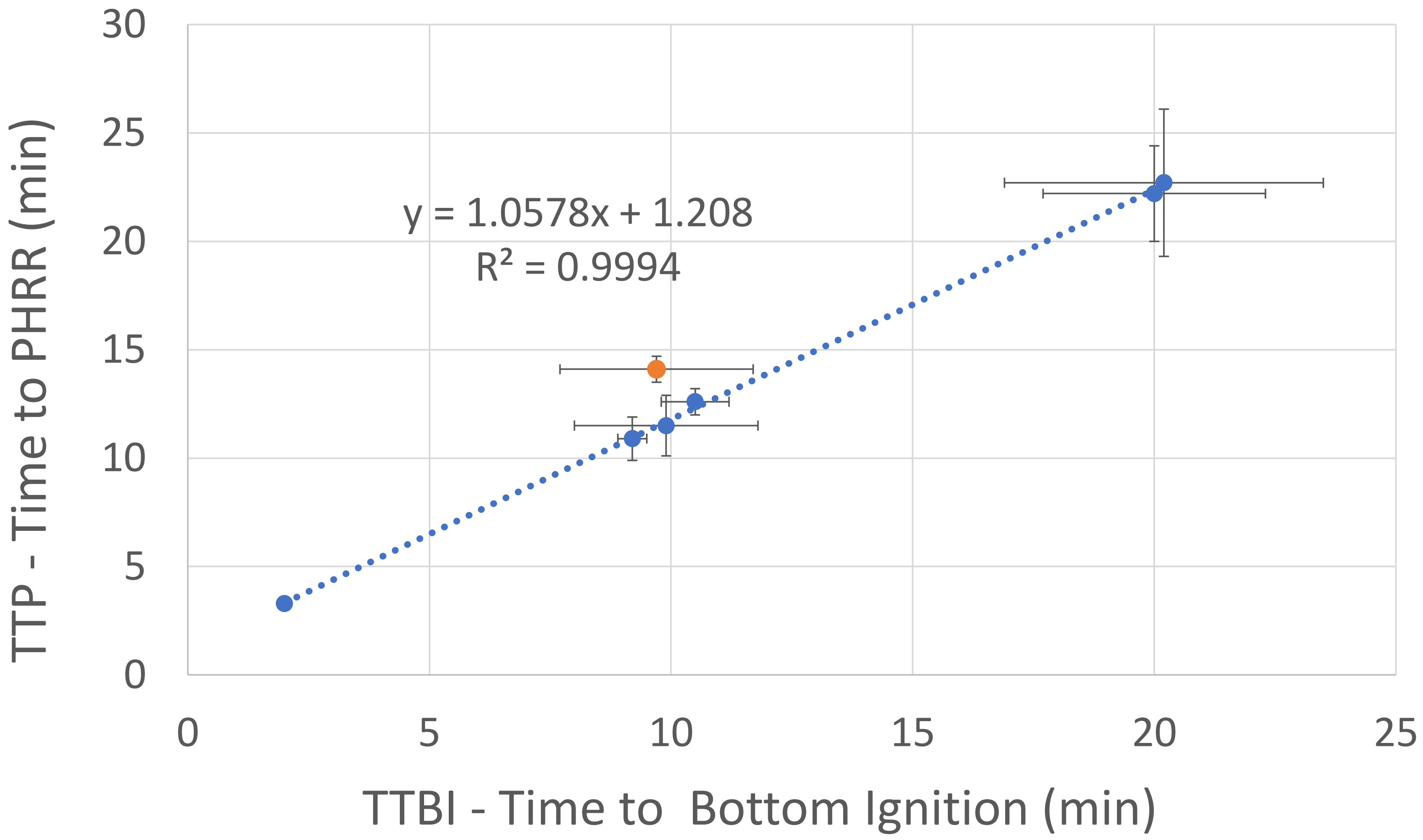
- increase time to peak from 3 min (C0) to 22 min (C1 and C6)
- decrease PHRR from about 3 MW to about 1 MW

What Happens Under the Chair?

Bottom Ignition (BI): persistent burning under the seat cushion due to the ignition of liquid product of pyrolysis

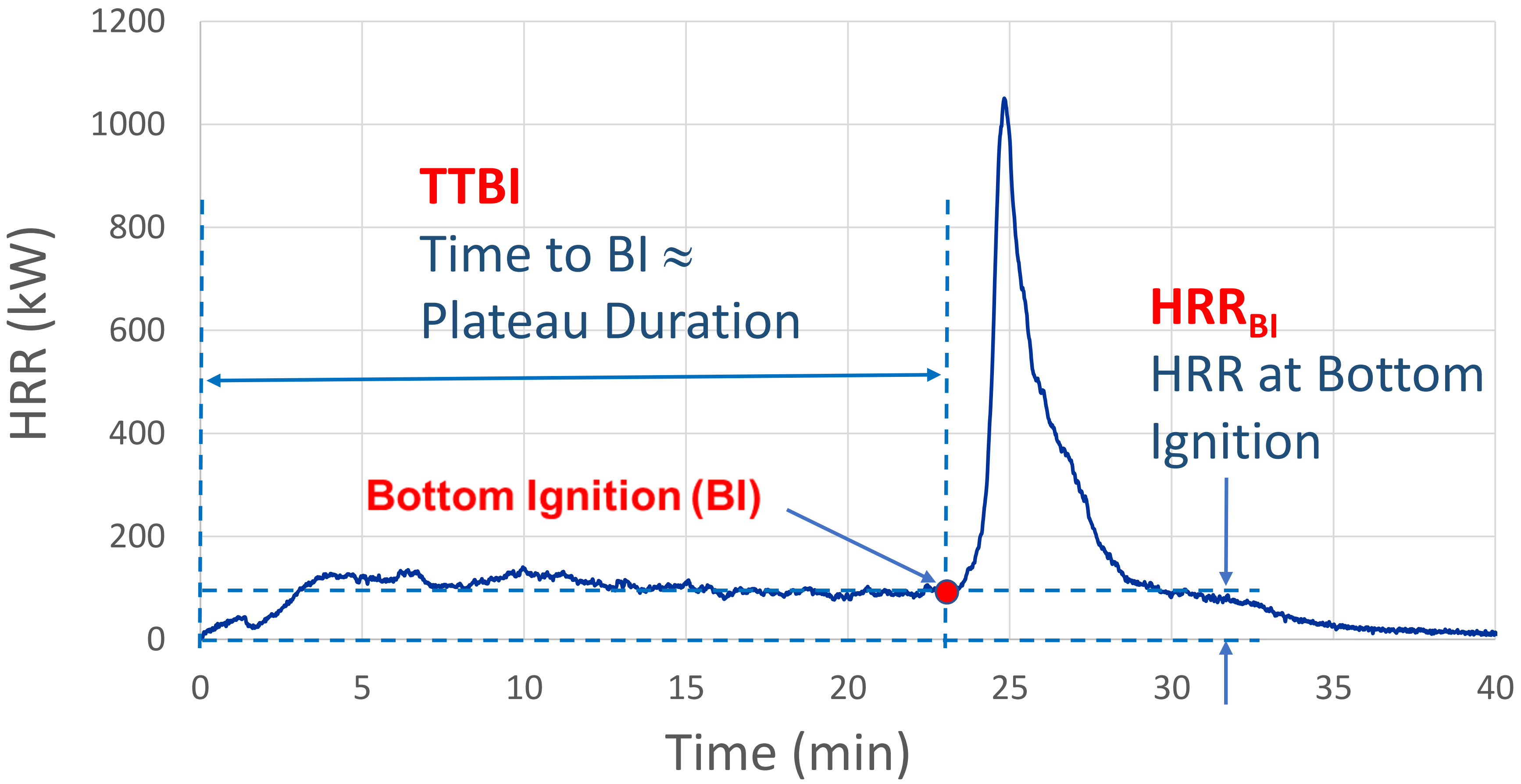
Bottom Ignition (BI) and PHRR

Bottom Ignition leads to PHRR within (2 ± 1) min



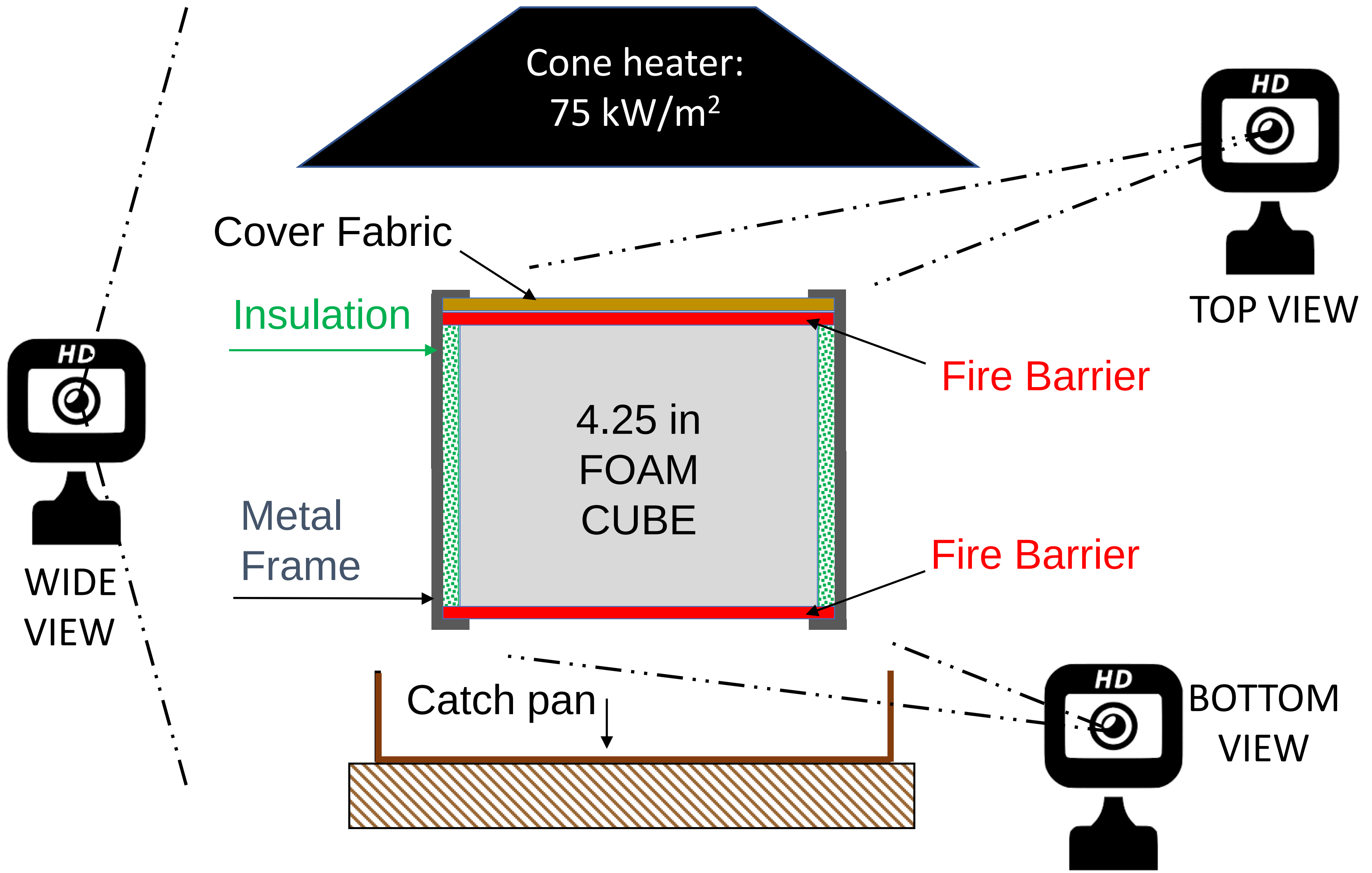
Effect of Fire Barriers on HRR

Bottom Ignition (BI) with consequent pool-fire formation was always observed

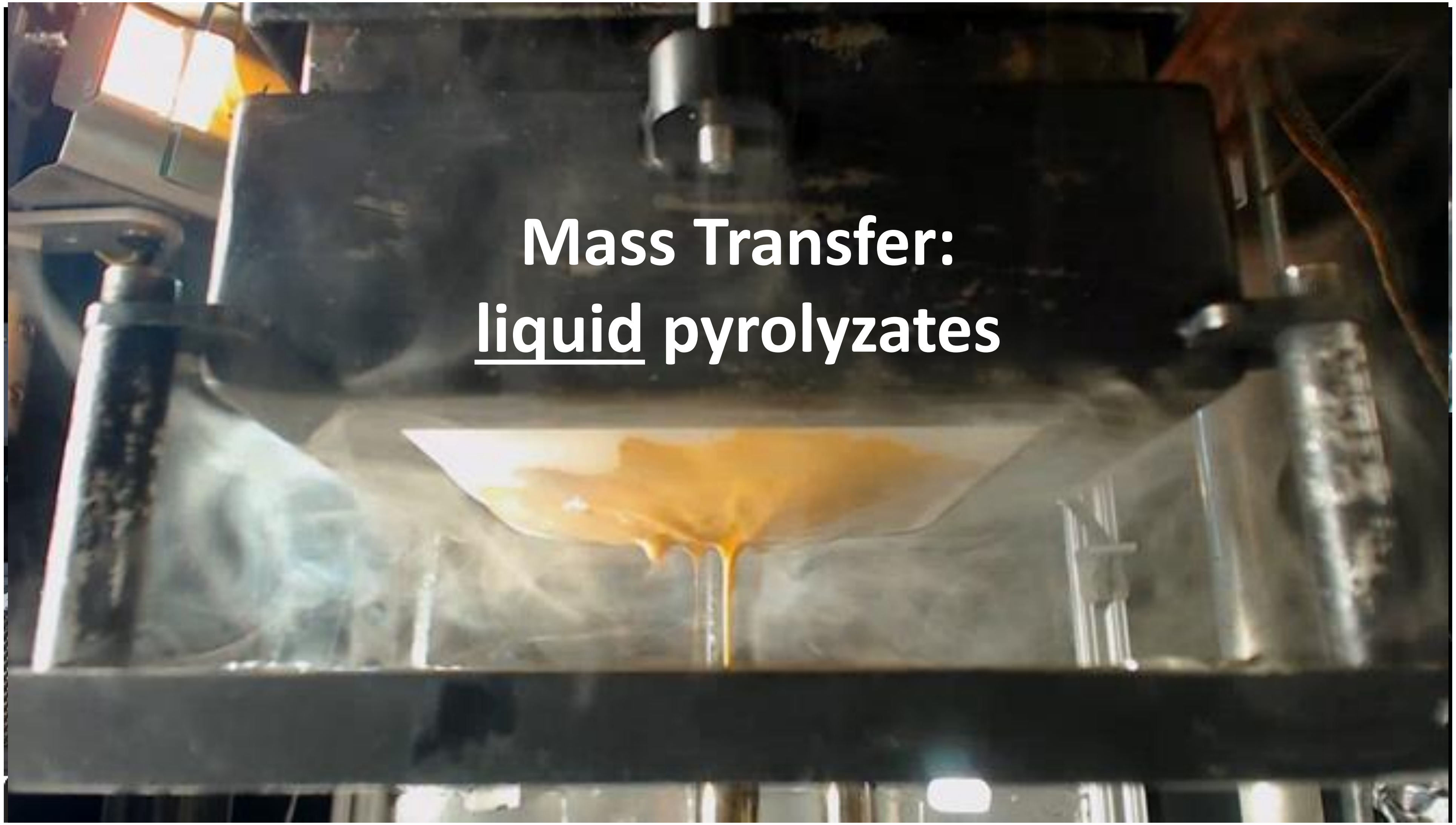


Key Factors used to characterize the performance of the Fire Barrier: **TTBI** and **HRR_{BI}**

Cube Test Set-up (Schematics)

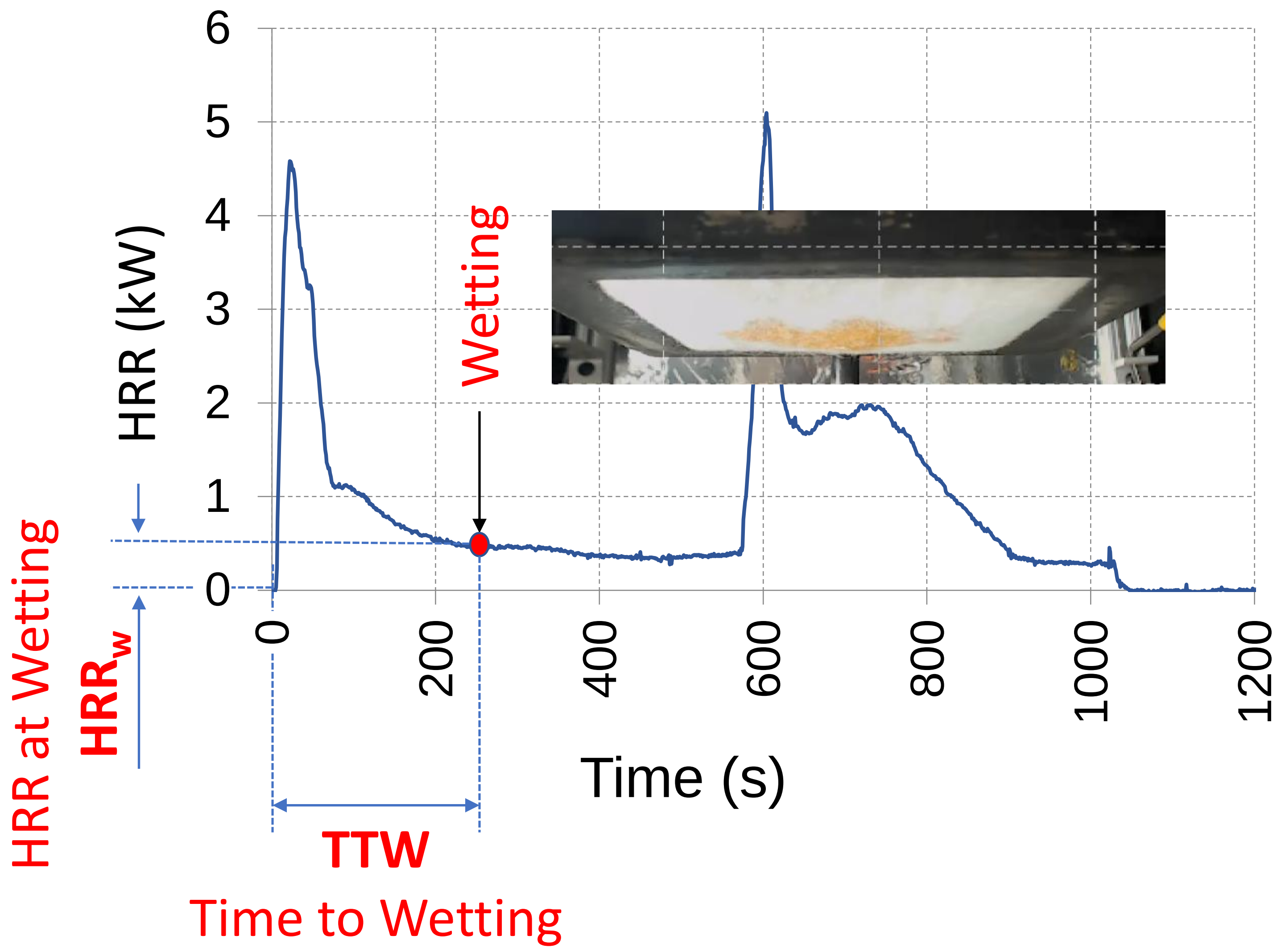


Example of a Typical Cube Test



"Wetting": appearance of visible liquid pyrolyzates on the bottom barrier

Example of HRR Curve in Cube Test



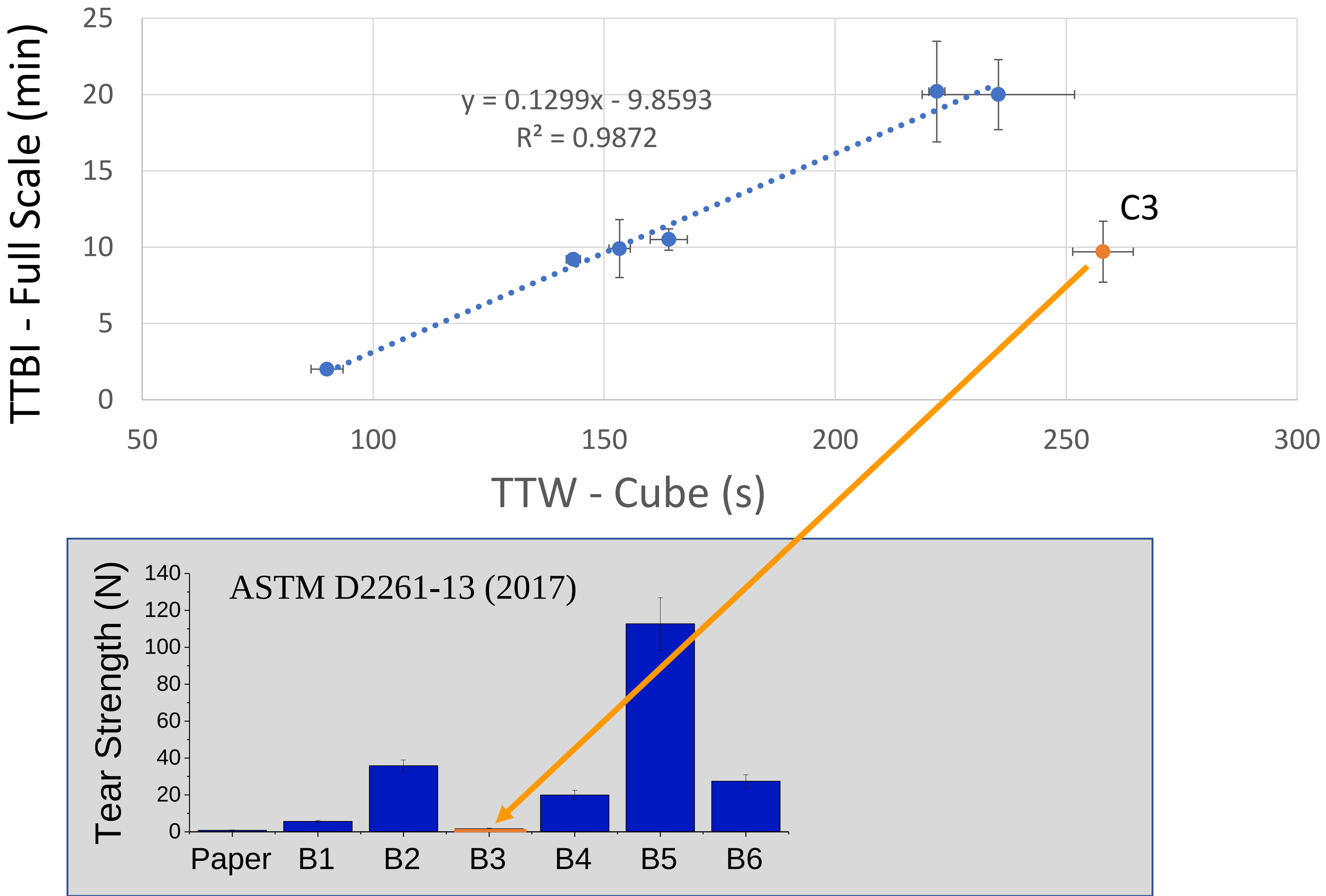
Cube to Full-Scale Correlation?

Correlation:

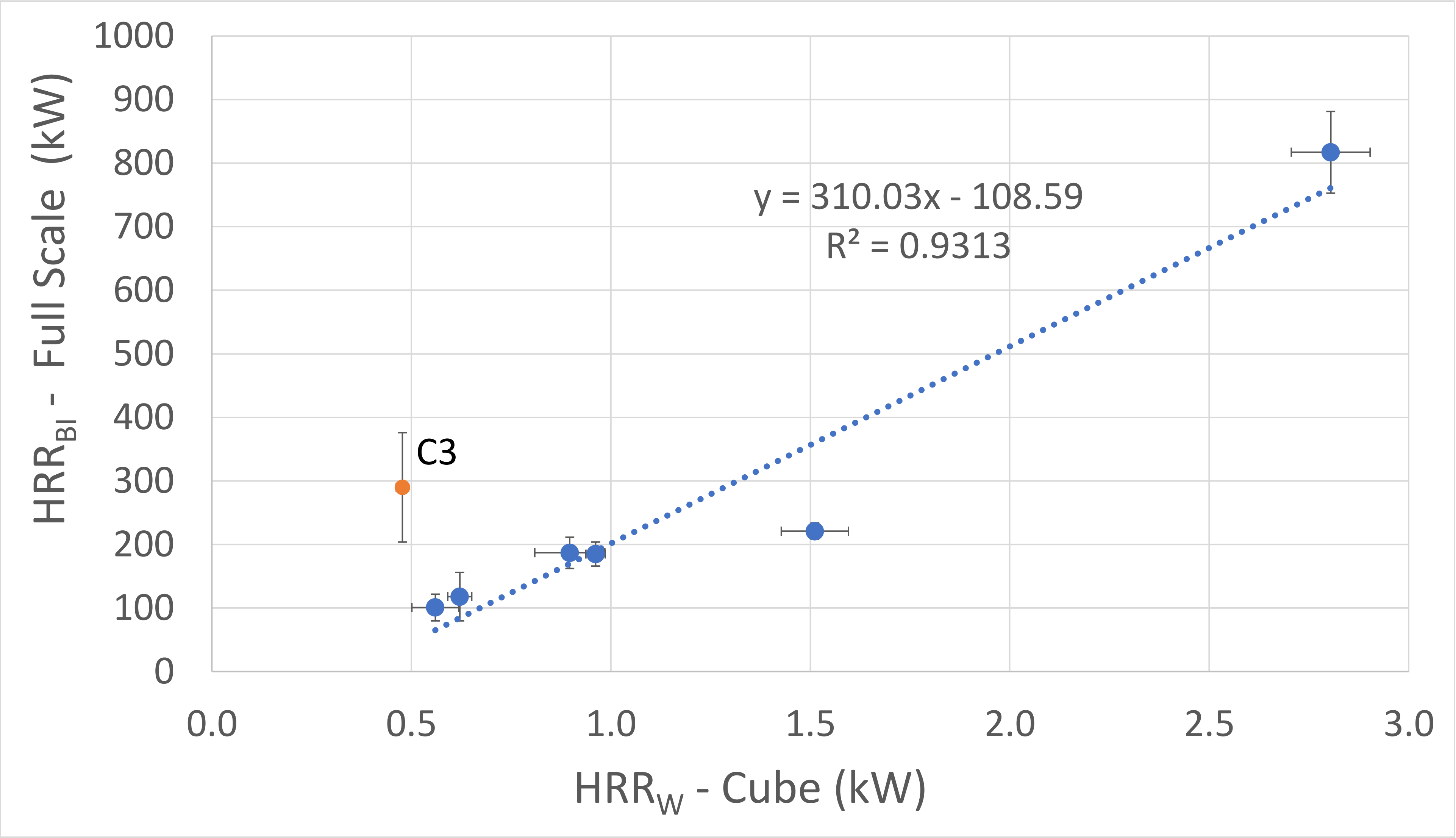
-TTBI to TTW?

-HRR_{BI} to HRR_{w}?

Prediction of TTBI (and TTP) by Cube



Prediction of Plateau Value



Conclusions

- In US, shifting from Chemical Fire Retardants toward Physical Mechanisms of Flame Retardancy (e.g., Fire Barriers)
- The Cube Test has been developed to capture Physical Mechanisms of Flame Retardancy (mass/heat transfer)
- Upholstered Furniture as a case study to prove the capability of the Cube Test to:

  - predict Full-scale performance (within the limited data set available)
  - properly rank the effectiveness of Fire Barriers

THANK YOU!

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- Planning Interlaboratory Study

Products:

1. Insulation
2. Cored laminated composites
3. Upholstered furniture