Residential Upholstered Furniture Flammability

Consumer Product Safety Commission
November 18, 2013
Rockville, MD

Thomas Fabian, Ph.D.
UL LLC

© 2013 UL LLC

Upholstered Furniture Flammability

PROJECT OVERVIEW

Demonstration experiments to explore if commercially available fire resistance technologies can retard and/or reduce fire growth

<u>3 Scales of Experiments</u>

- **Material level**
- **Mock-up level**
- **Full furniture level**

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Approach

Task 1 – Select and procure sample materials

Task 2 – Characterization of sample materials

Task 3 – Material combination combustibility experiments

Task 4 – Mock-up assembly combustibility experiments

Task 5 – Full-scale furniture combustibility experiments

Task 6 – Develop technical report

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Tasks 1 & 2 – Sample Materials

Sample Materials

Fabric (2)

- **C: Cover fabric - beige, polyester microsuede**
- **D: Decking - beige, cotton**

Foam (2)

- **PU: Polyurethane foam (29.6 ±0.6 kg/m^3)**
- **frPU: TB 117 Fire retardant polyurethane foam (27.6 ±0.6 kg/m^3)**

Polyester Wrap (1)

- **W: Polyester wrap (1 oz smooth bond)**

Fire Barrier (11) – FB#

Chemistries: para-aramids, cotton, rayon, blends, and elastic

Physical form: flat/high-loft, woven/non-wovens, plain weave/knits, single/multi-layer

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Materials

CHARACTERIZATION TECHNIQUES

Physical

- Density
- Thickness

Composition

- Bulk chemistry: FTIR
- Elemental analysis: ICP-MS & SEM-EDS
- B content: ICP-AES
- Br & Cl content: titration
- Volatiles, semi-volatiles and non-volatiles: Py-GC/MS

Flammability

- Thermal degradation: TGA
- Potential heat: oxygen bomb calorimeter (NFPA 259)
- Ignitability and combustibility: cone calorimeter (ASTM E 1354)
- California TB 117

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Materials

SUMMARY: FABRICS

Characteristic	Cover Fabric C	Decking D
Color	Beige	Beige
Bulk Material	Polyester	Cotton
Inorganic Residue (%)	1.4	2.1
Area Density (g/m^2)	717.9 ±6.3	1036.1 ±15.4
Potential Heat (kJ/kg)	21689 ±2	17238 ±28
Notes	Polyurethane binder	Polydimethylsiloxane treatment

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Materials

SUMMARY: FOAMS

Characteristic	Untreated Foam PU	Treated Foam frPU
Color	White	White
Bulk Material	80:20 TDI/polypropylene oxide polyol, polyether based polyurethane	80:20 TDI/polypropylene oxide polyol, polyether based polyurethane
Antioxidant	Ciba-Geigy	Ciba-Geigy
Costabilizer	Alkylated diphenylamine	Alkylated diphenylamine
Flame Retardant Chemicals	--	TDCPP, TPP, TBPP
Inorganic Residue (%)	1.5	2.5
Density (g/m^3)	29.6 ±0.6	27.6 ±0.6
Potential Heat (kJ/kg)	28167 ±602	26899 ±374
Eff. Heat of Combustion (kJ/g)	25.4 ±0.1	22.8 ±0.2
Peak HRR (kW/m^2)	284 ±27	303 ±26

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Materials

SUMMARY: FLAT FIRE BARRIERS

Characteristic	FB1	FB2	FB3	FB4	FB5	FB6
Color	Yellow	Yellow	White	Off-white	Off-white	Off-white
Bulk Material	Para-aramid/ polyester/ rayon blend	Para-aramid	melamine or styrene-acrylic derivative coated glass fiber	PAN-PVC copolymer	PAN-PVC copolymer	PAN-PVC copolymer and cotton
Flame Retardant Chemicals			TPP, TBPP, Chlorinated paraffin, Antimony trioxide	Antimony trioxide	Antimony trioxide	Antimony trioxide
Inorganic Residue (%)	12	< 0.1	92	41	45	42
Inorganic Additives			calcium and aluminum silicates	calcium and aluminum silicates	calcium and aluminum silicates	calcium and aluminum silicates
Area Density (g/m^2)	295.8 ±21.3	268.7 ±12.6	463.6 ±5.1	869.6 ±27.5	1177.6 ±32.0	684.6 ±4.7
Thickness (mm)	0.3 ±0.0	0.4 ±0.0	0.1 ±0.0	0.6 ±0.0	0.8 ±0.0	0.3 ±0.0

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Materials

SUMMARY: HIGH-LOFT FIRE BARRIERS & POLYESTER WRAP

Characteristic	FB7	FB8	FB9	FB10	FB11	Poly Wrap W
Color	Off-white	Off-white	Off-white	Off-white	Off-white	White
Bulk Material	Cotton	Cotton-Rayon bilayer	Rayon	Cotton-Rayon-Rayon trilayer	Cotton/ polyester/ rayon blend	Polyester
Flame Retardant Chemicals	Boric acid	Boric acid	Boric acid			
Inorganic Residue (%)	7		22		22	1
Inorganic Additives		silica	silica	silica	silica	
Area Density (g/m^2)	1325.6 ±143.9	1095.7 ±93.3	1434.3 ±54.7	1060.4 ±123.5	1548.2 ±127.2	1443.9 ±83.7
Thickness (mm)	7.3 ±0.6	8.0 ±0.7	8.3 ±0.4	10.1 ±0.8	7.2 ±0.7	

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Nomenclature

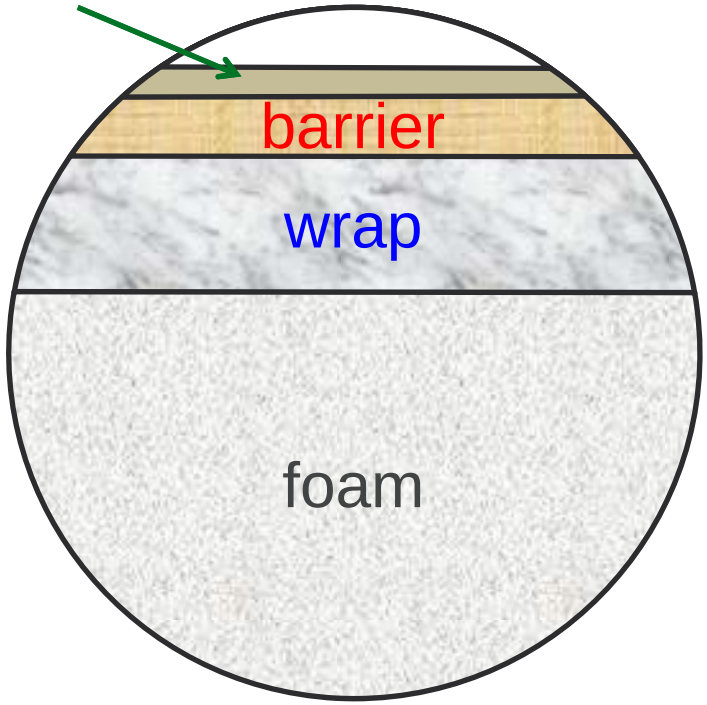
PU = no fr foam
frPU = TB 117 foam

Polyester cover fabric

{fr}PU-W-FB#-C

Polyester wrap

11 fire barriers (flat, high-loft)



NOT ALL COMPONENTS MAY BE PRESENT

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Task 3 – Material Combination Combustibility Experiments

Material Combo Combustibility Experiments
OVERVIEW

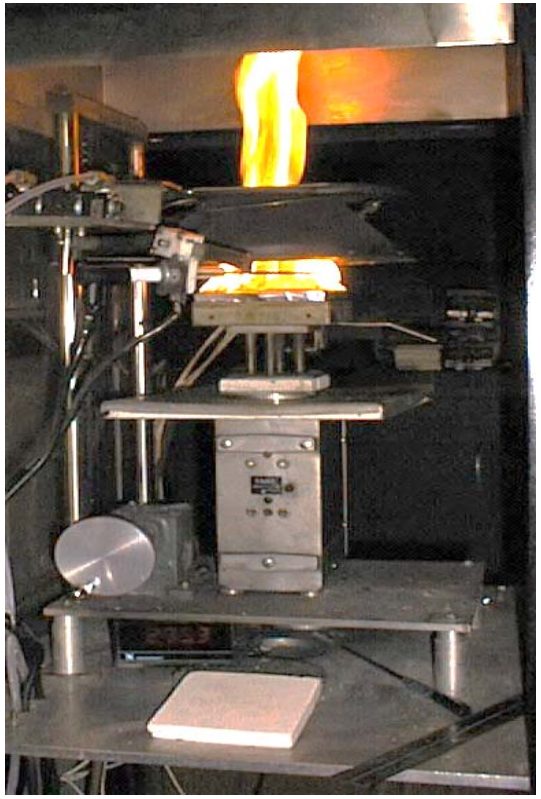
Explore response of various material combinations to early stage fires

<u>ASTM E 1354 Cone Calorimeter</u>

- **100×100 mm (4×4 inch)**
- **30 kW/m^2**
- **Triplicate**

<u>Metrics</u>

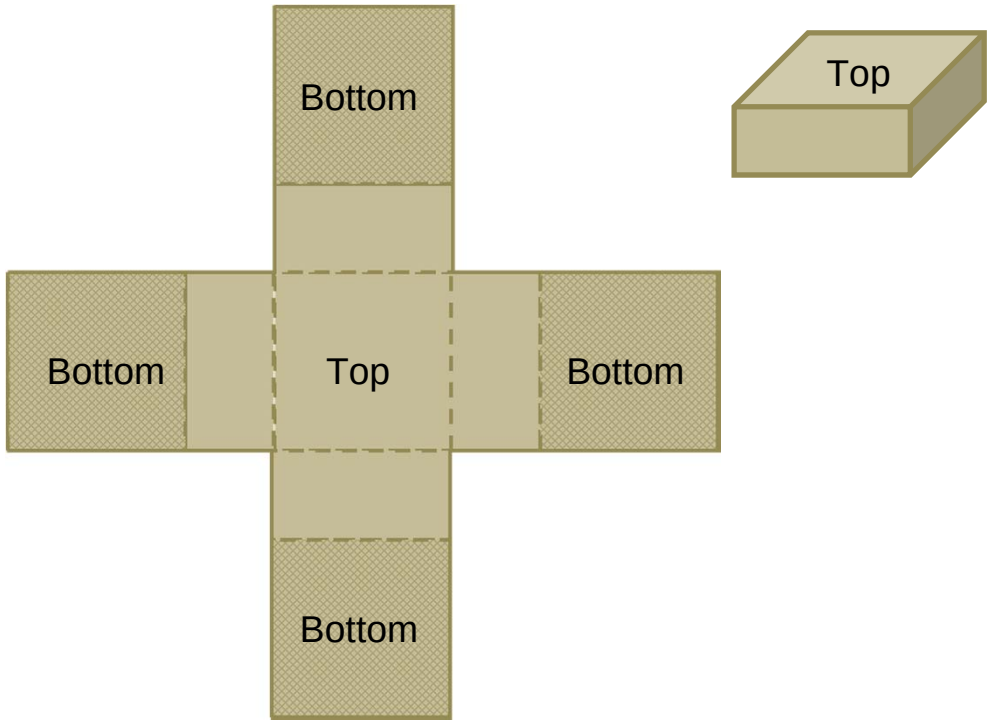
- **Ignition & reignition**
- **Burn duration**
- **Heat release rate**
- **Mass loss**



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

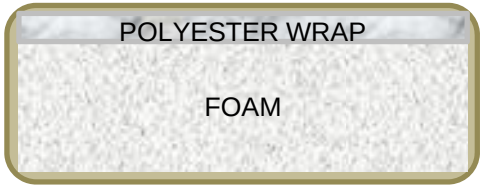
Material Combo Combustibility Experiments

SAMPLES



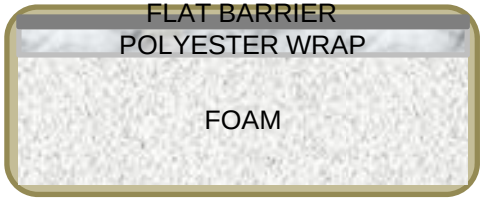
<u>Samples (19 in triplicate)</u>

- **foam-W-C**



- **PU-high loft barrier-C**

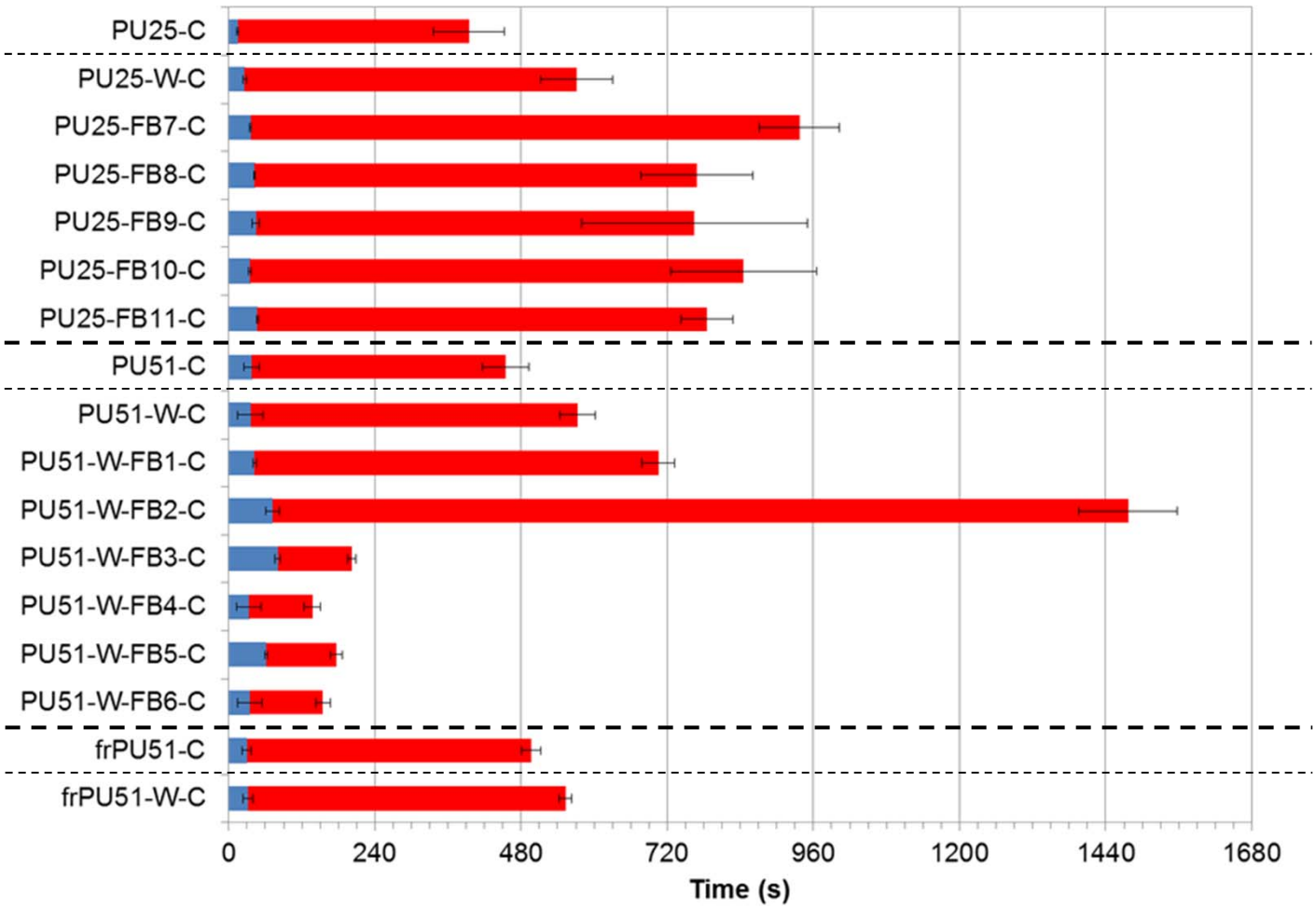
- **PU-W-flat barrier-C**



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments

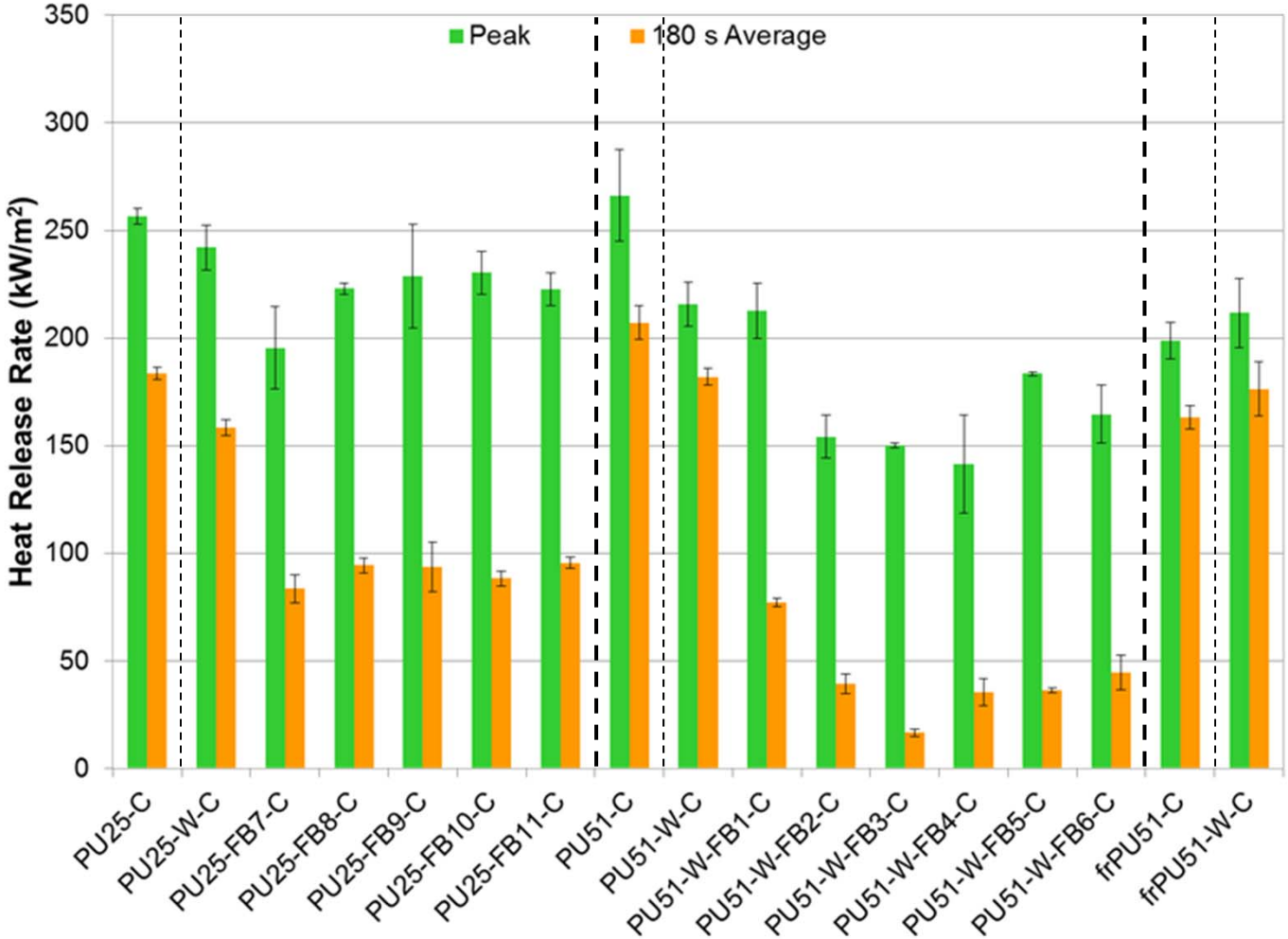
t_{ign} & BURN DURATION



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments

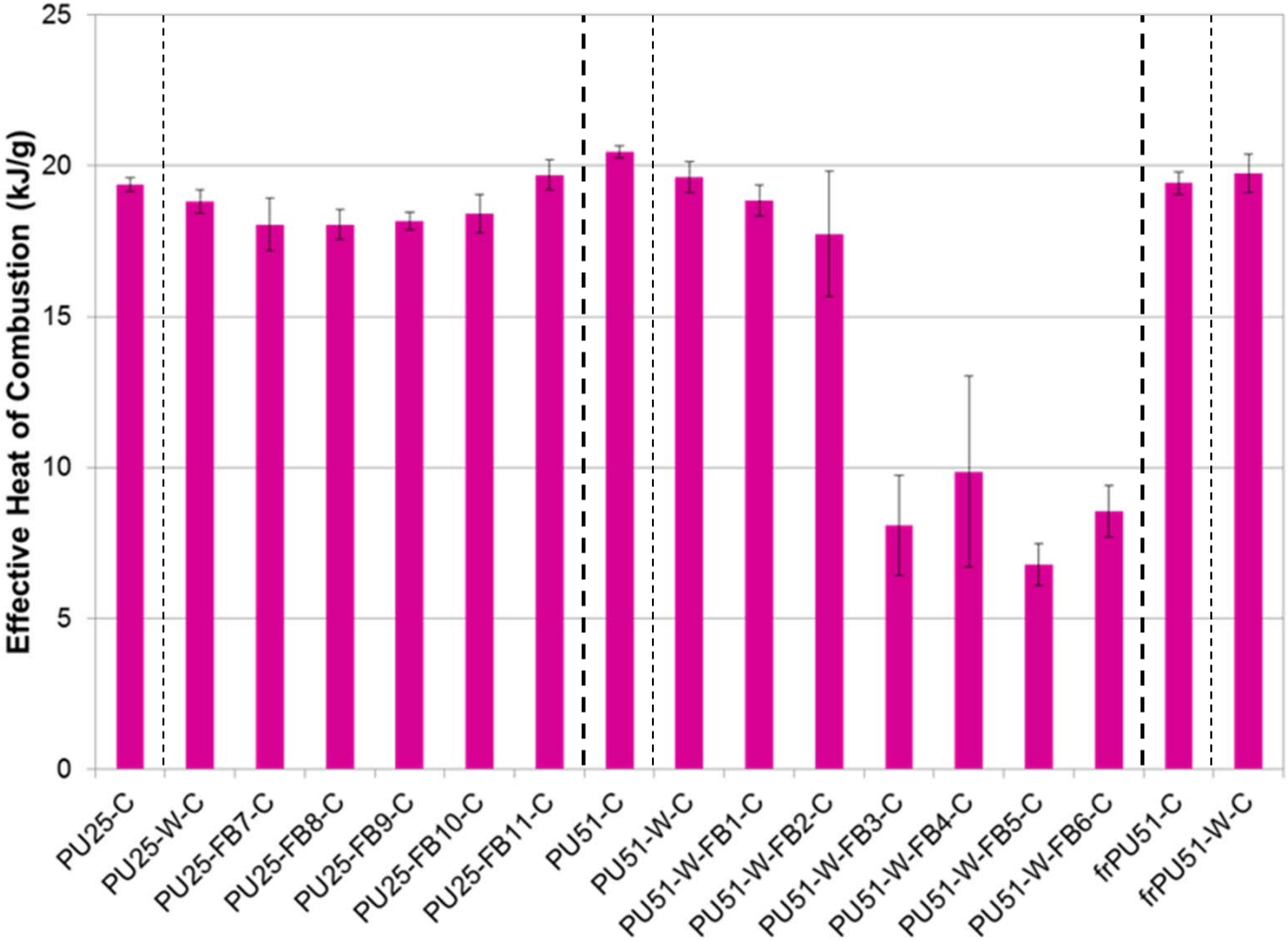
HEAT RELEASE RATES



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments

HEAT OF COMBUSTION



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments
SUMMARY OF FINDINGS

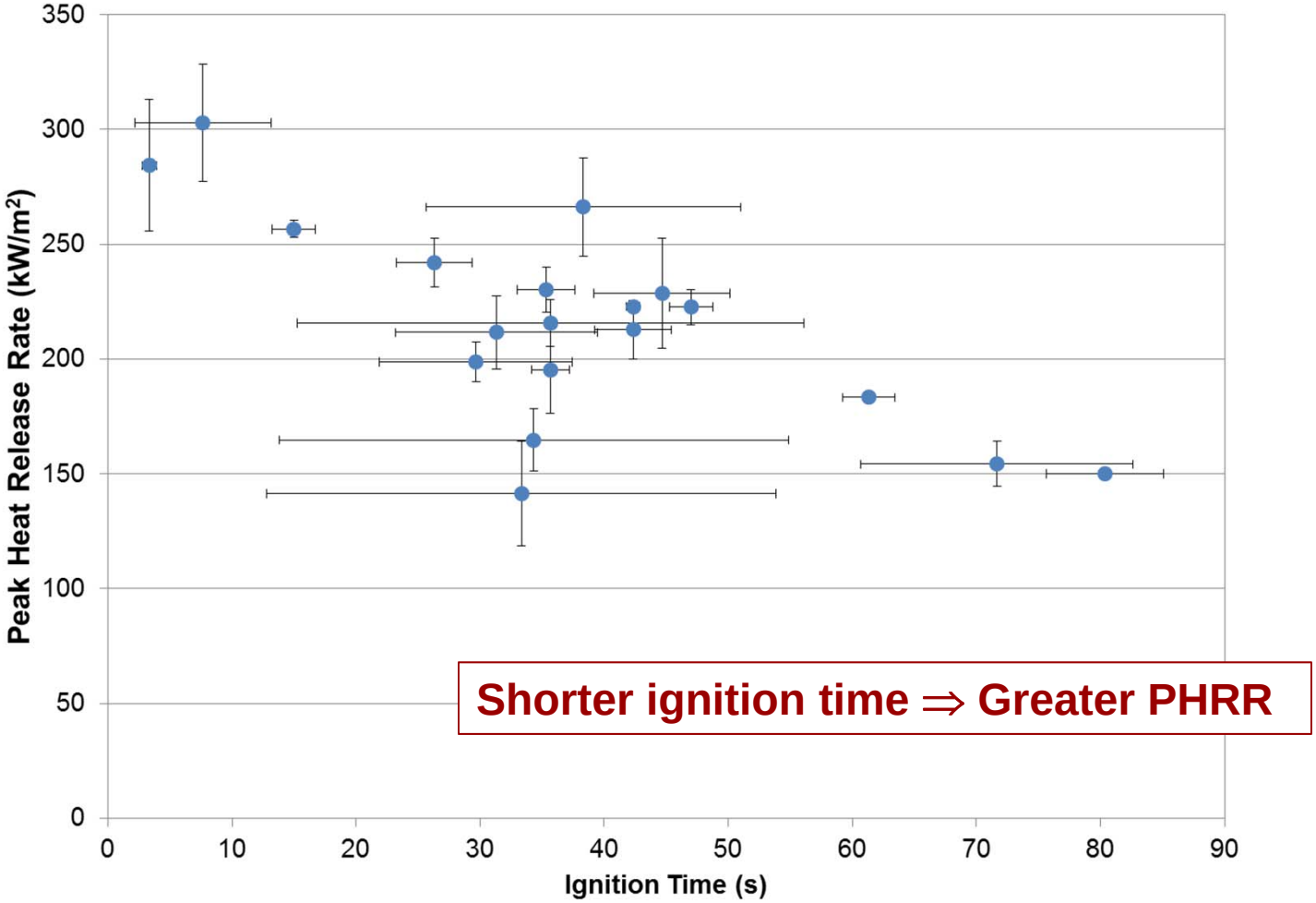
All approaches exhibited some degree of reduced ignitability/flammability.

1. frPU foam usage:
   - Slightly shorter burn duration
2. High-loft barrier usage:
   - Prolonged time to ignition by 9 to 21 s; extended burn duration by 174 to 355 s
   - PHRR was modestly reduced; 180 s AHRR was significantly reduced
   - Total heat releases were 6 to 13 % lower
3. Flat barrier usage:
   - Prolonged time to ignition up to 2x longer
   - Para-aramid blends extended burn duration by 106 and 868 s; others were 415 to 433 s shorter
   - PHRR was reduced up to 34 % and 180 s AHRR was significantly reduced (58 to 91 %)
   - THR for para-aramid blends was 9 and 42 % lower; others were 80 to 95 % lower

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments

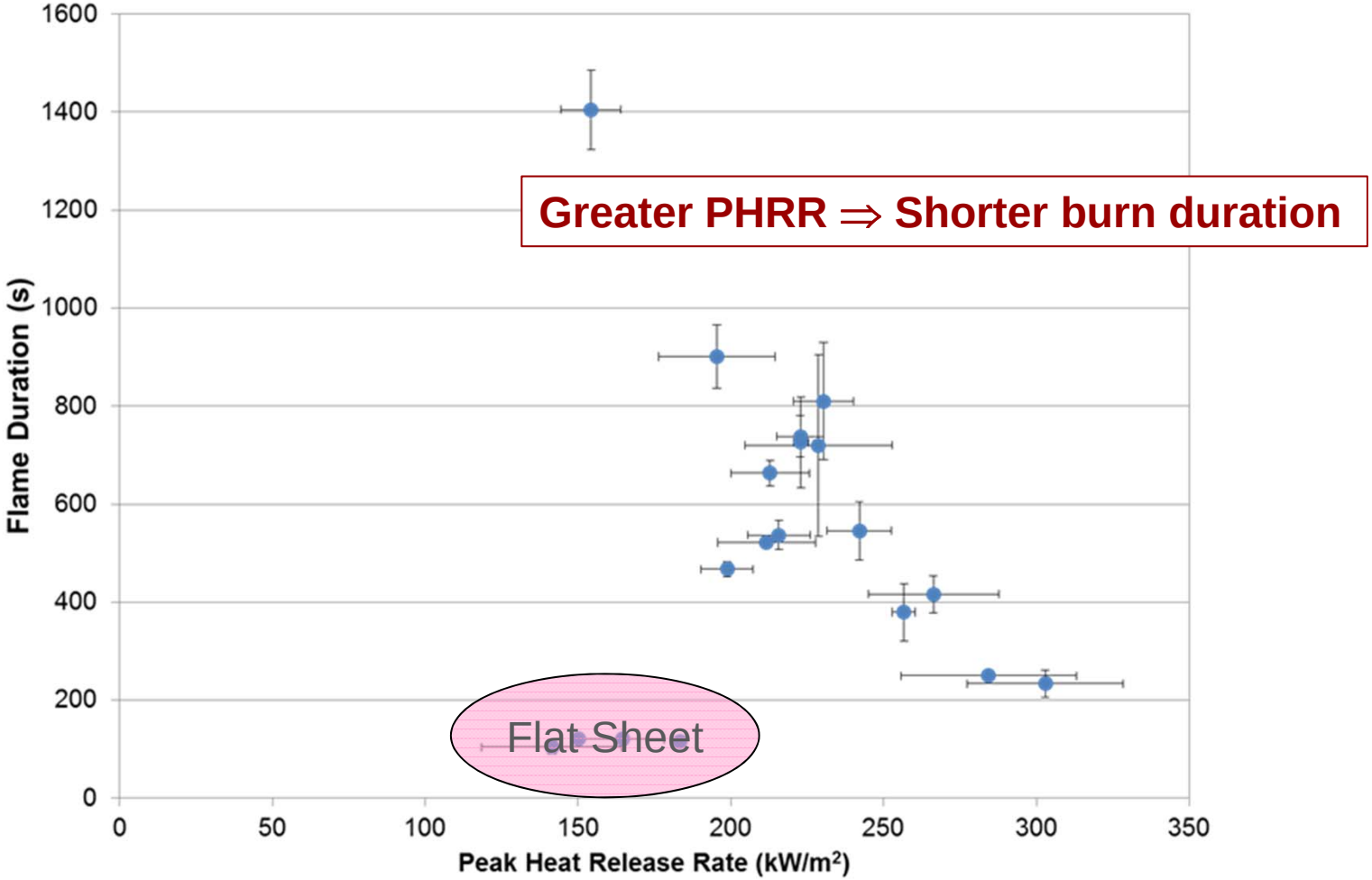
t_{ign} VS. HEAT RELEASE RATE



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Experiments

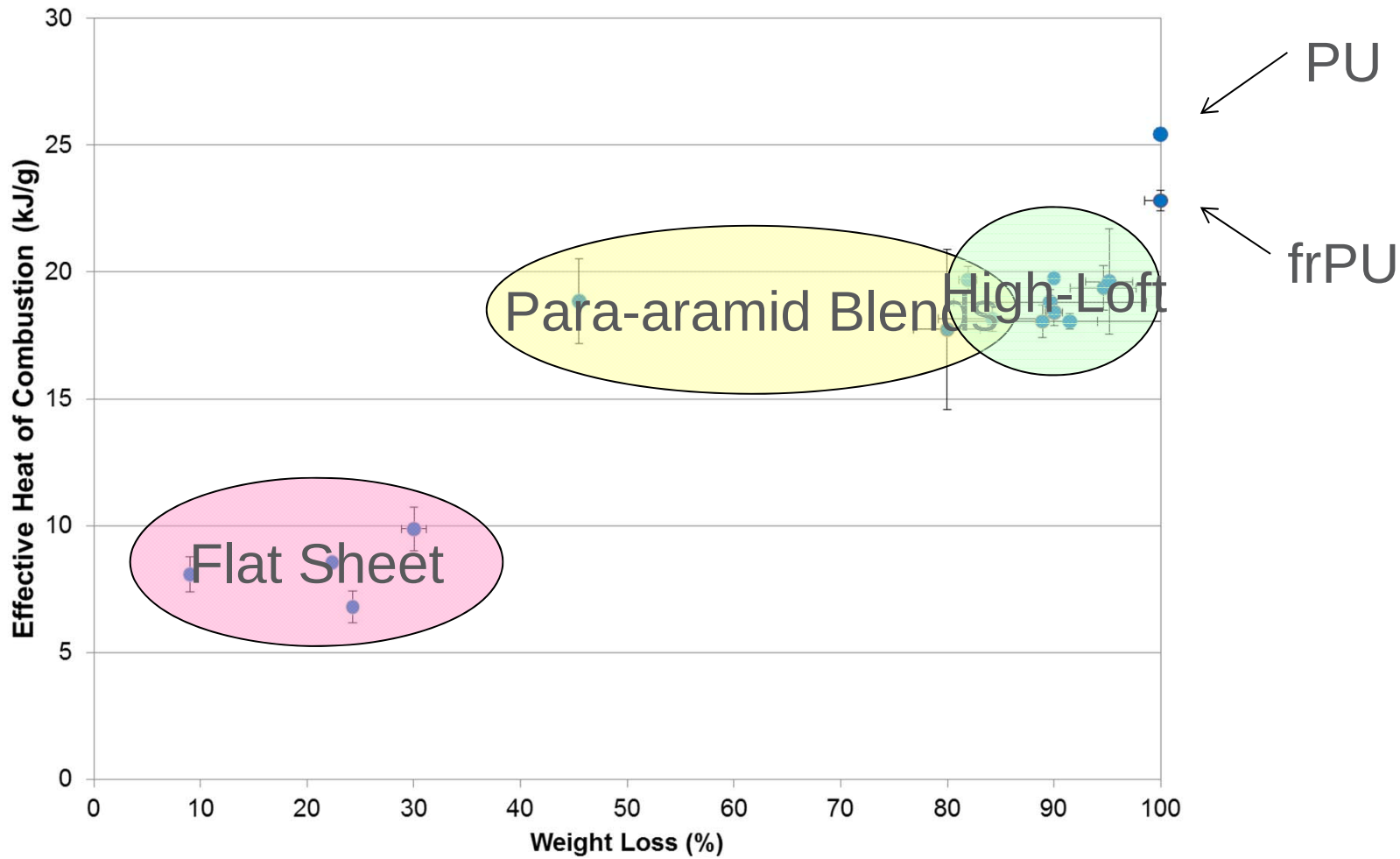
HEAT RELEASE RATE VS. BURN DURATION



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Tests

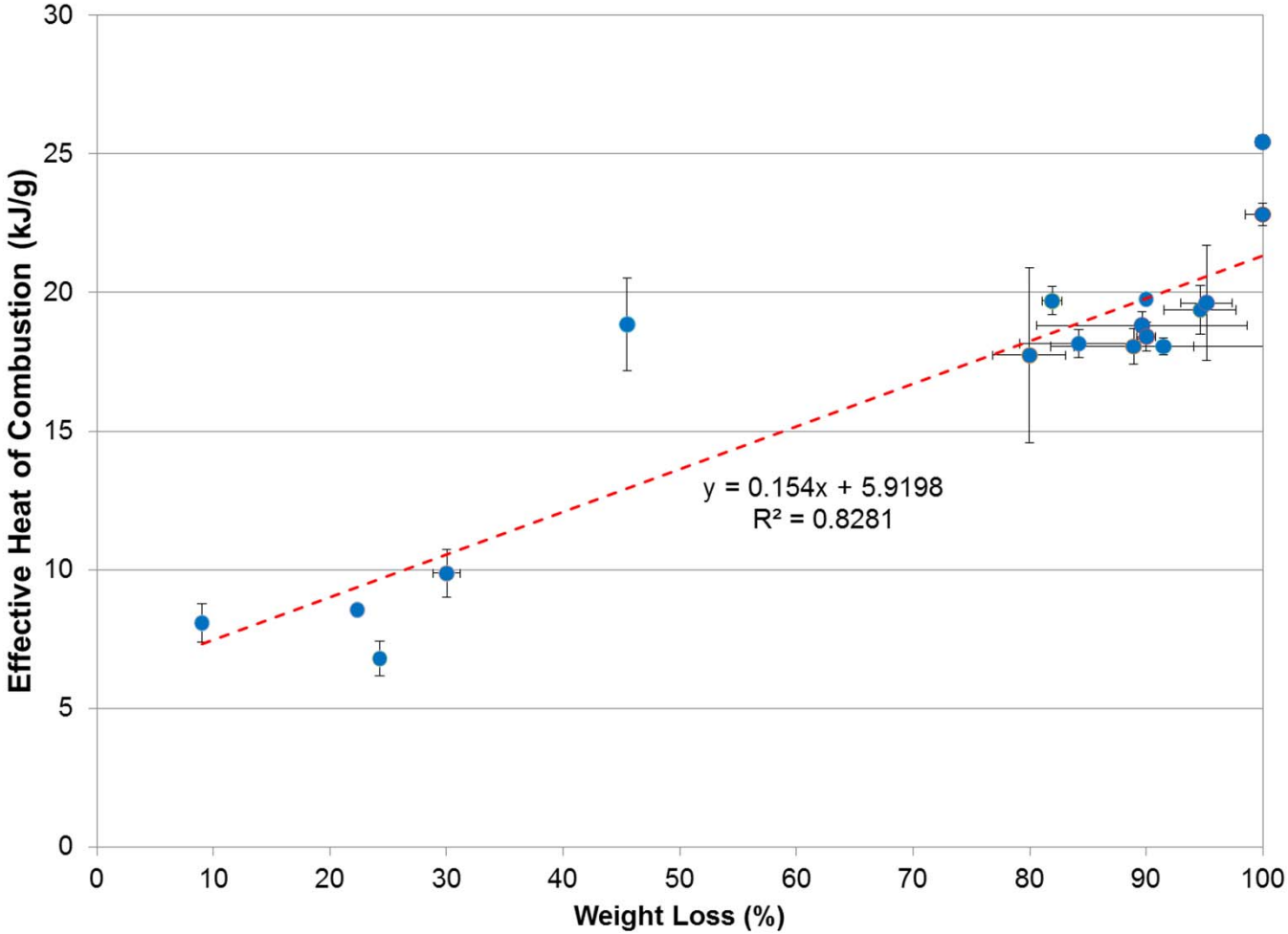
HOC VS. WEIGHT LOSS



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Tests

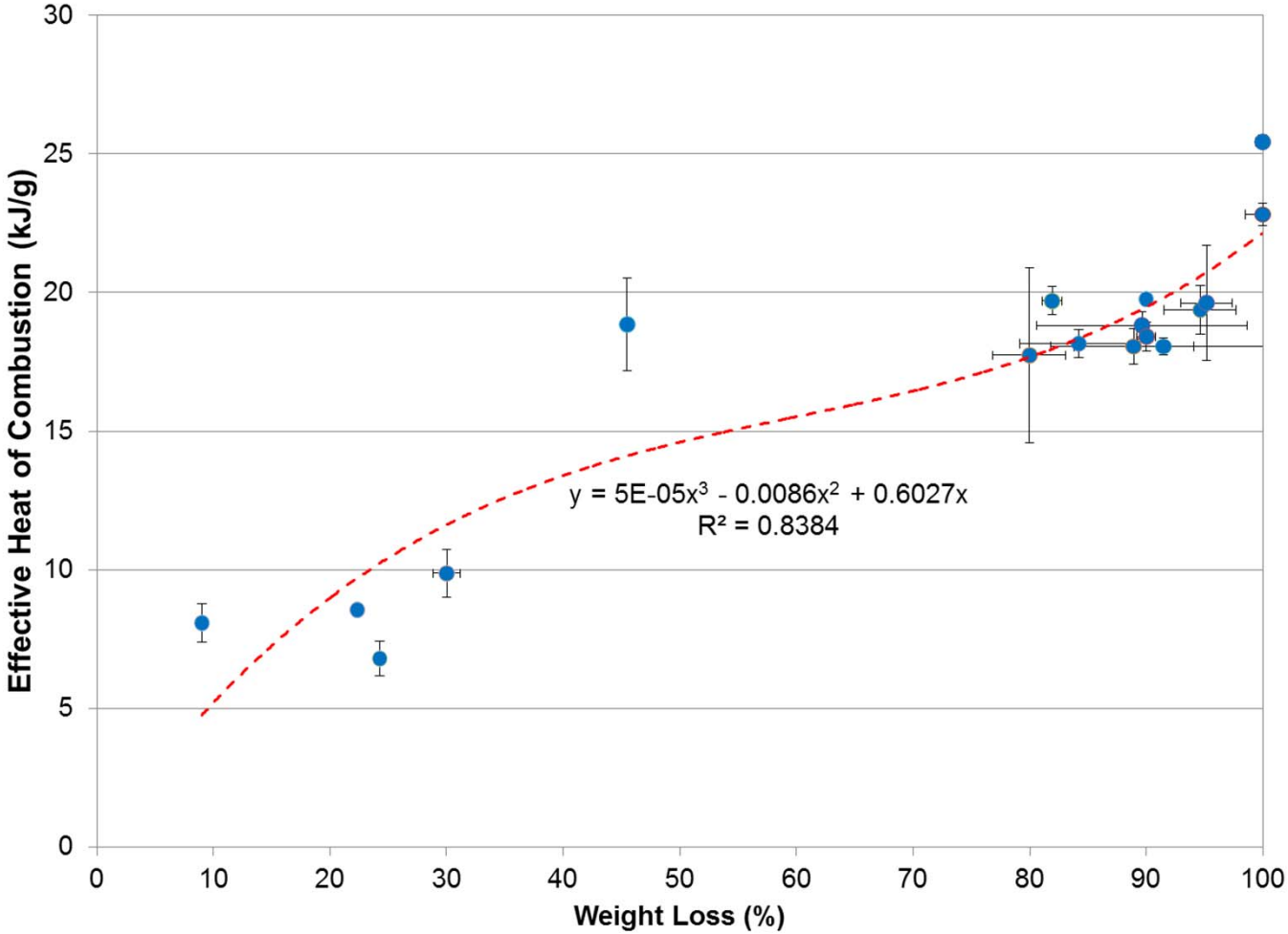
HOC VS. WEIGHT LOSS



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Material Combo Combustibility Tests

HOC VS. WEIGHT LOSS



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Task 4 – Mock-up assembly combustibility experiments

Mock-up Combustibility Experiments
OVERVIEW

Explore how composite arrangements react to open flame ignition

<u>Samples</u>

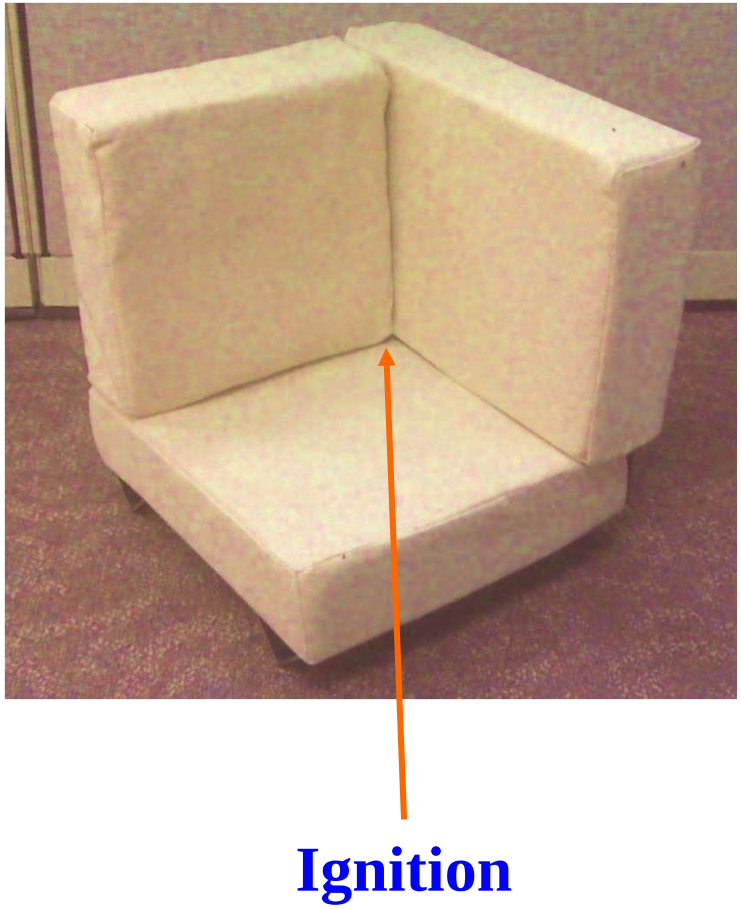
- **foam-W-C**
- **PU-high loft barrier-C**
- **PU-W-flat barrier-C**
- **30 × 30 cm cushions**

<u>Ignition source</u>

- **BS 5852 source 1 ("match flame equivalent" gas flame)**

<u>Intermediate calorimeter metrics</u>

- **Heat release rate**
- **Mass loss**

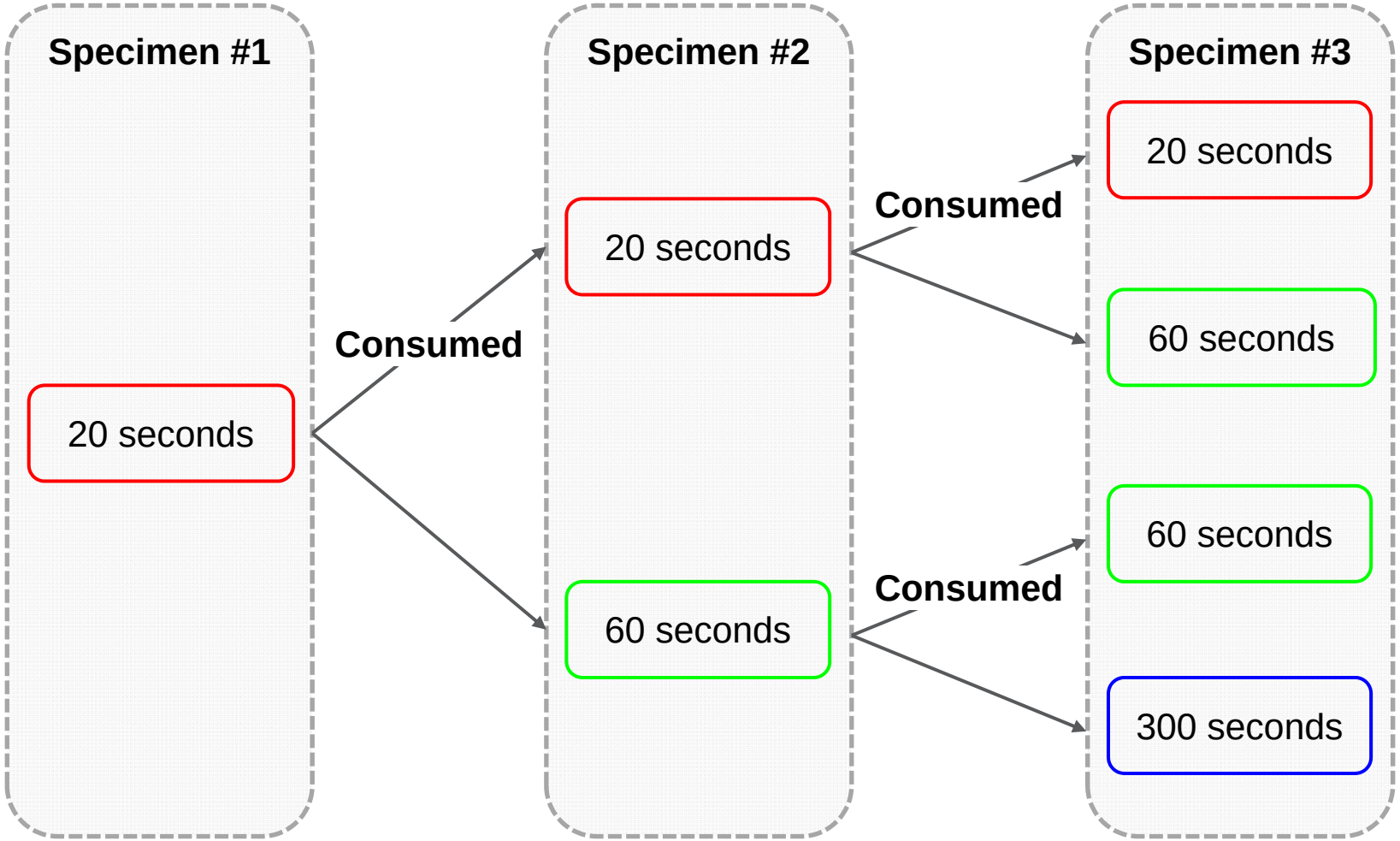


* Mock-up arrangements do not represent furniture construction

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments

IGNITION EXPOSURE SEQUENCE



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments
EXPOSURE SEQUENCE

rapid self-extinguishment

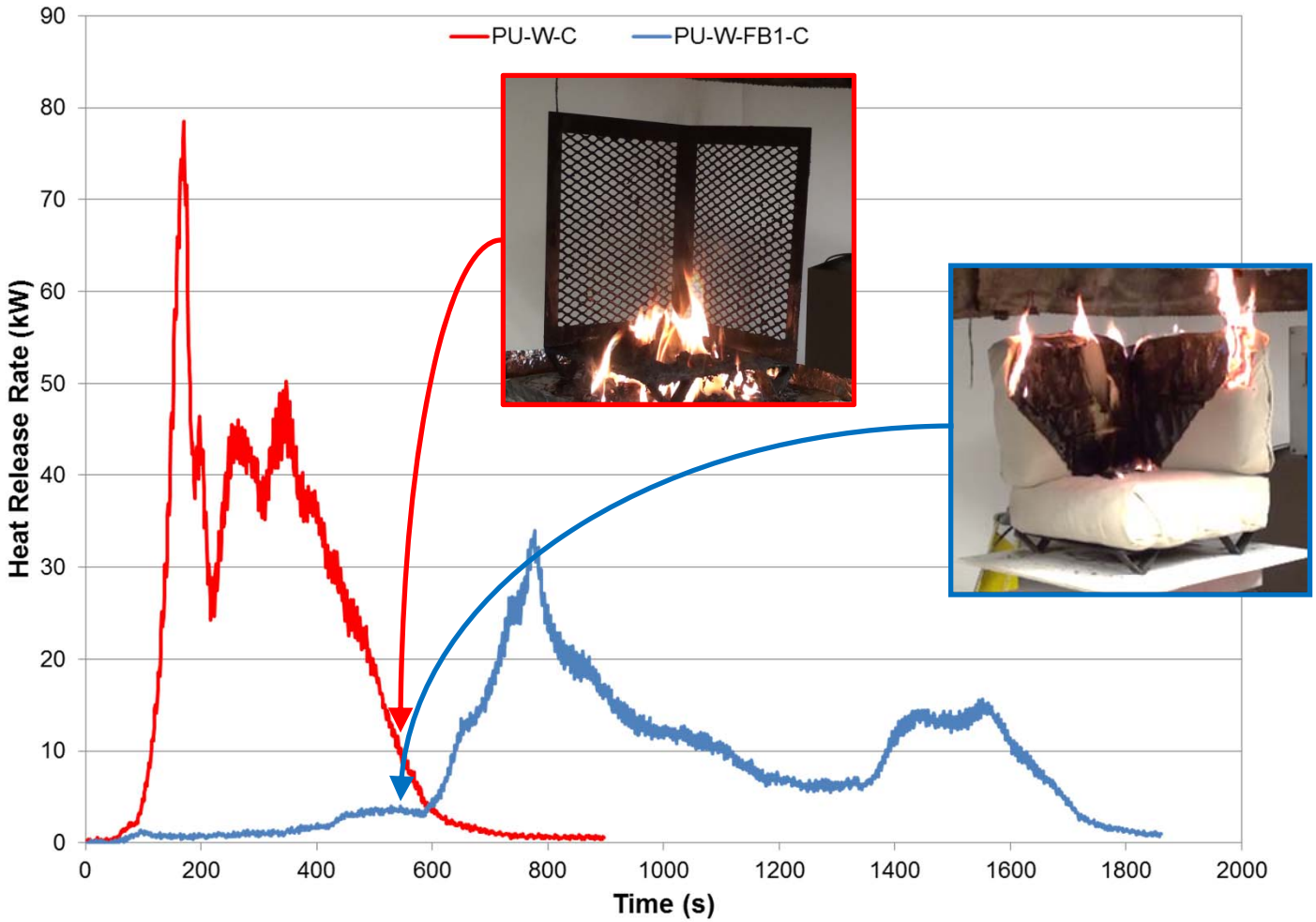
delayed self-extinguishment

consumed

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments

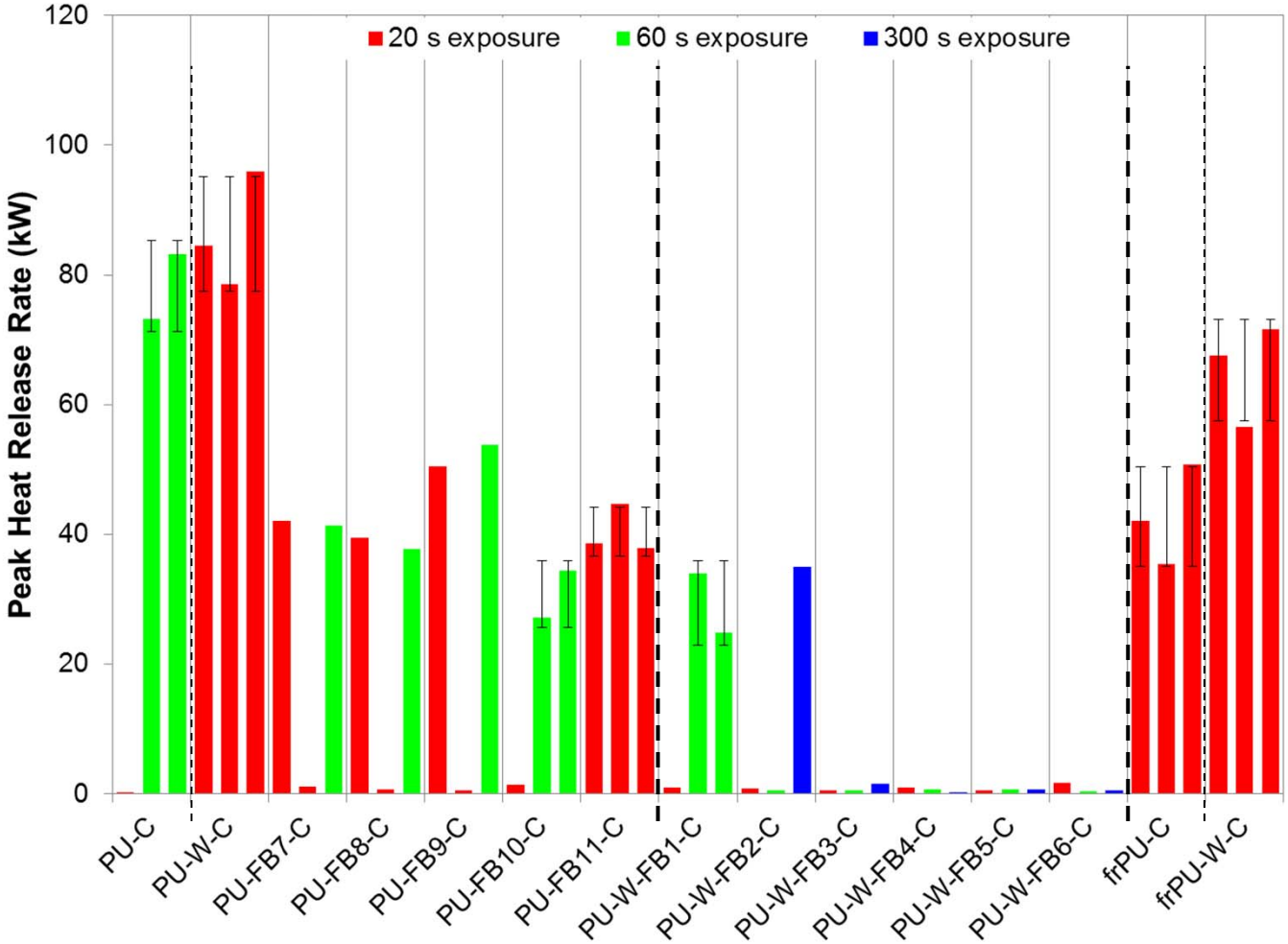
PU-W-C vs. PU-W-FB1-C



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments

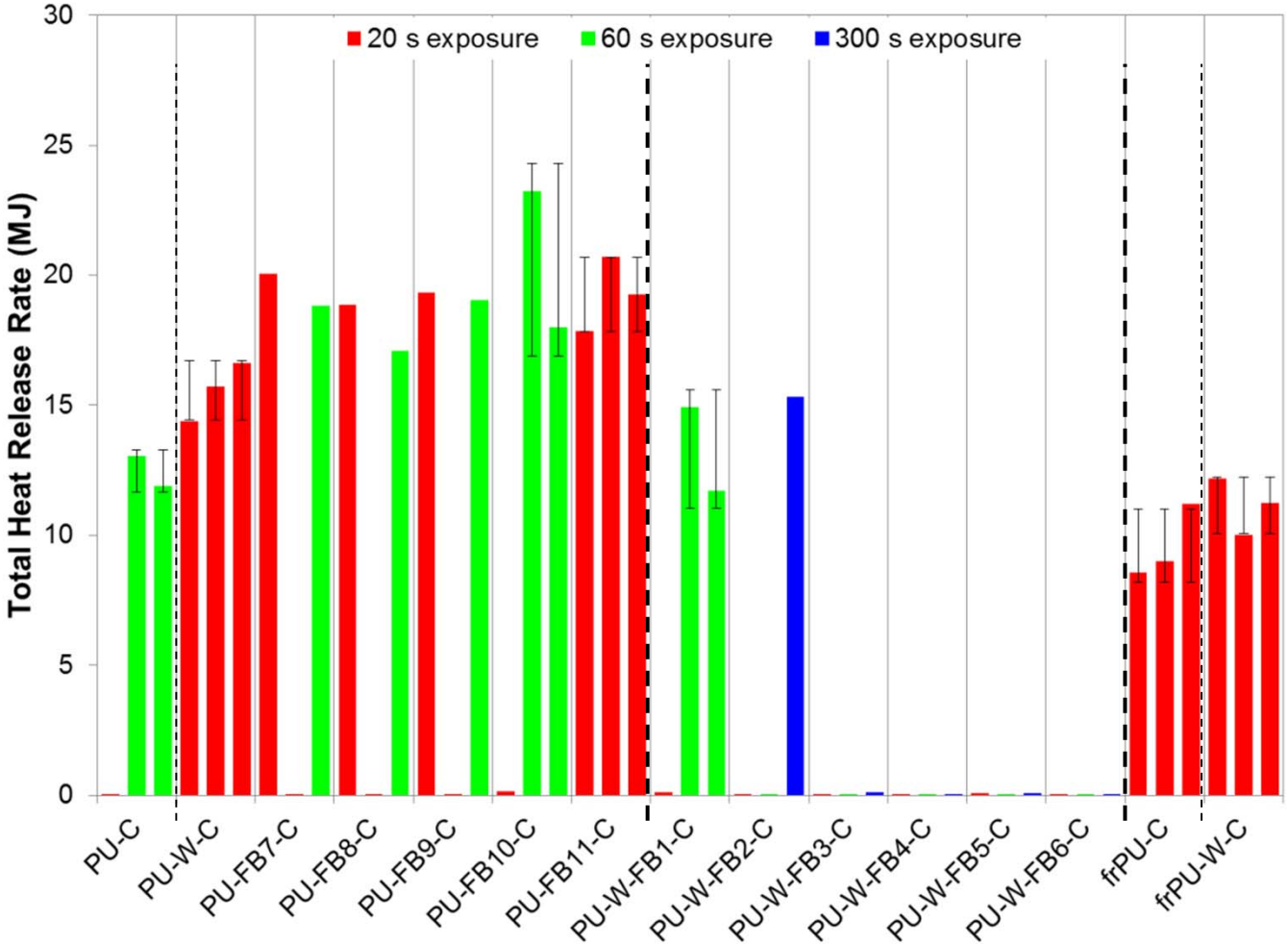
PEAK HEAT RELEASE RATE



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments

TOTAL HEAT RELEASE



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Mock-up Combustibility Experiments
SUMMARY OF FINDINGS

Construction is critical.

All approaches exhibited some degree of reduced ignitability/flammability.

1. **frPU foam usage:**
   - PHRR reduced 45 %
2. **High-loft barrier usage:**
   - Extended survivable ignition exposure durations
   - PHRR was reduced 40 to 66 %
   - Total heat releases tended to be greater
3. **Flat barrier usage:**
   - Extended survivable ignition exposure durations with 4 of 6 barriers surviving 300 s
   - Two para-aramid blends that did not survive 300 s exposure still exhibited 59 and 76 % reduction in PHRR

All approaches extended burn duration except non-para-aramid flat barriers.

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Task 5 – Full-scale furniture combustibility experiments

Furniture Combustibility Experiments
OVERVIEW

Explore how constructed furniture pieces react to open flame ignition

<u>Samples *</u>

- **PU-W-C cushions & W-C frame**
- **frPU-W-C cushions & W-C frame**
- **PU-FB8-C cushions & W-C frame**
- **PU-FB8-C cushions & FB3-C frame**

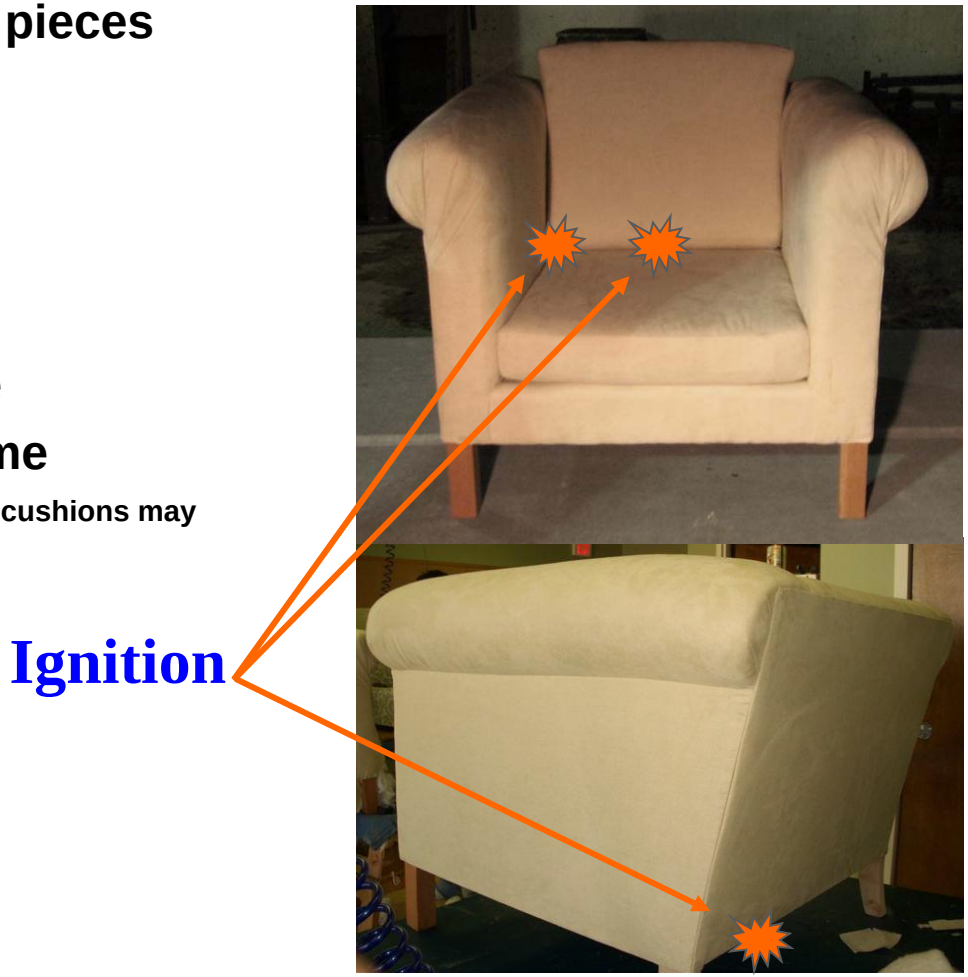
*** UL has been advised by PFA that use of foam in back cushions may not be representative of current practice**

<u>Ignition source</u>

- **BS 5852 source 1 ("match flame equivalent" gas flame) for 20 s**

<u>Furniture calorimeter metrics</u>

- **Heat release rate**
- **Mass loss**



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

FURNITURE CONSTRUCTION

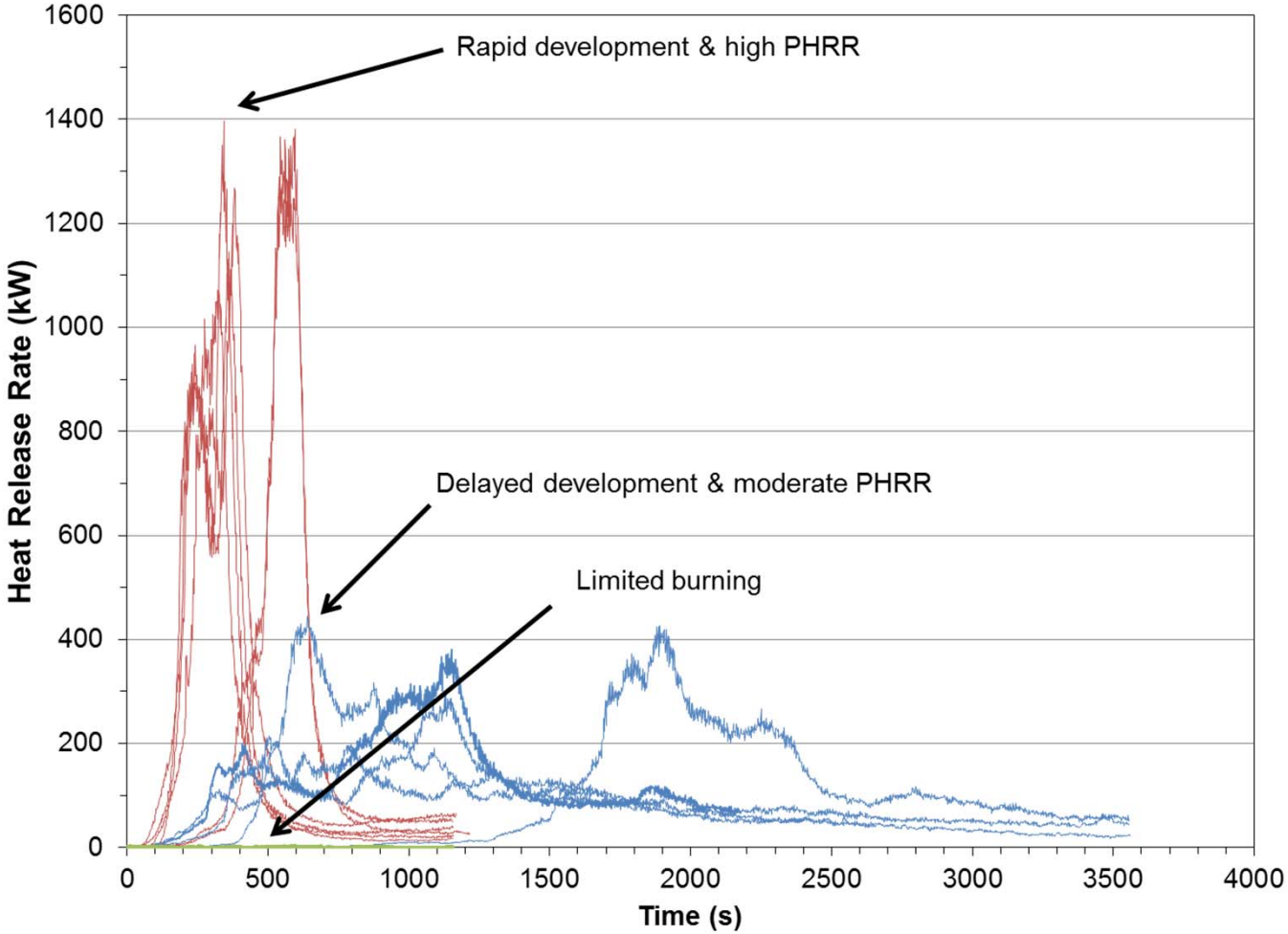
Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample	Frame Cover Elements (from frame to exterior)	Back & Seat Cushions
Chair 1 (Baseline) PU-W-C	Underside: synthetic Accord dustcover Seat: burlap, polyester wrap (W), decking (D) Inside back: burlap, medium weight (4-5 oz) decking, polyester wrap (W), cover fabric (C) Inside arm: burlap, PU foam, polyester wrap (W), cover fabric (C) Outside arm & back: medium weight (4-5 oz) decking, polyester wrap (W), cover fabric (C)	PU-W-C (PU foam wrapped in polyester wrap and encased with cover fabric)
Chair 2 (FR foam) frPU-W-C	Same as Chair 1 except frPU foam substituted on the arm & interior side	frPU-W-C (same as Chair 1 substituting frPU foam)
Chair 3 (High-loft barrier clad foam) PU-FB8-C	Same as Chair 1 except high-loft barrier FB8 substituted for polyester wrap on inside arm	PU-FB8-C (same as Chair 1 substituting high-loft barrier FB8)
Chair 4 (Full barrier clad) PU-FB3/FB8-C	Underside: flat barrier FB3 Seat: burlap, polyester wrap (W), flat barrier FB3, decking (D) Inside back: burlap, medium weight (4-5 oz) decking, polyester wrap (W), flat barrier FB3, cover fabric (C) Inside arm: burlap, PU foam, polyester wrap (W), flat barrier FB3, cover fabric (C) Outside arm & back: medium weight (4-5 oz) decking, polyester wrap (W), flat barrier FB3, cover fabric (C)	PU-FB8-C (same as Chair 3)

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

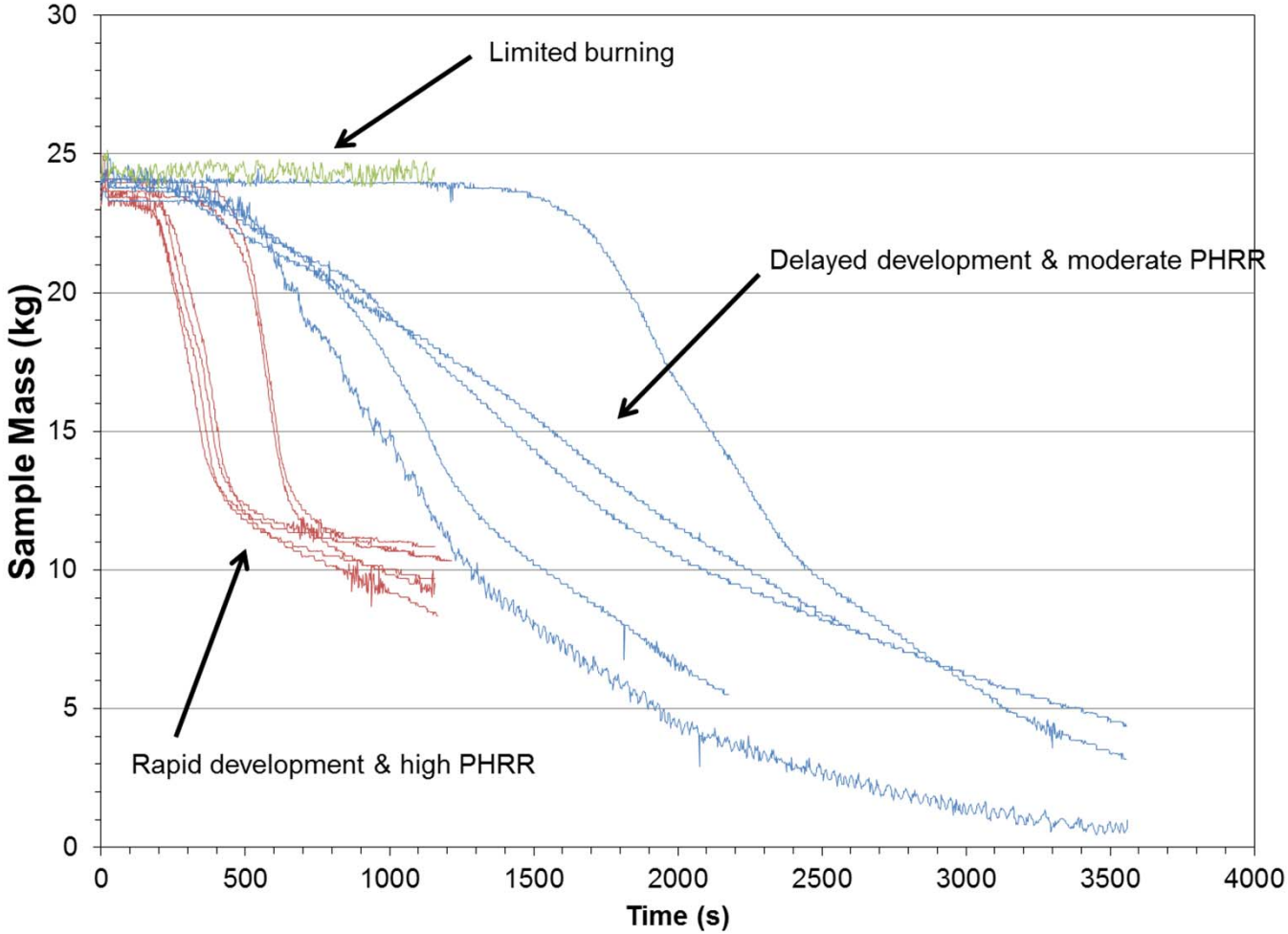
HEAT RELEASE RATE OVERVIEW



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

MASS LOSS OVERVIEW



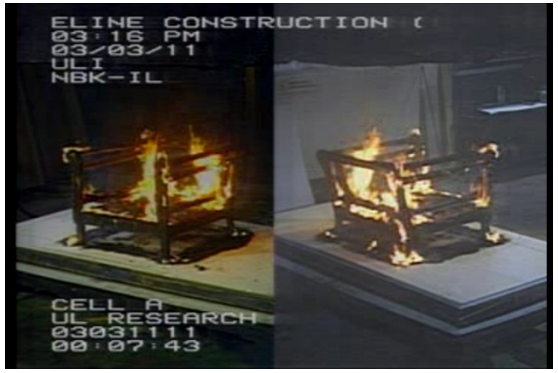
Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

FIRE PROGRESSION EXAMPLES

60 s

@ PHRR



+ 120 s

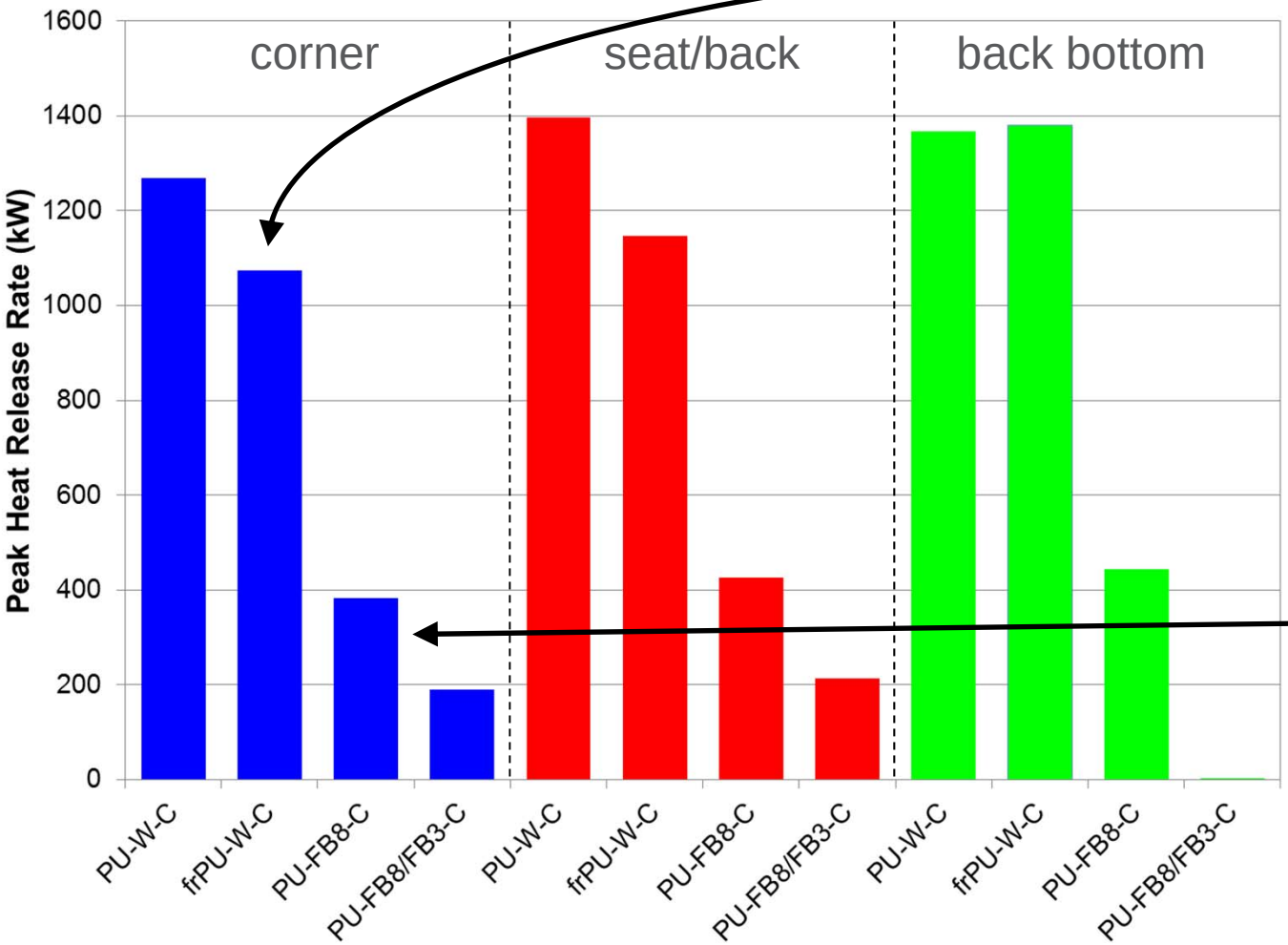
60 s

@ PHRR

+ 420 s

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

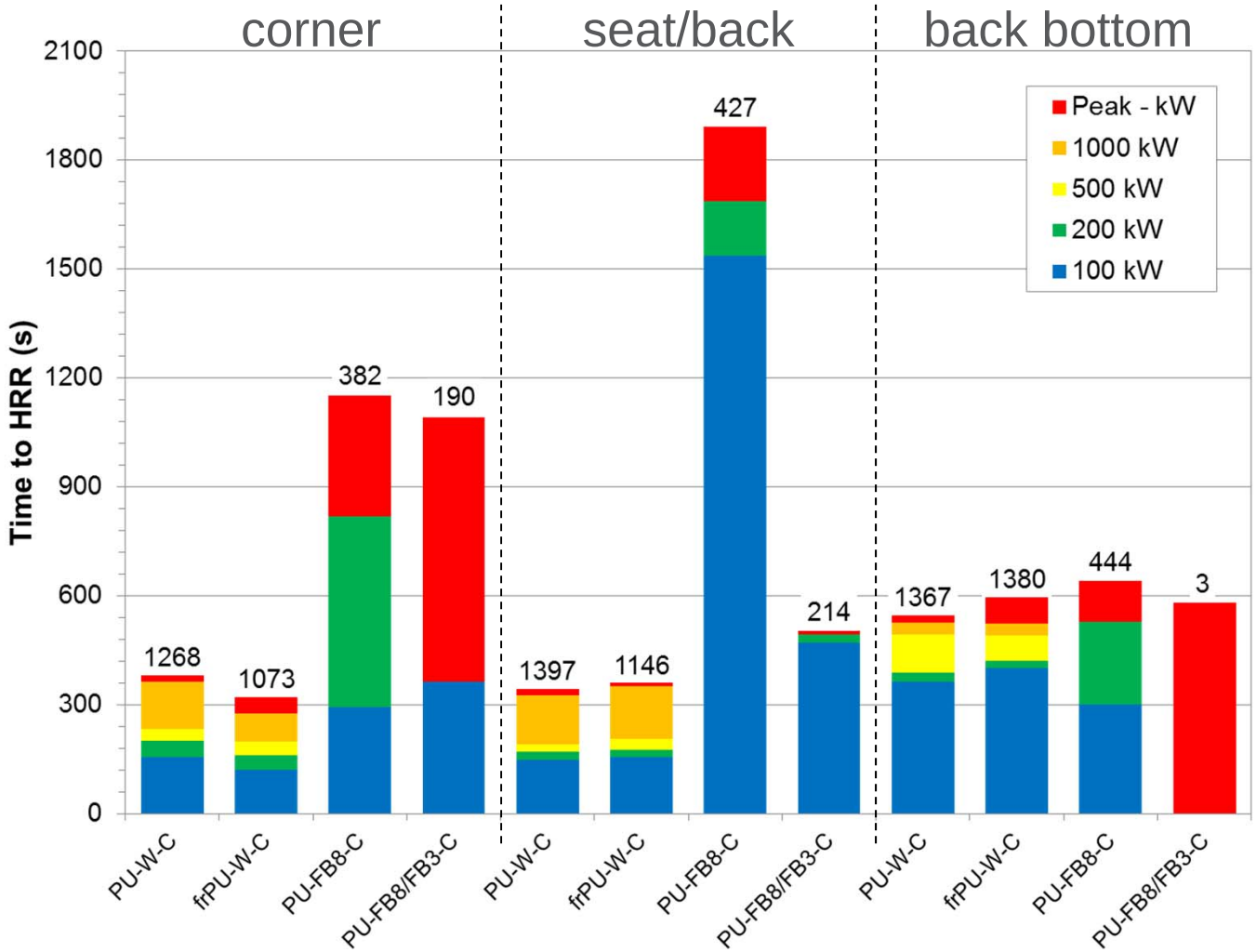
Upholstered Furniture Flammability Furniture Tests



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

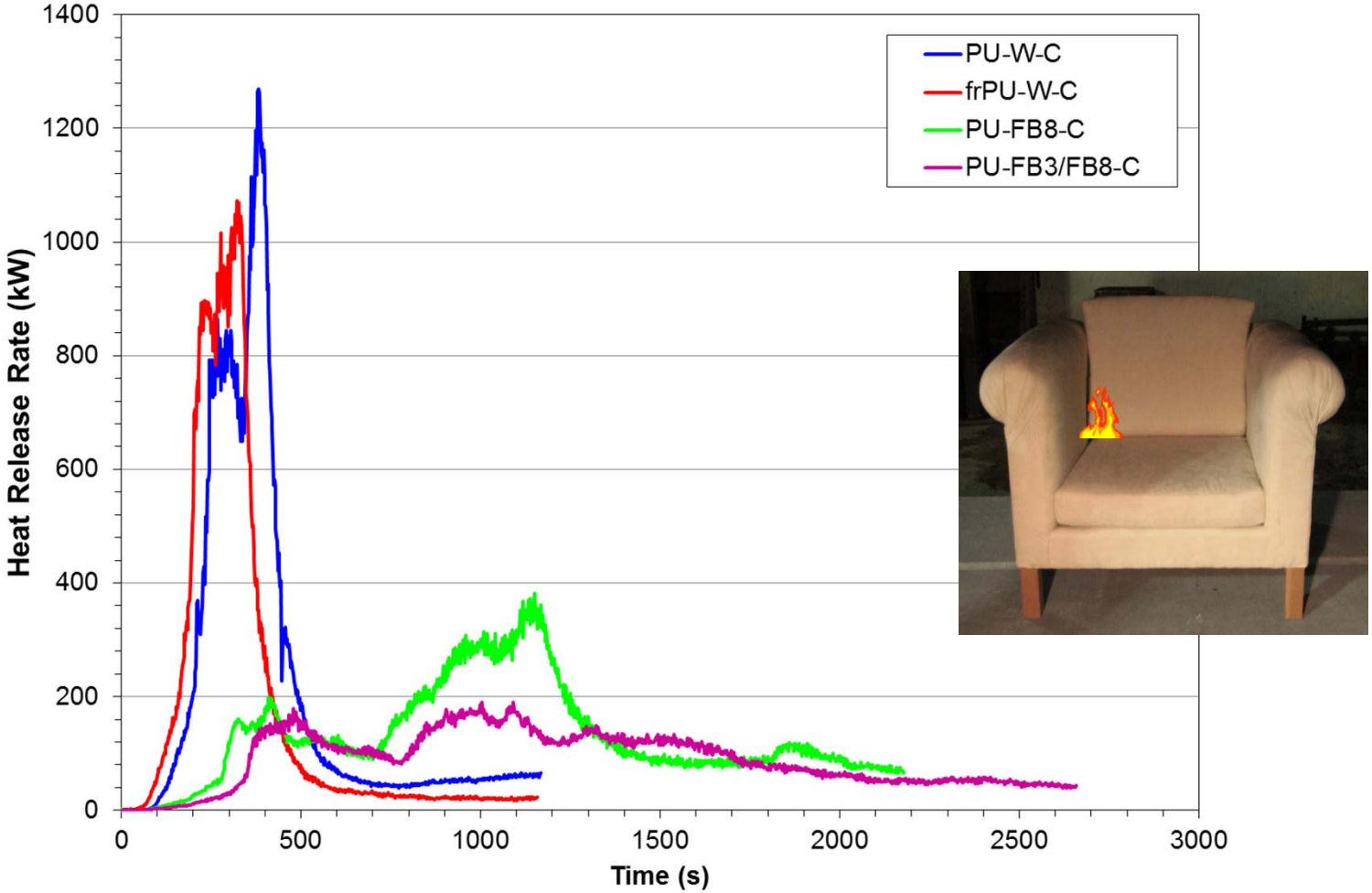
HEAT RELEASE RATE GROWTH



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

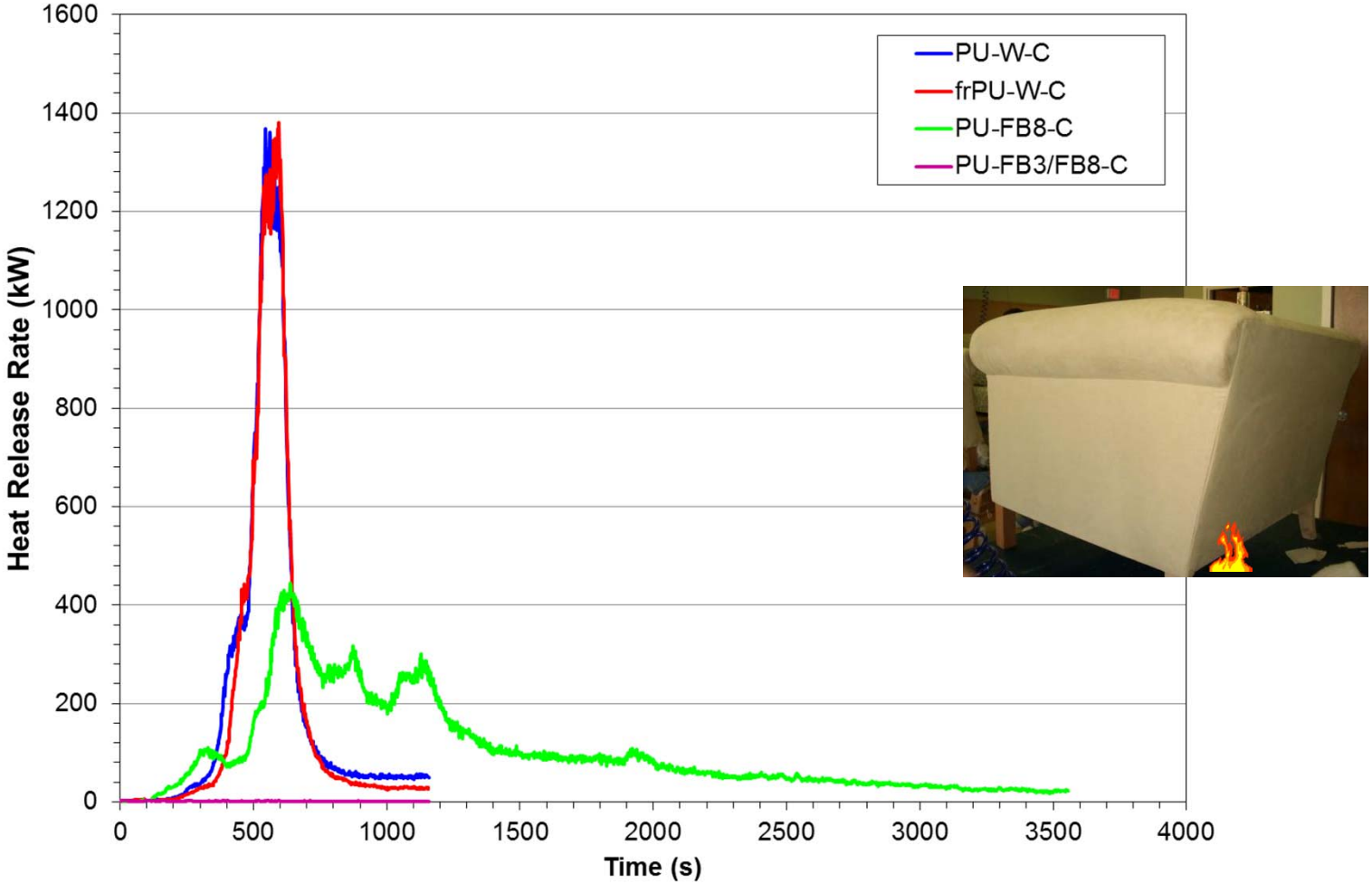
MATERIAL INFLUENCE ON INTERIOR CORNER IGNITION



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

MATERIAL INFLUENCE ON BACK BOTTOM IGNITION



Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

SUMMARY OF FINDINGS: IGNITION LOCATION

Ignition location was found to have an effect

Ignition at interior corner propagated slightly quicker but had a lower PHRR than seat/back location

Back bottom was more difficult to ignite than cushion area

- **Fire propagated slower and self-extinguished in one case**
- **When fire propagated to involve the cushions, the PHRR was greater**

Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Furniture Combustibility Experiments

SUMMARY OF FINDINGS: MATERIAL INFLUENCE

All approaches exhibited some level of reduced ignitability/flammability.

<u>Approach 1: TB 117 FR foam substitution for PU foam</u>

- **Reduced PHRR when cushions were ignited (1.3 vs. 1.1 MW)**
- **Comparable PHRR when back was ignited (1.3+ MW)**
- **Time to PHRR was comparable**

<u>Approach 2: High-loft FR barrier in place of polyester wrap</u>

- **Reduced PHRR by ~3X to 400 kW**
- **Time to PHRR was extended when cushions were ignited**

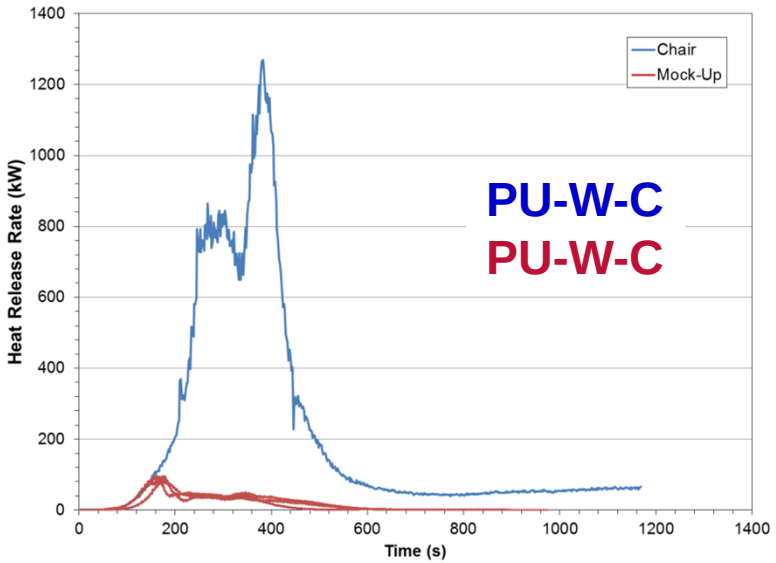
<u>Approach 3: Approach 2 + flat barrier covered sides</u>

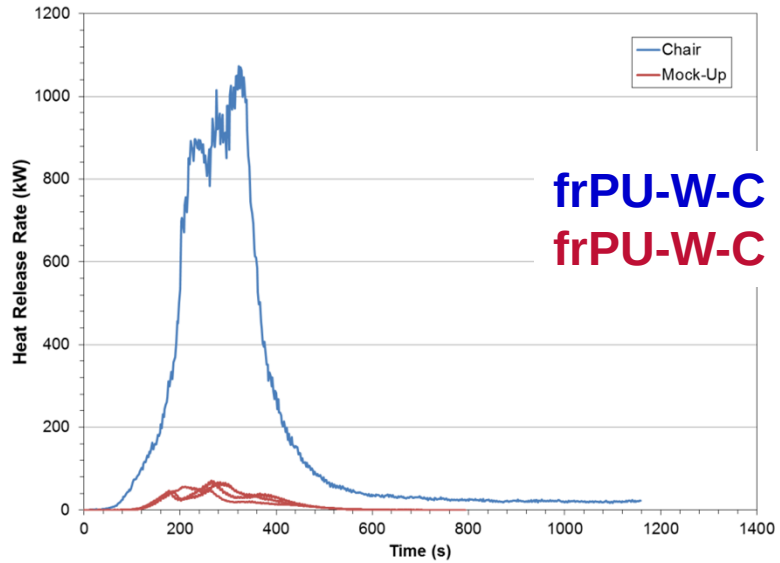
- **Further reduced PHRR by ~50 % to 200 kW**
- **Ignition of back did not propagate and self-extinguished**

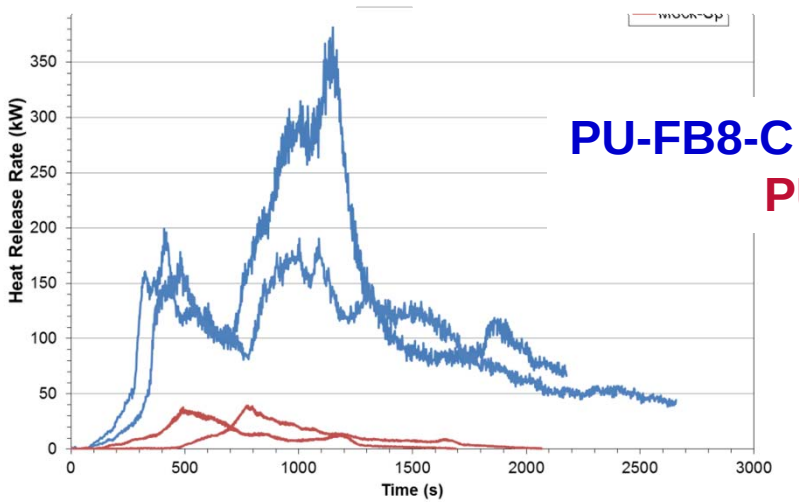
Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

Sample Scale Effects

MOCK-UP VS. FURNITURE COMBUSTIBILITY







Copyright© 2011-2013 UL LLC. All rights reserved. No portion of this material may be reprinted in any form without the express written permission of UL LLC or as otherwise provided in writing.

THANK YOU

Thomas.Fabian@ul.com

http://www.ul.com/fireresearch