Determining the Effect of Fire Barriers on the Combustion Behavior of Cored Composite Products using a Cone Calorimeter

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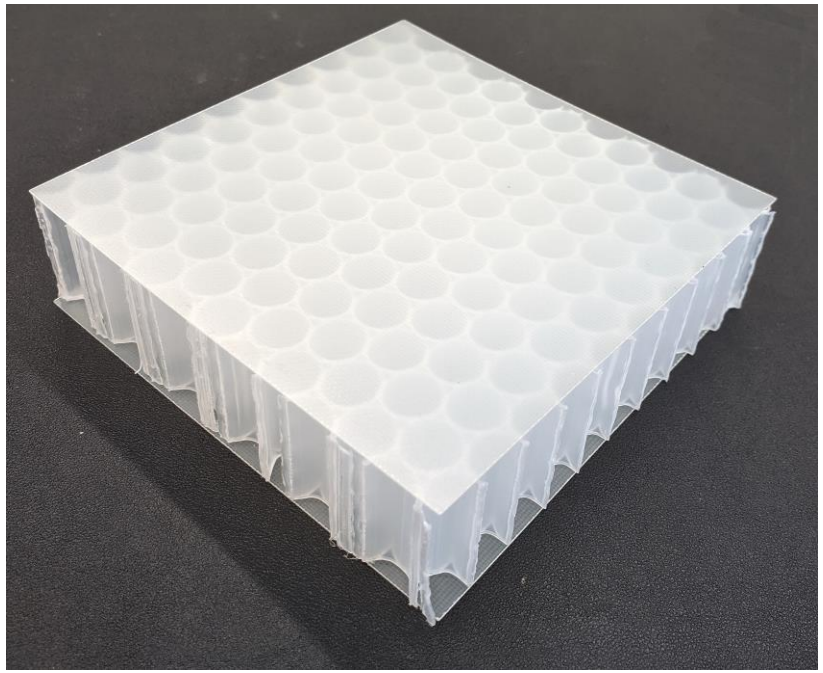
Some of the data in this presentation hasn't been through the NIST review process and should be considered experimental / draft results.

Cored Composites Product?

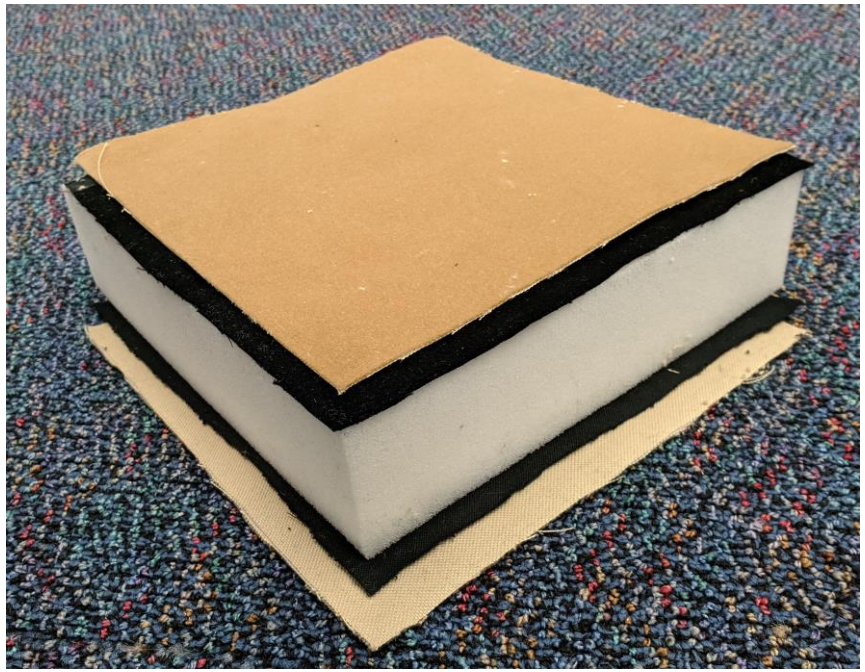
Product including two main components:

- CORE (acts as main fuel load of the item)
- SKIN (acts as Fire Barrier, FB)

Examples



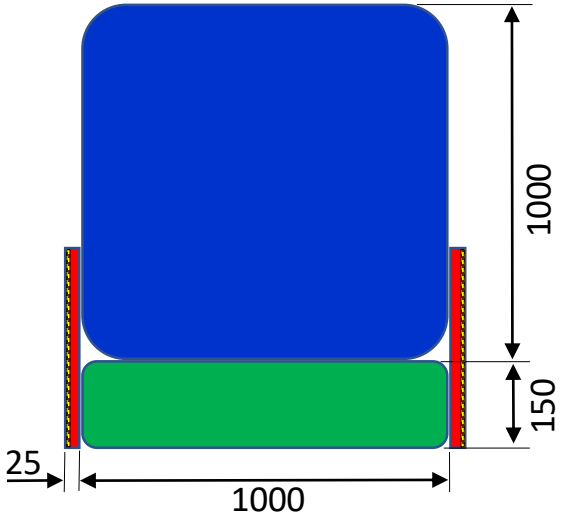
Cored Laminate: honeycomb (core), glass reinforced epoxy (skin)



Upholstered Furniture: padding material (core), upholstery fabrics (skin)

Case Study: Chair Mock-ups

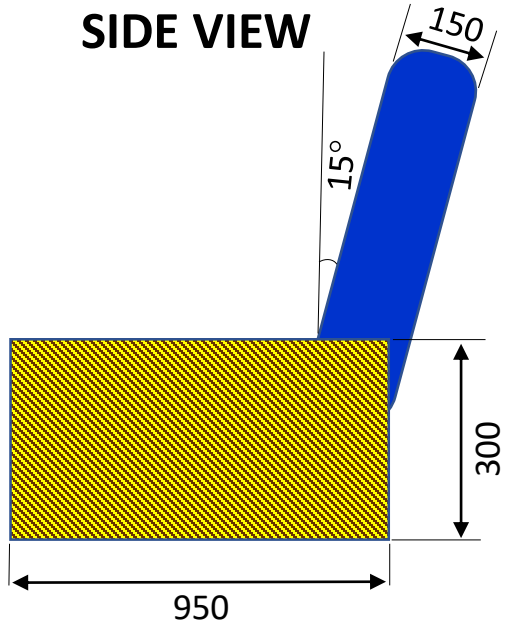
FRONT VIEW



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

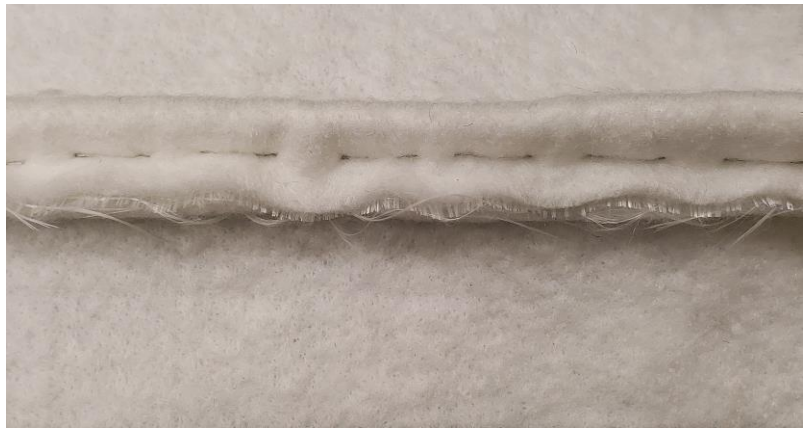
Dimensions in mm

SIDE VIEW



All chair components protected by FB

Seams (Metal Staples)



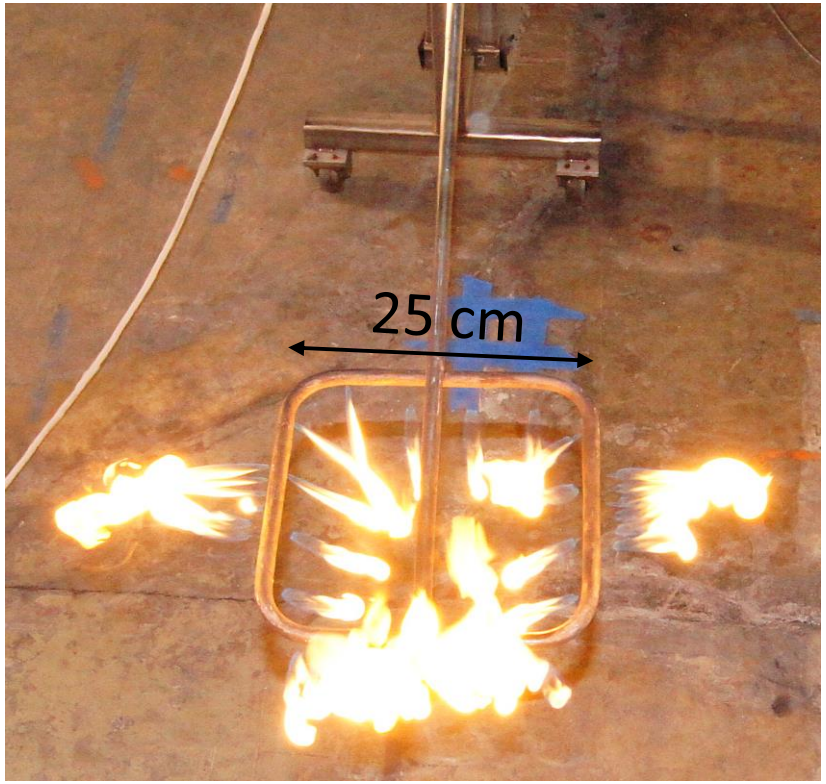
7 chair types (C0 to C6):
C0: cover fabric (B0) only
C1 to C6: cover (B0) +1 fire barrier (B1 to B6)

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

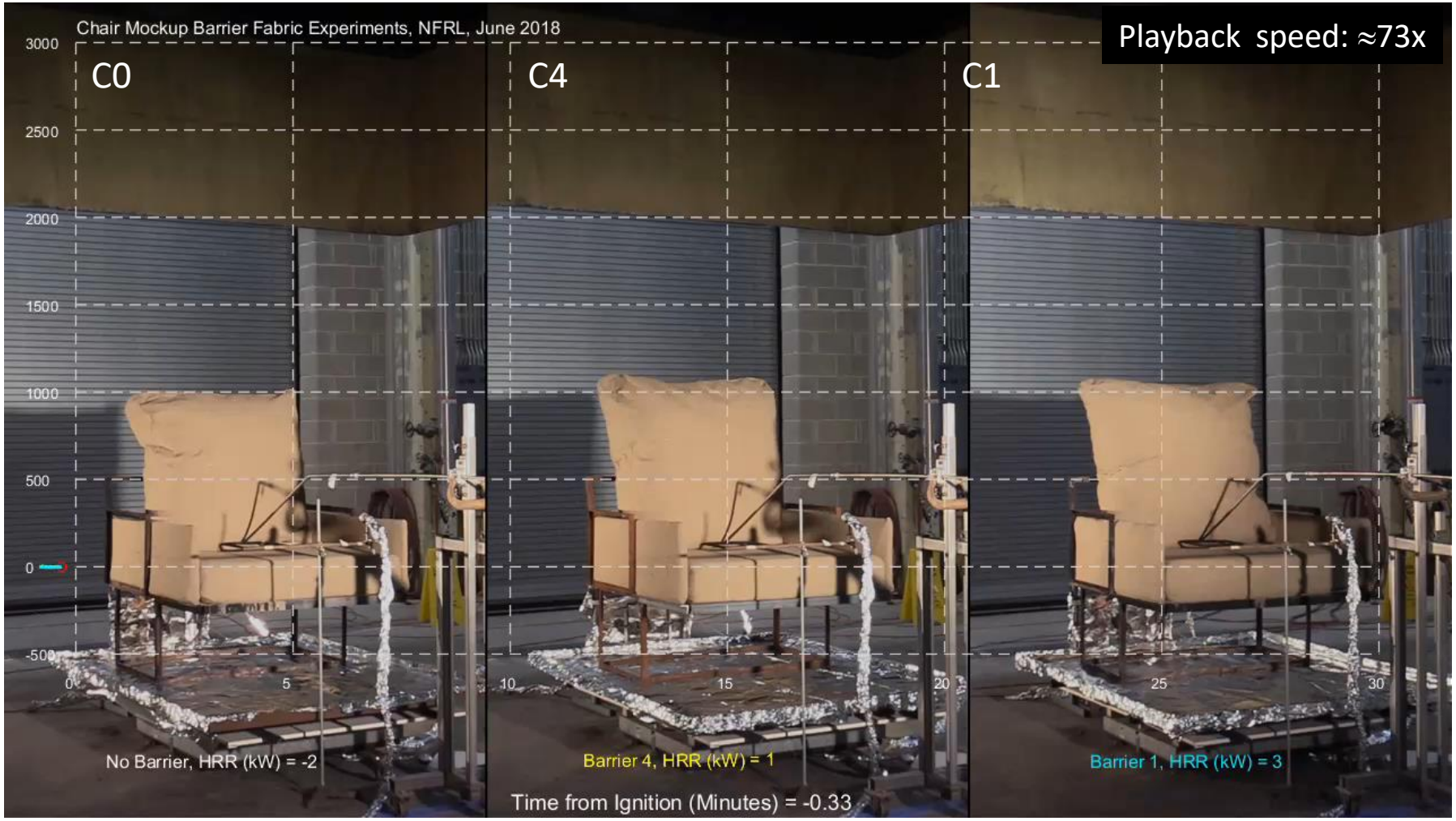
B0 to B6 are expected to be compliant with California Bill AB 2998

Ignition Source

- Square Burner (18 kW for 80s)



Effect of Fire Barriers



Fire barriers allows to:

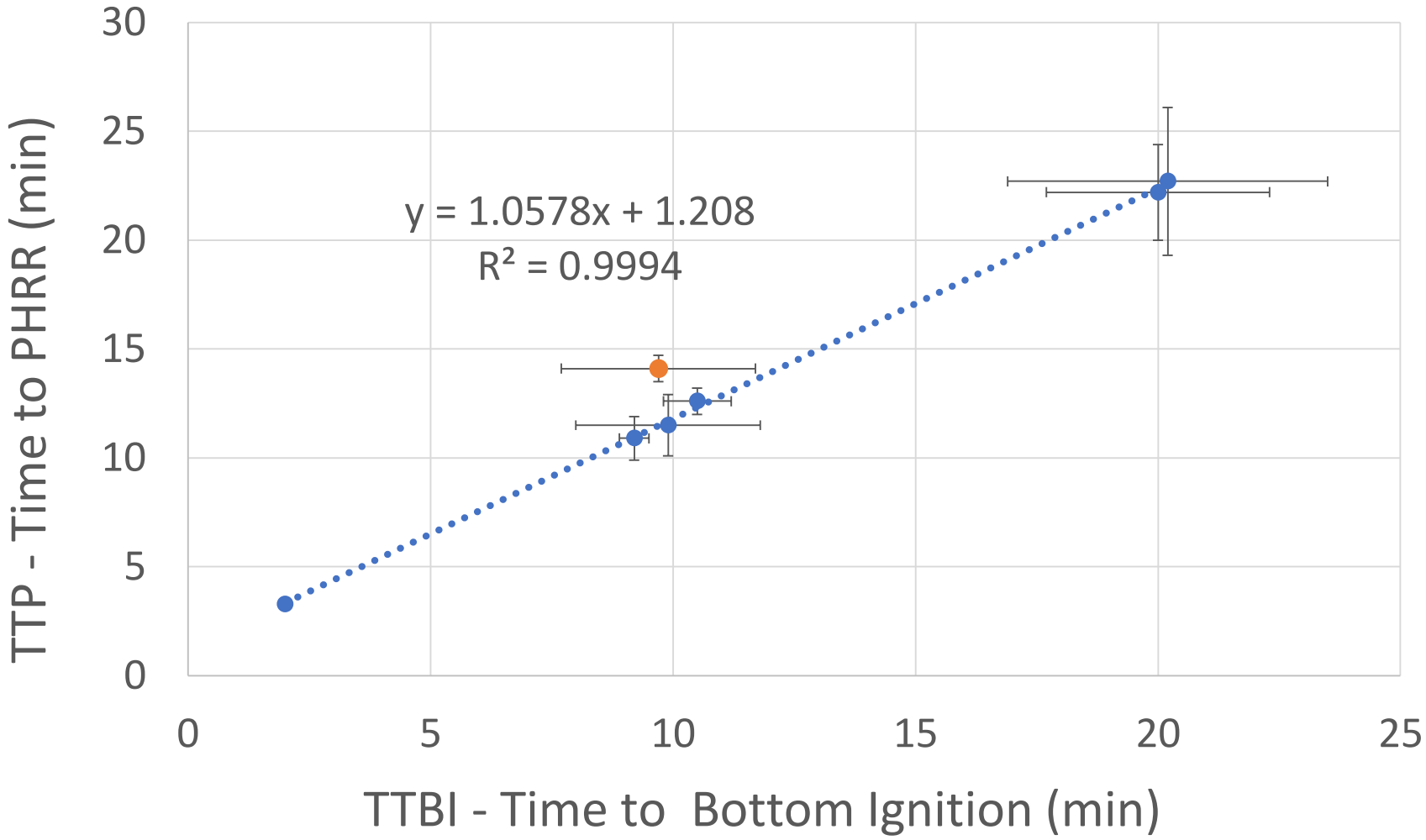
- increase time to peak from 3 min (C0) to 22 min (C1 and C6)
- decrease PHRR from about 3 MW to about 1 MW

Barrier Failure

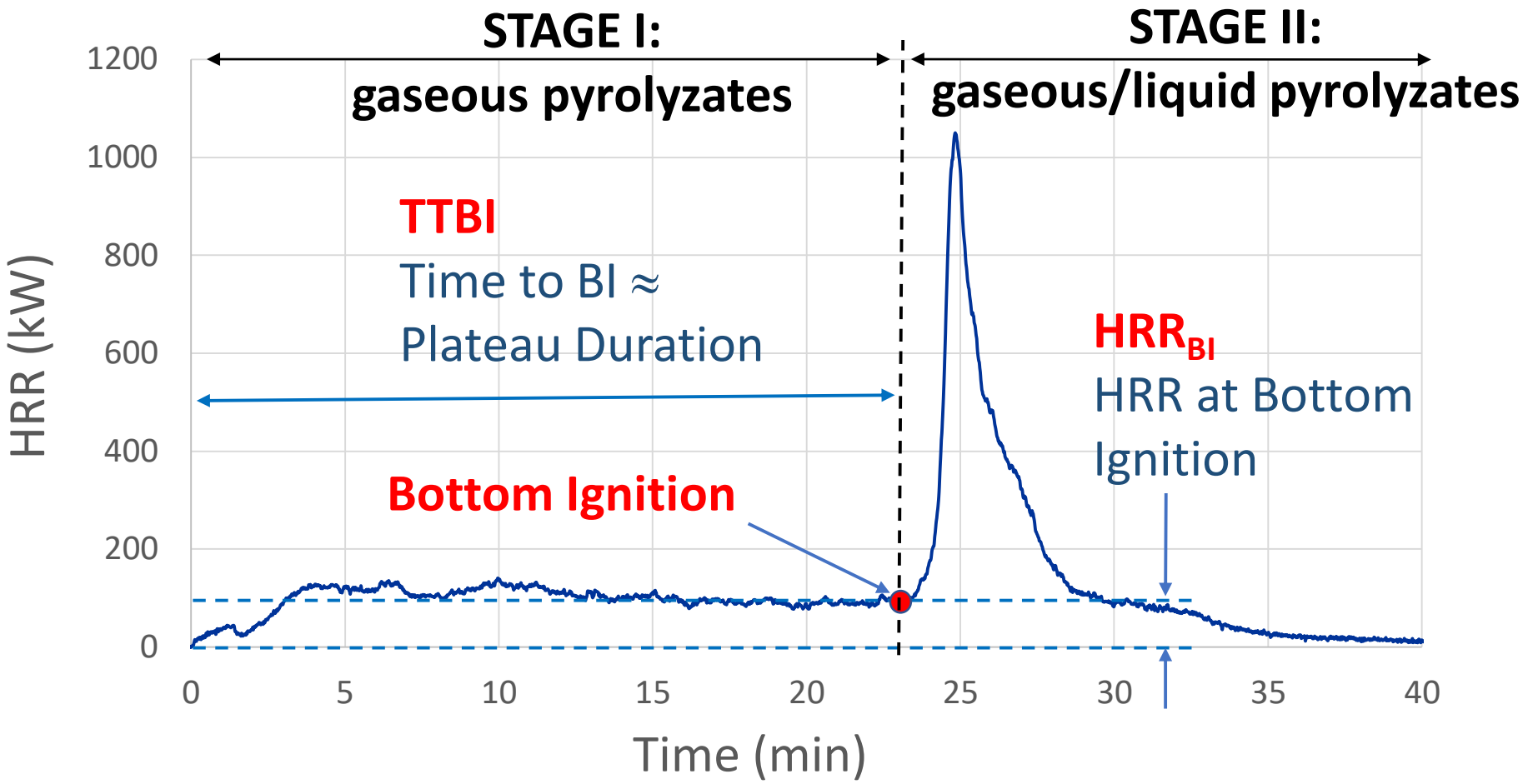
Bottom Ignition (BI): persistent burning under the seat cushion due to the ignition of liquid product of pyrolysis

Bottom Ignition (BI) and PHRR

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

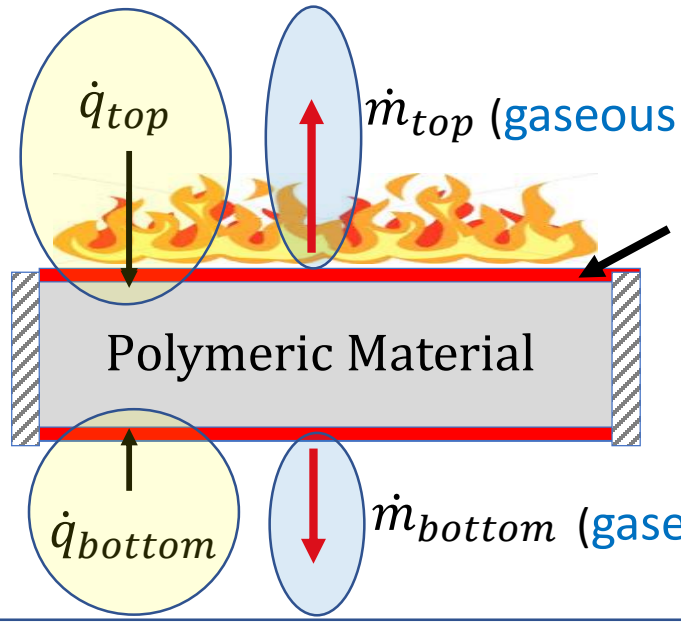


Burning of Upholstered Furniture



TTBI and **HRR_{BI} used to characterize Stage I burning**

Idealized cross-section of a Cored Product



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**)

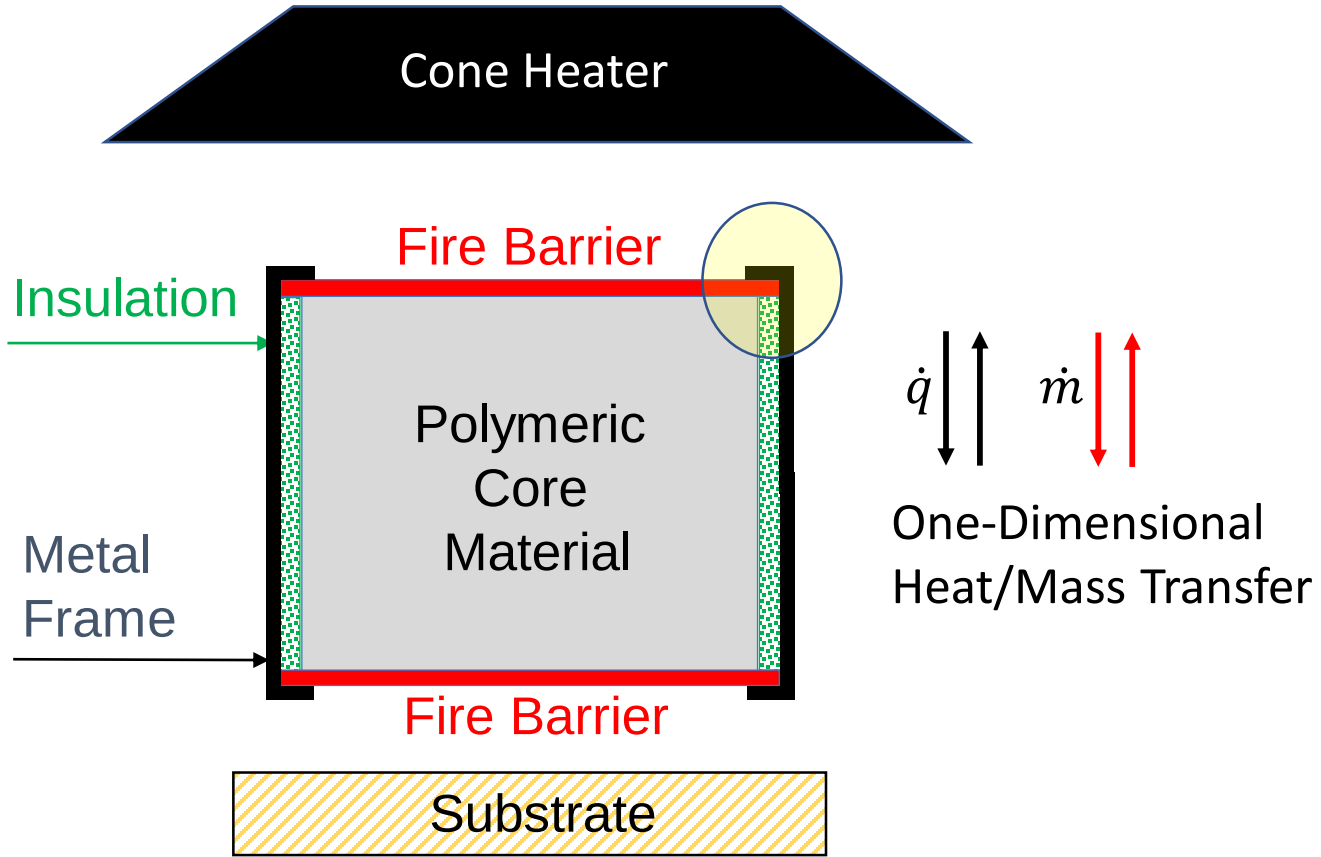
NIST Cube Test (ASTM WK65005)

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

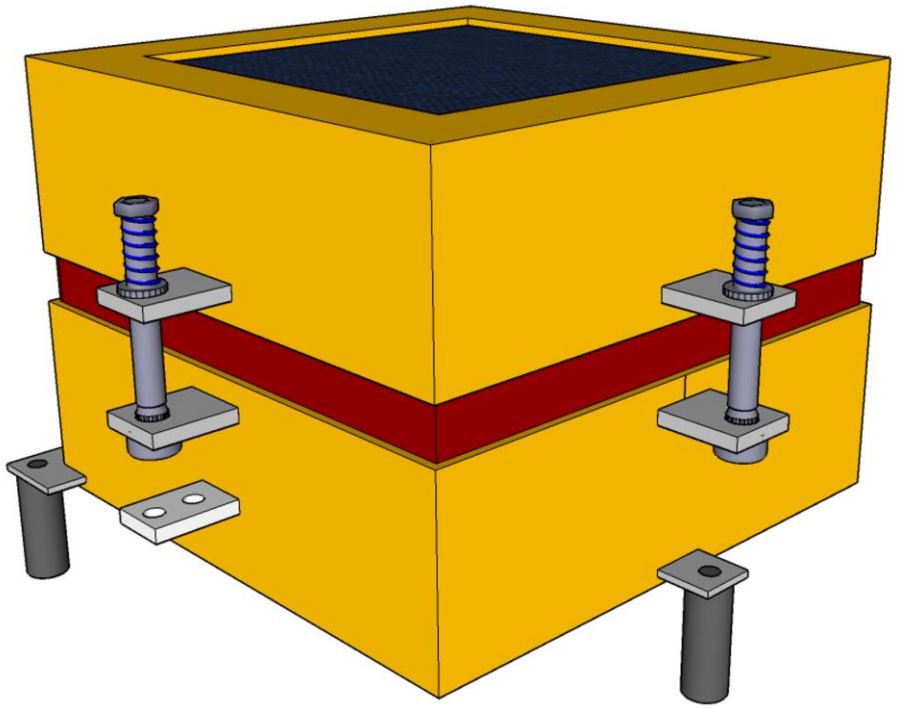
What is used for? Characterize the combustion behavior of a flammable core material in presence of fire barriers.

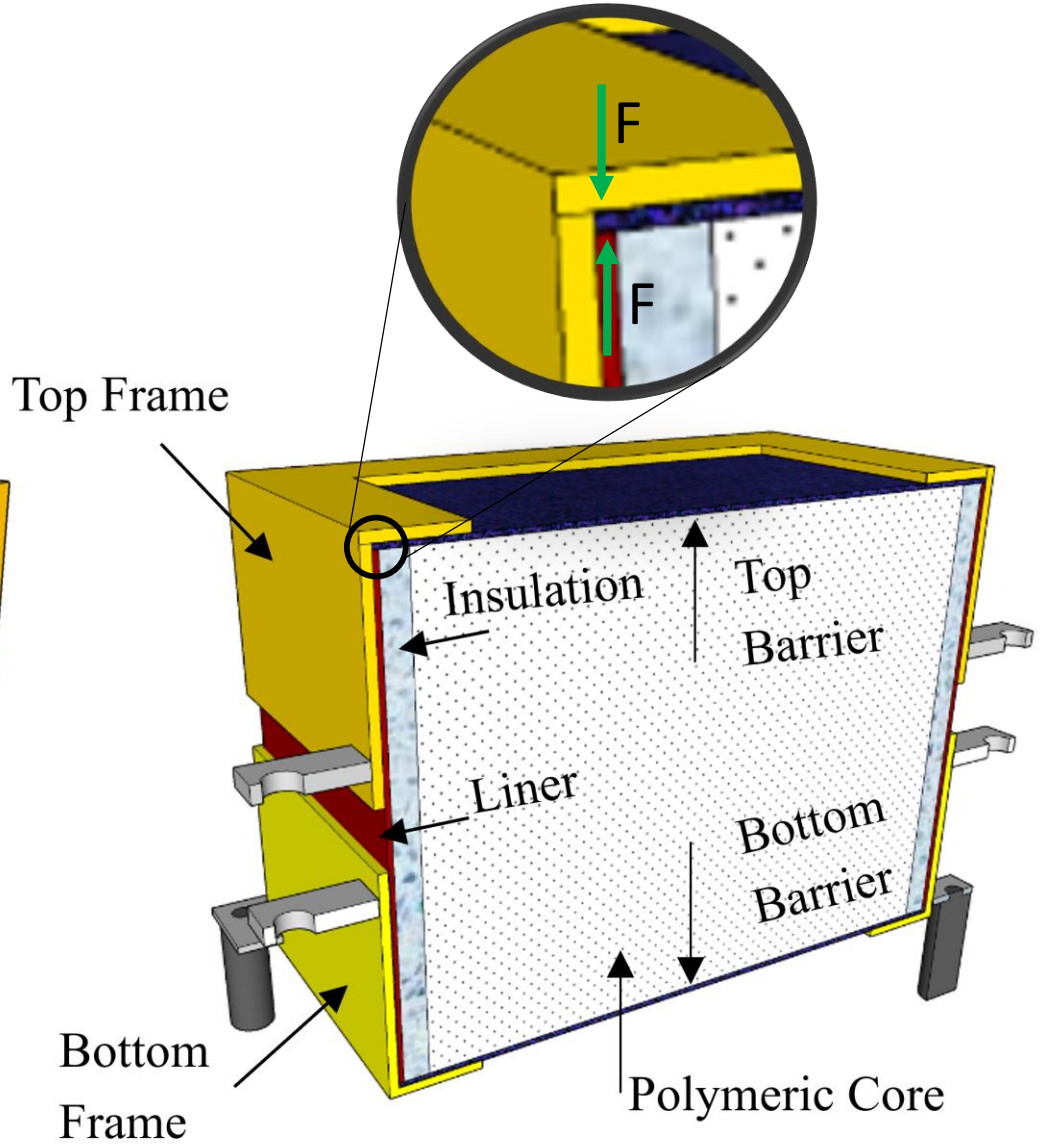
The sample is intended to be a representative cross-section of an item

Sample dimensions:
100 mm × 100 mm × product thickness

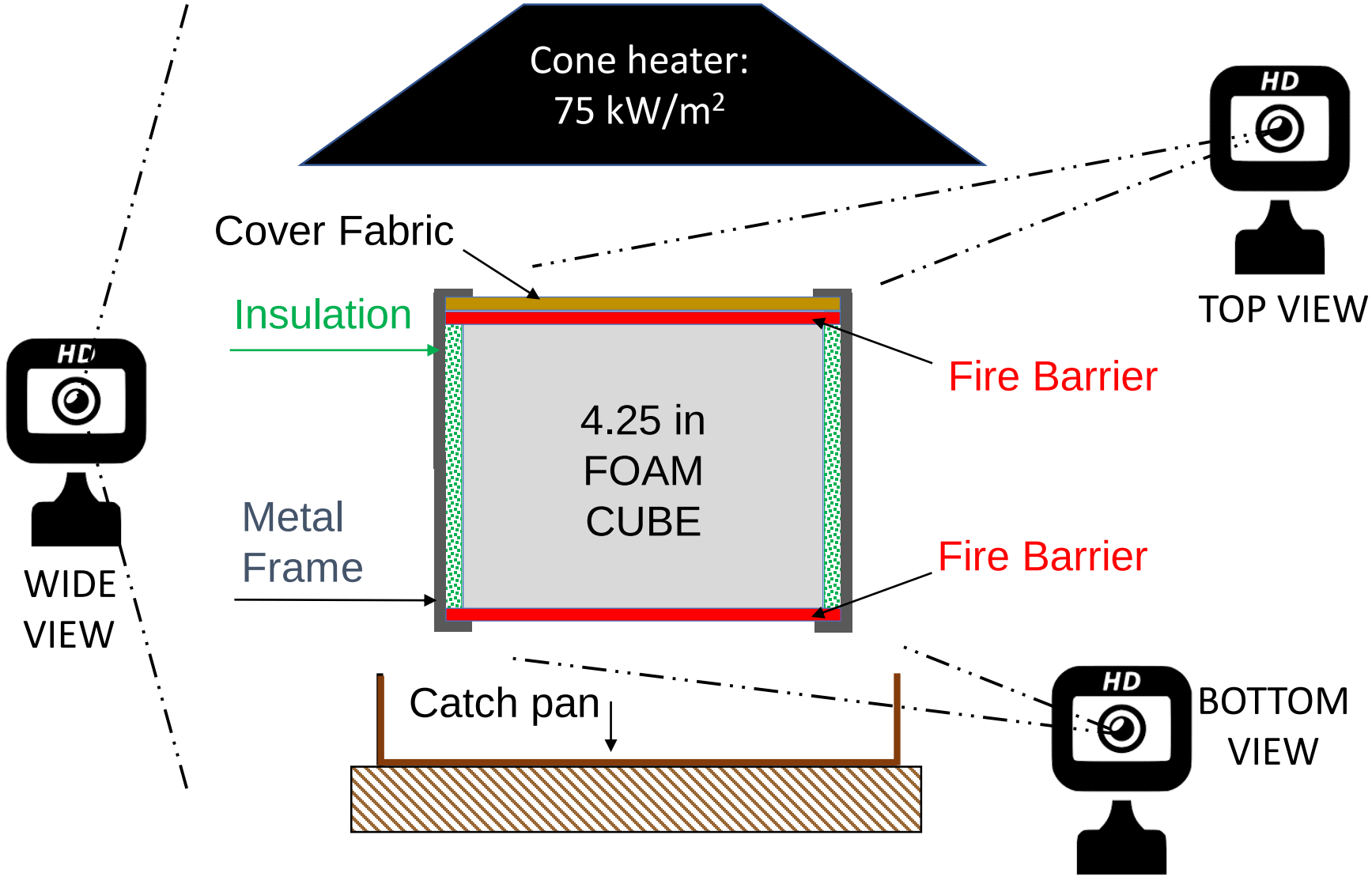


Schematic Drawing

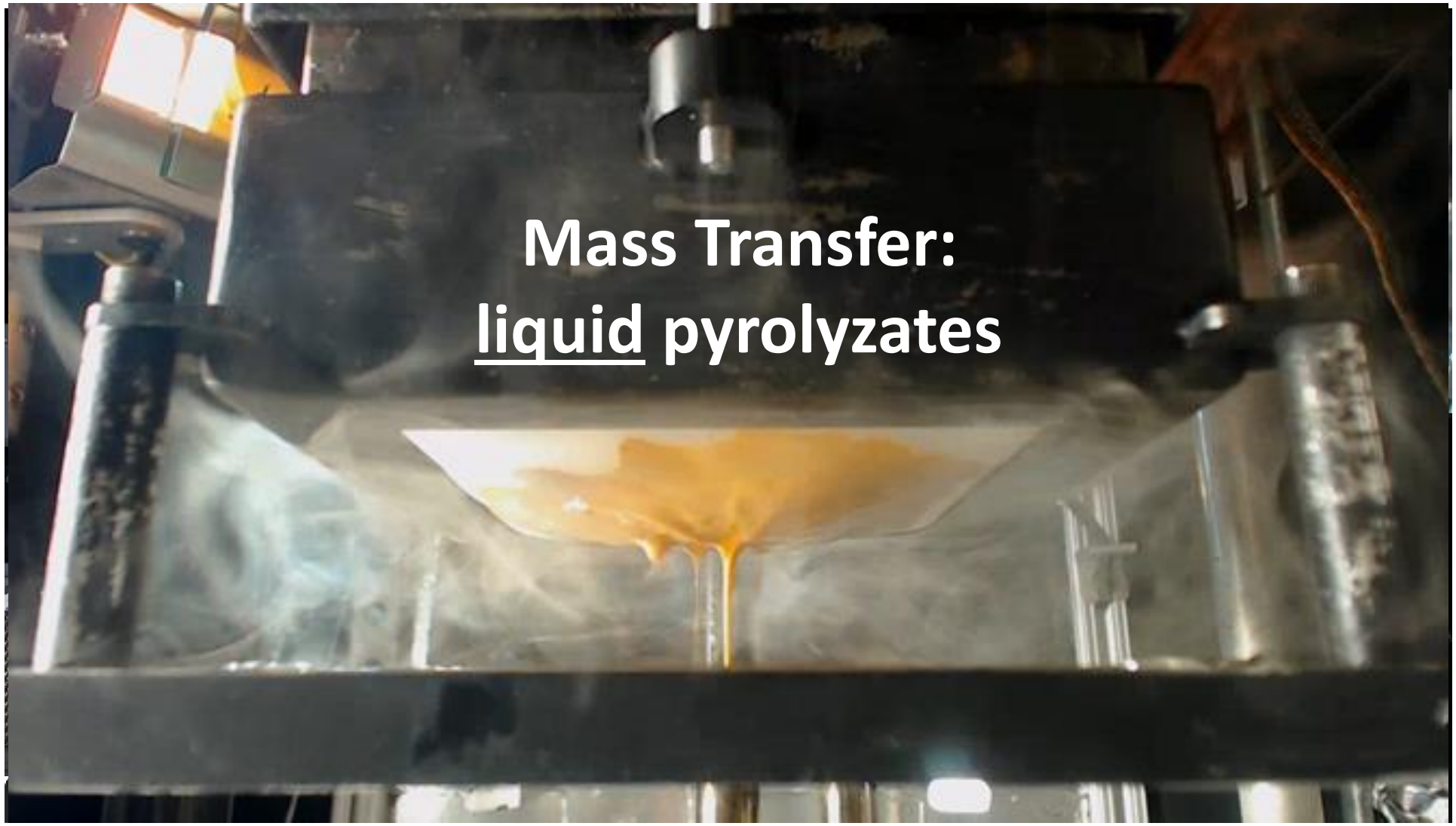




Cube Test Set-up (Schematics)

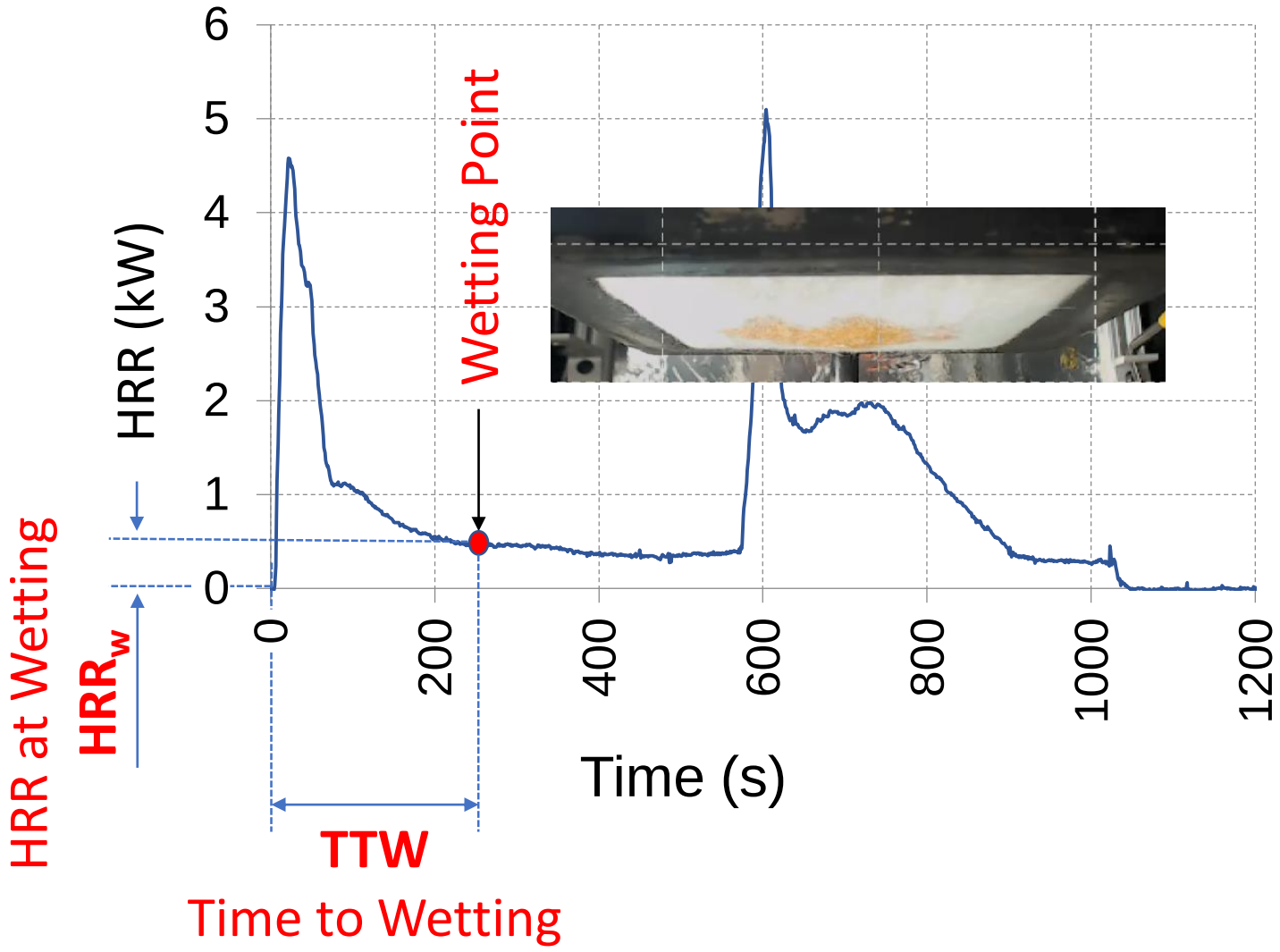


Example of a Typical Cube Test

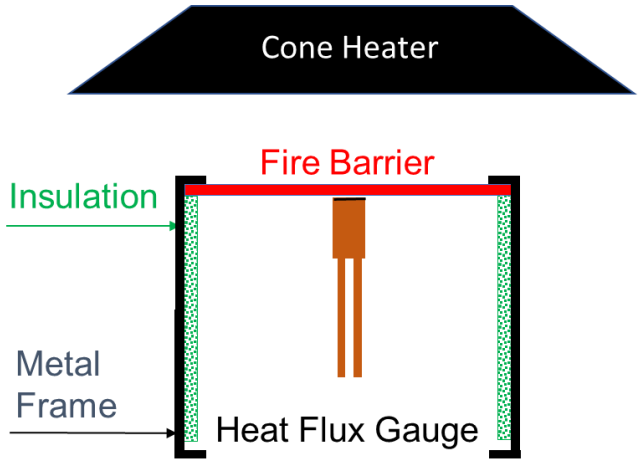


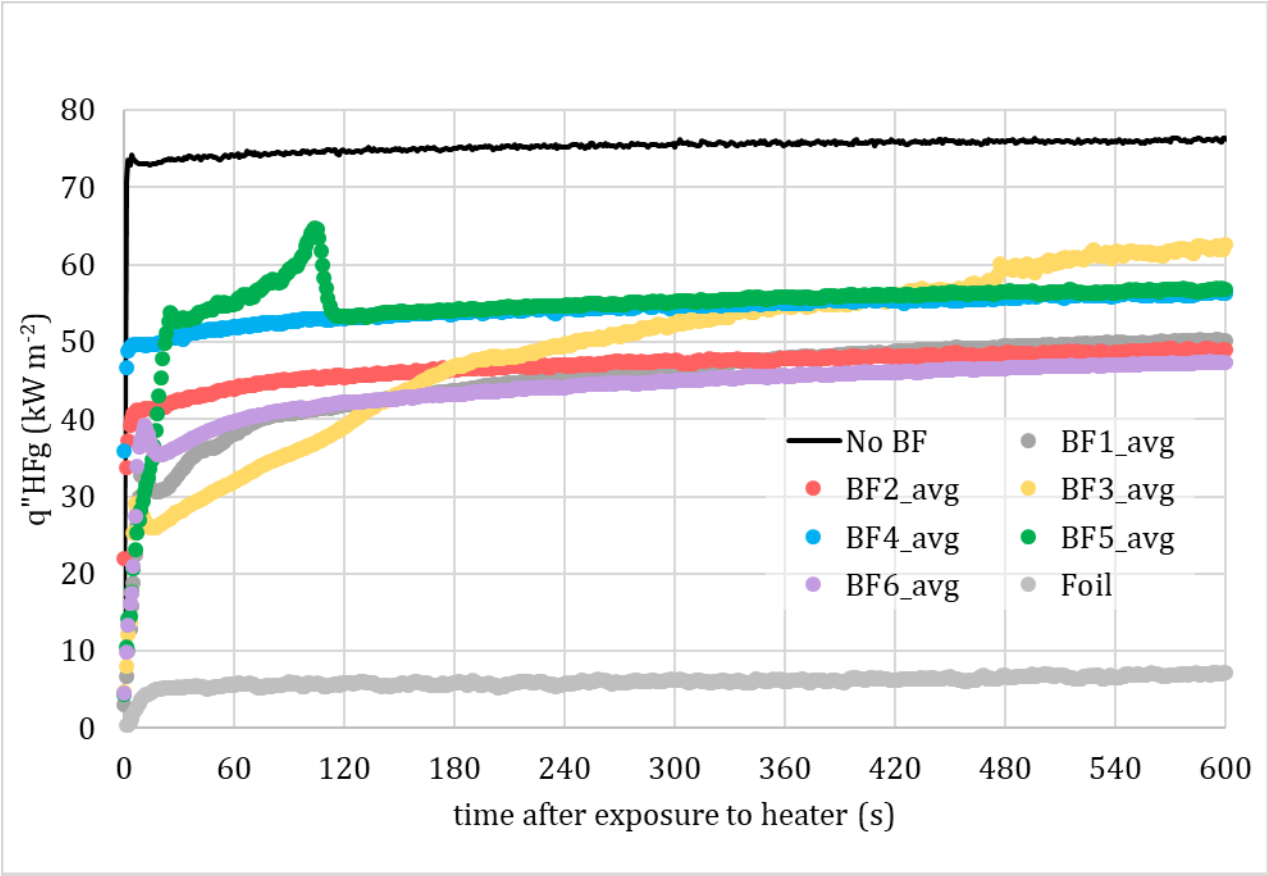
"**Wetting**": appearance of visible liquid pyrolyzates on the bottom barrier

Example of HRR Curve in Cube Test



Heat transfer through Barriers





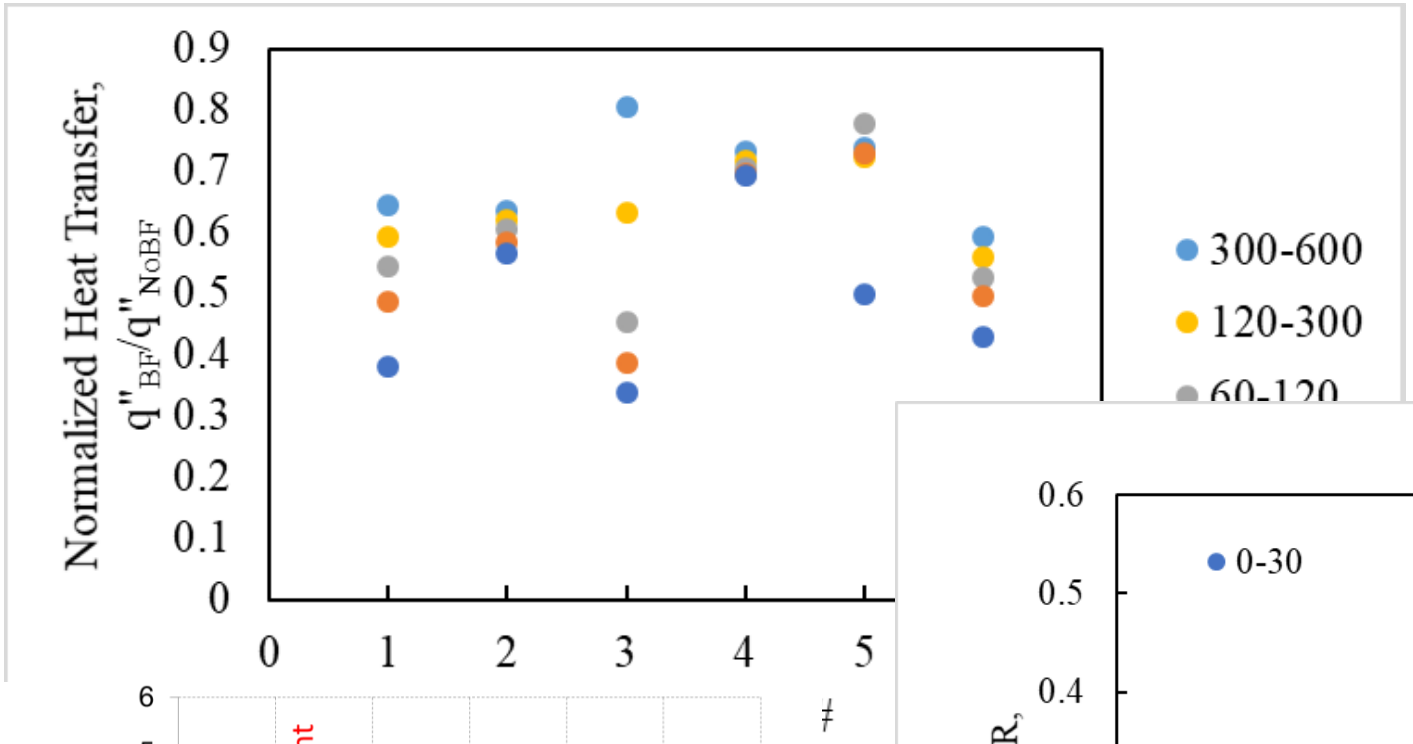
Calculate effectiveness of barrier by calculating normalized heat transfer

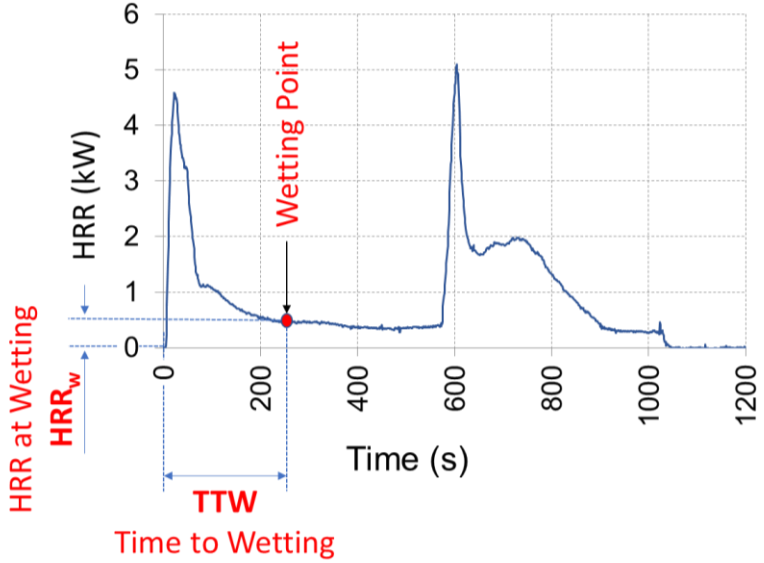
$$\frac{q''_{BF}}{q''_{No\ BF}} = \frac{heat\ transfer\ through\ barrier}{heat\ transfer\ without\ barrier}$$

Can calculate during different time intervals, $t_0 < t < t_f$, as BF degrades

$$\frac{q''_{BF}}{q''_{No\ BF}} = \frac{\int_{t_0}^{t_f}(q''_{BF})dt}{\int_{t_0}^{t_f}(q''_{No\ BF})dt}$$

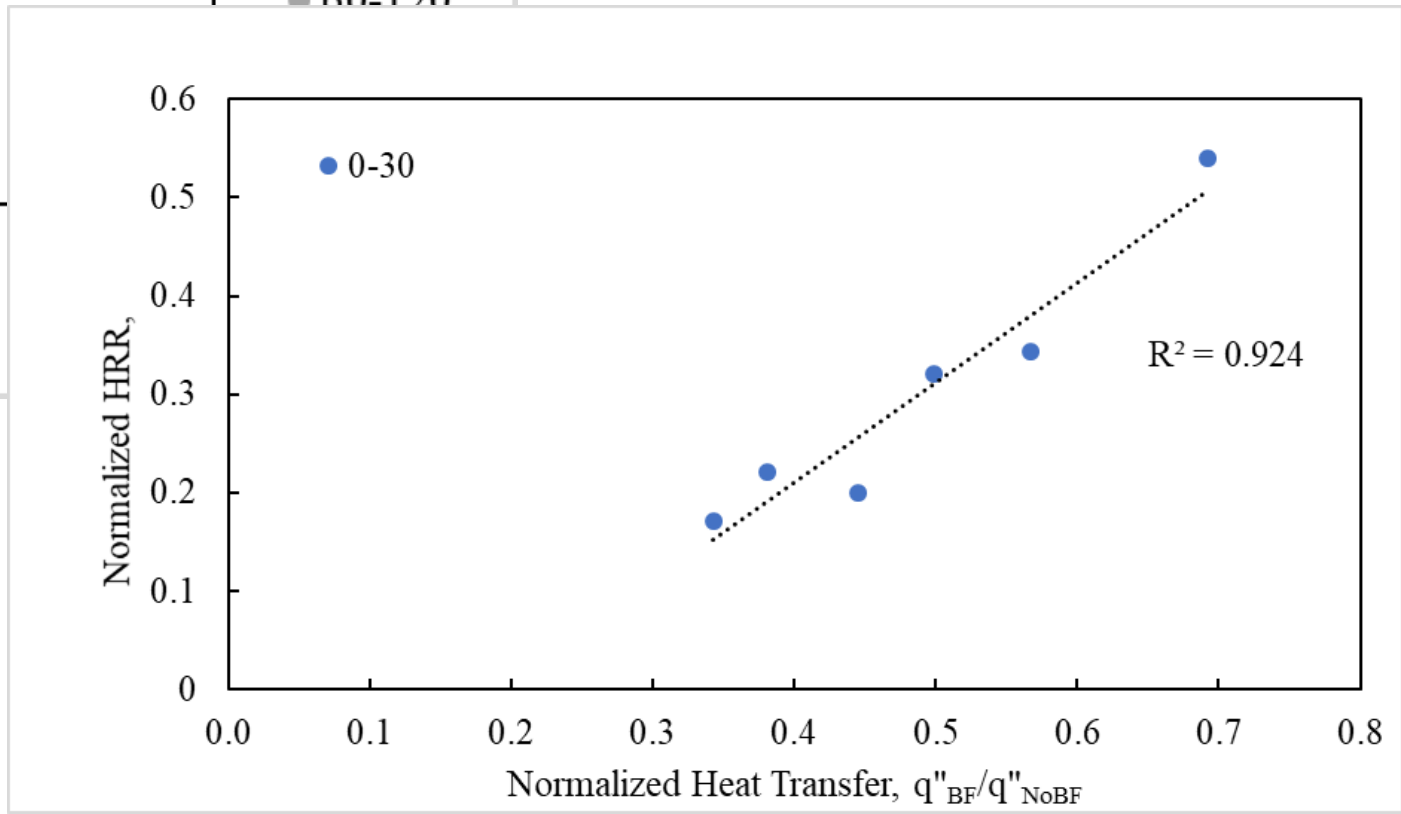
Heat transfer through Barriers





Calculate effectiveness of barrier by calculating normalized HRR

$$\text{Normalized HRR} = \frac{HRR_{w,BF}}{HRR_{w,No\ BF}}$$

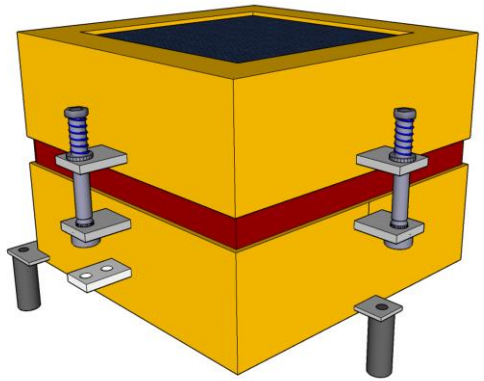


Case Study: Upholstered Furniture (UF)

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)

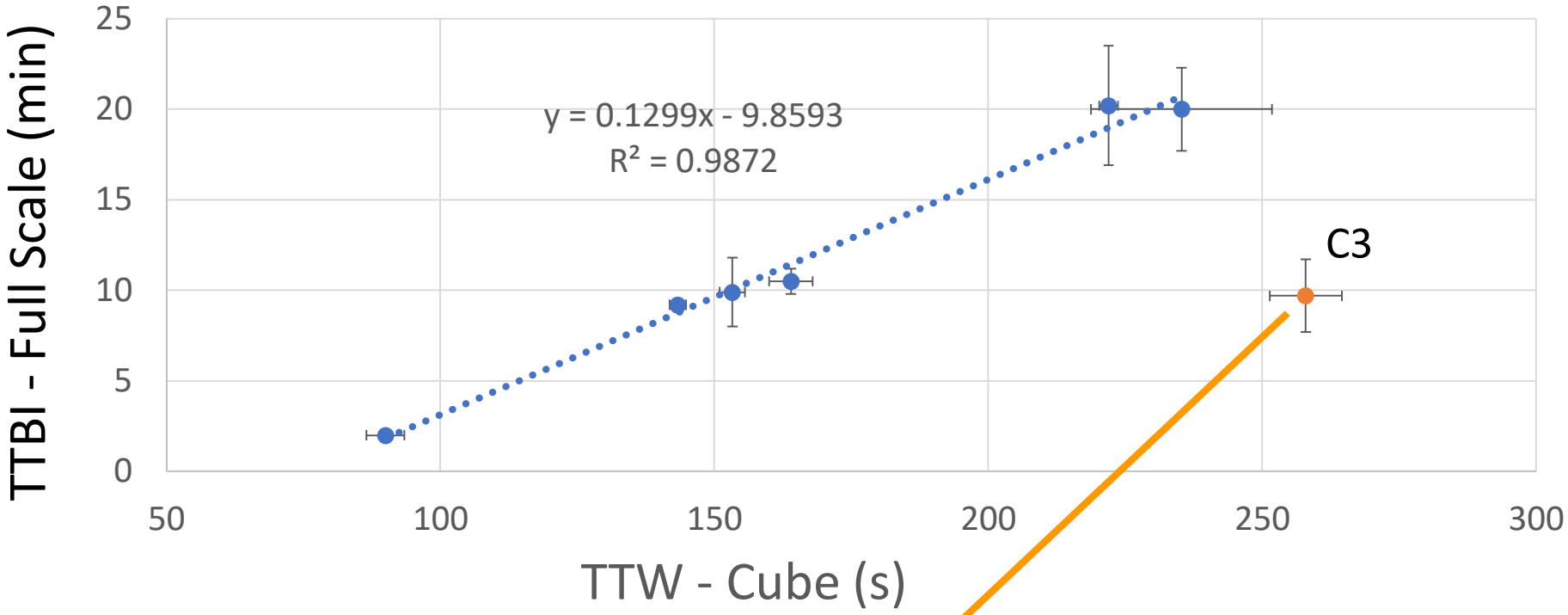
Cube to Full-Scale Correlation?

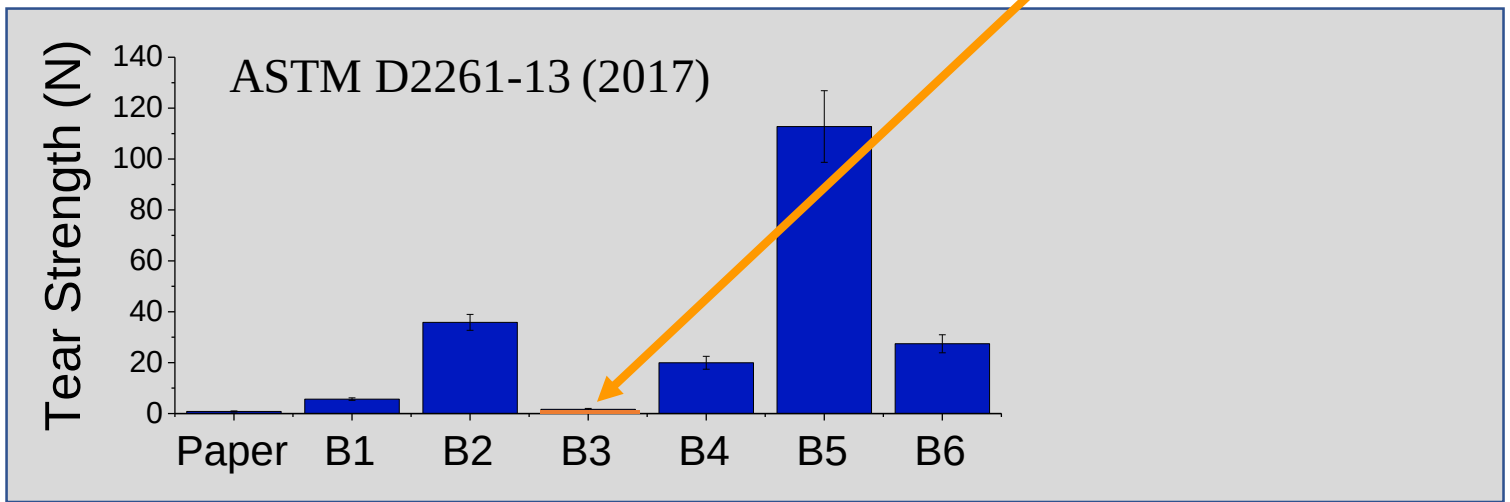
Correlation:

-TTBI to TTW?

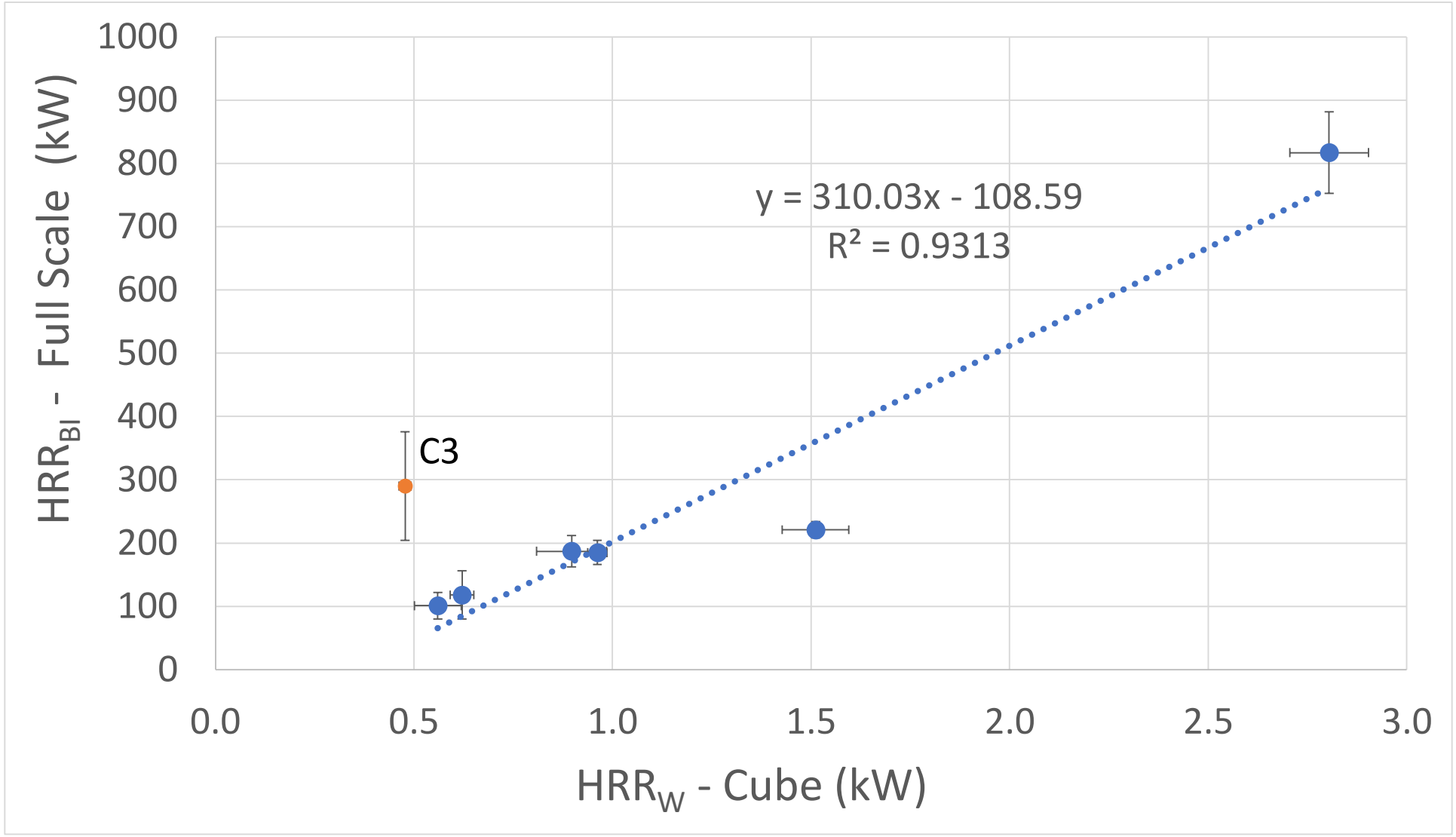
-HRR_{BI} to HRR_{w}?

Prediction of TTBI (and TTP) by Cube





Prediction of Plateau Value



Conclusions

- The Cube Test is a tool developed to capture mass/heat transfer mechanisms through fire barriers
- The Cube test has been successfully used to predict Stage I burning (within the limited data set available) in Upholstered Furniture and properly rank the effectiveness of Fire Barriers
- Other cored systems (honeycombs+ fiber reinforced epoxy, insulation foam + aluminum foil, etc.) are currently under investigation

THANK YOU!

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