HEAT RELEASE TESTING OF FABRICS: SAMPLE BACK SIDE INSULATION AND FIBER TYPE EFFECTS

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Outline

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  - Heat Release Tests
- Heat Release Testing – Sample Back Side Insulation Effects
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  - Effect of thermal insulation on heat release
- Heat Release Testing – Fiber Content Effects
  - Wool with other fibers
  - Vertical Burn Testing Results (ASTM D6413)
- Conclusions & Acknowledgements

Fabric Fire Testing

Flame Spread Tests

- Fabric flammability often measured via flame spread tests (horizontal and vertical).
- Examples include:
  - ASTM D6413 (vertical flame spread)
  - ASTM D1230 (45° flame spread)
  - NFPA 701

- Tests provide measurements on length of flame spread and potentially ability to self extinguish – not why the results were obtained or why one material may/may not be better than another.

Heat Release Tests

- Heat release testing not often used for fabrics.
  - Fabrics thermally thin.
  - Heat release typically not a required performance measurement for sale / allowed use.

- Heat release testing methods which have been used for fabrics:
  - ASTM D7309 (Micro combustion calorimeter)
  - ASTM E1354 / ISO 5660 (cone calorimeter)
  - OSU Calorimeter

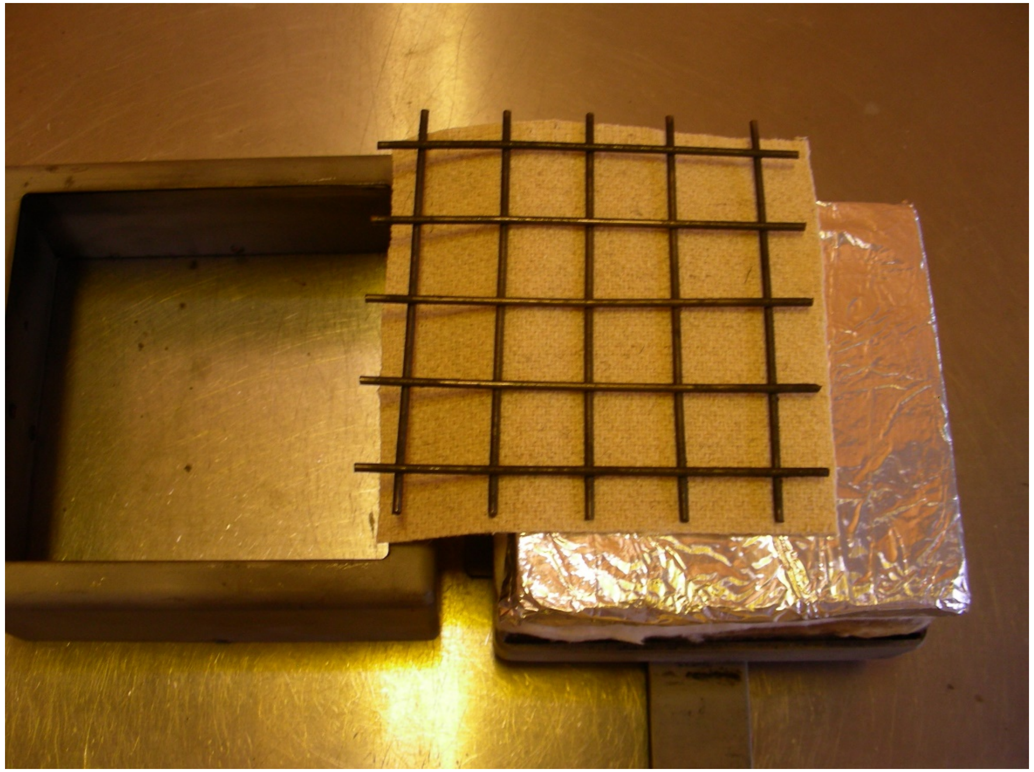
Heat Release Tests

- Heat release testing of fabrics presents some minor sampling challenges:
  - Ease of deformation of the fabric – metal frames and grids to hold fabric in place often required.
  - Thermally thin material (may flash off at high heat fluxes, giving very little information)
  - Backing material issues.
    - Standard ceramic wool can deform under frame and grid, which may cause fabric to push through gaps in metal grid.
    - Testing done with ceramic wool and ceramic brick backing to measure effect of backing on heat release.

Heat Release Testing – Sample Back Side Insulation Effects

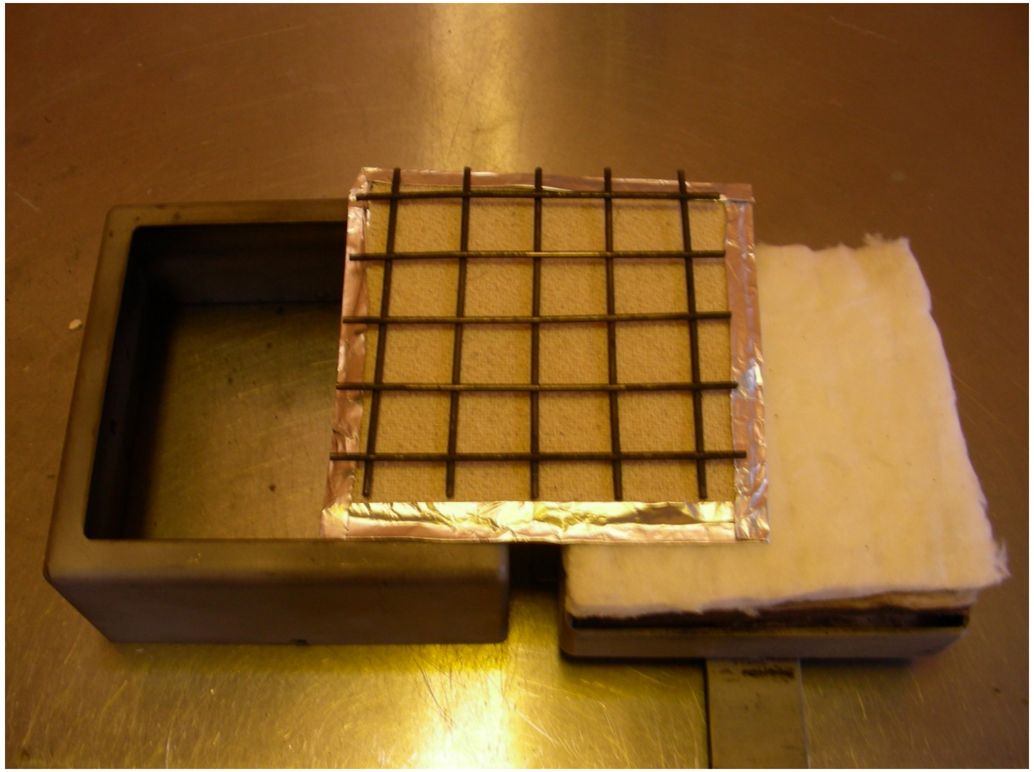
35 kW/m^2 and 50 kW/m^2 results

- All samples tested with metal frame and grid (to hold fabric in place) and with aluminum foil backing, but with different backing (ceramic brick or ceramic wool)
- Samples laid up with care to prevent fabric from bunching up/poking through metal frame and grid.



Foil wrapped brick (left)

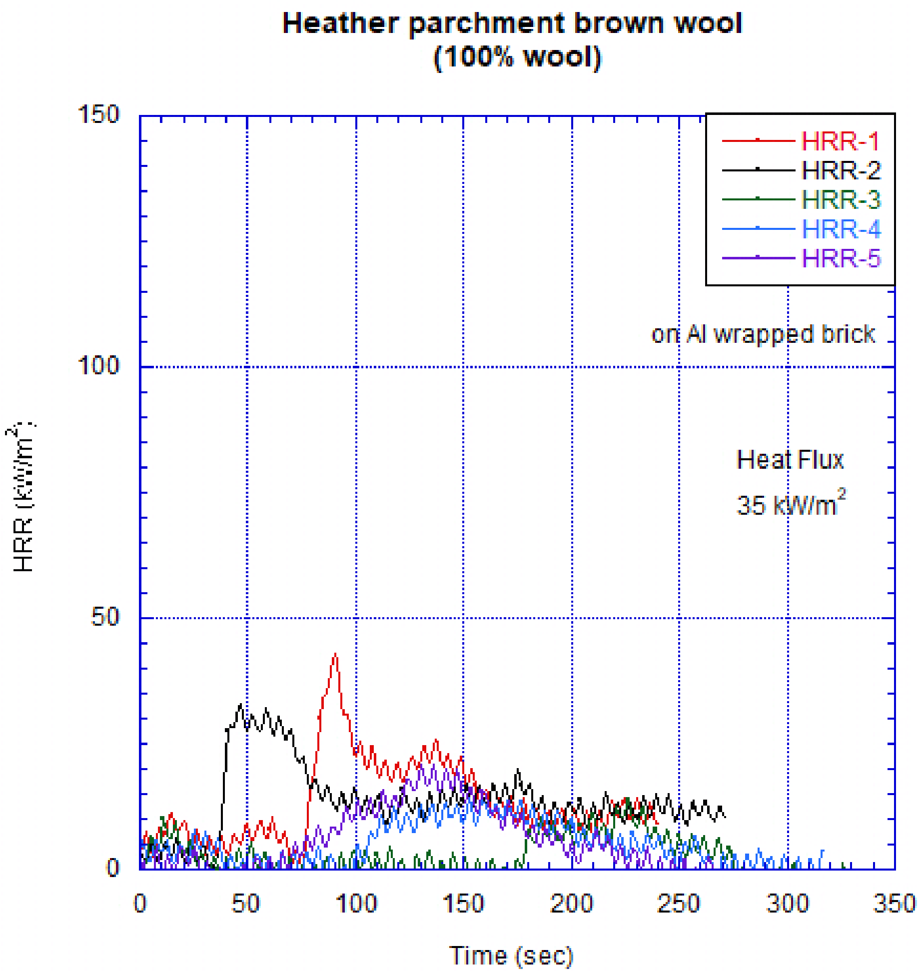
Foil wrapped fabric (right)

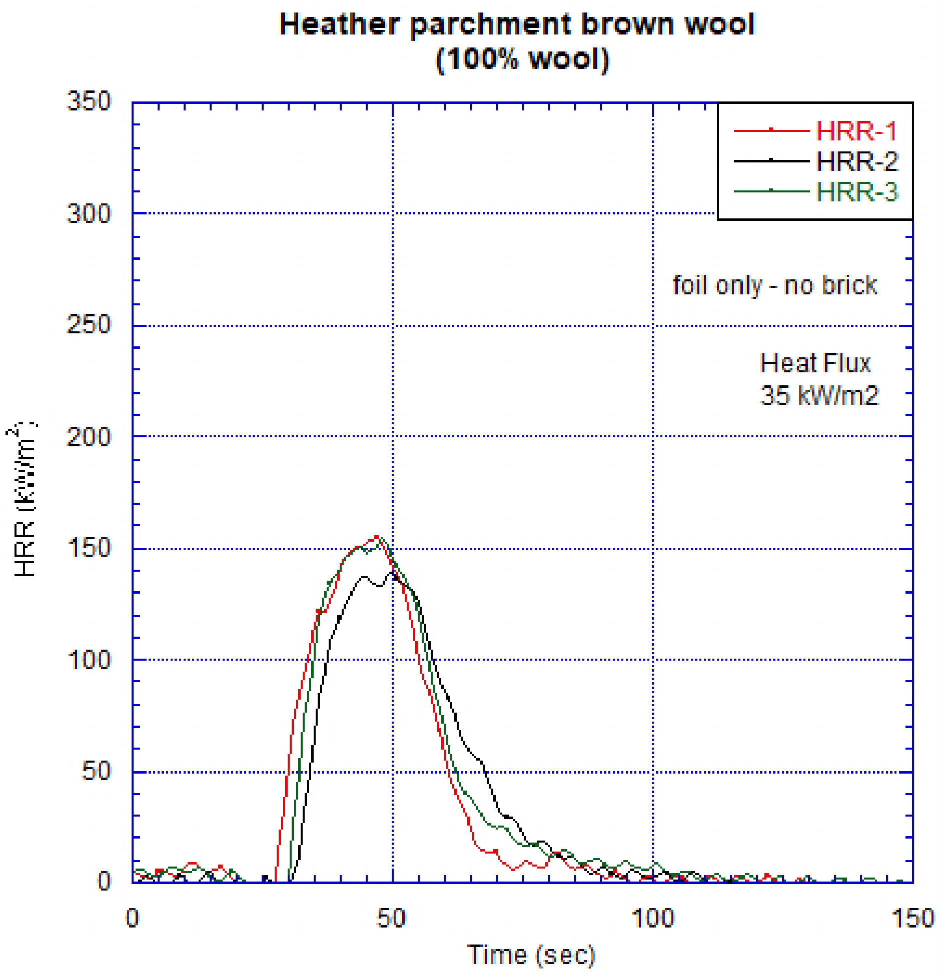


35 kW/m^2 and 50 kW/m^2 results

- Overall findings – regardless of fabric and heat flux, measured heat release higher for samples tested on ceramic wool vs. those tested on ceramic brick.
- Higher peak HRR, average HRR, total HR, MARHE values.
- Some materials did not ignite at 35 kW/m^2 heat flux.

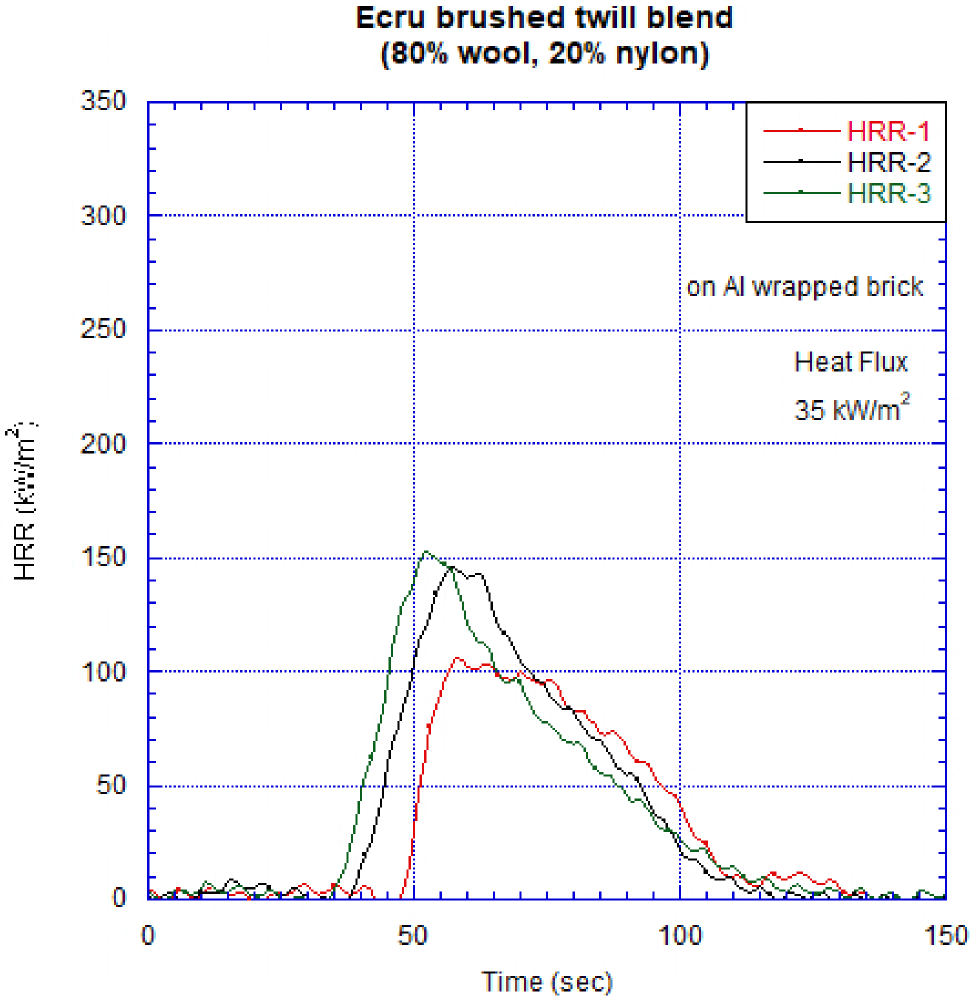
Example 35 kW/m² results

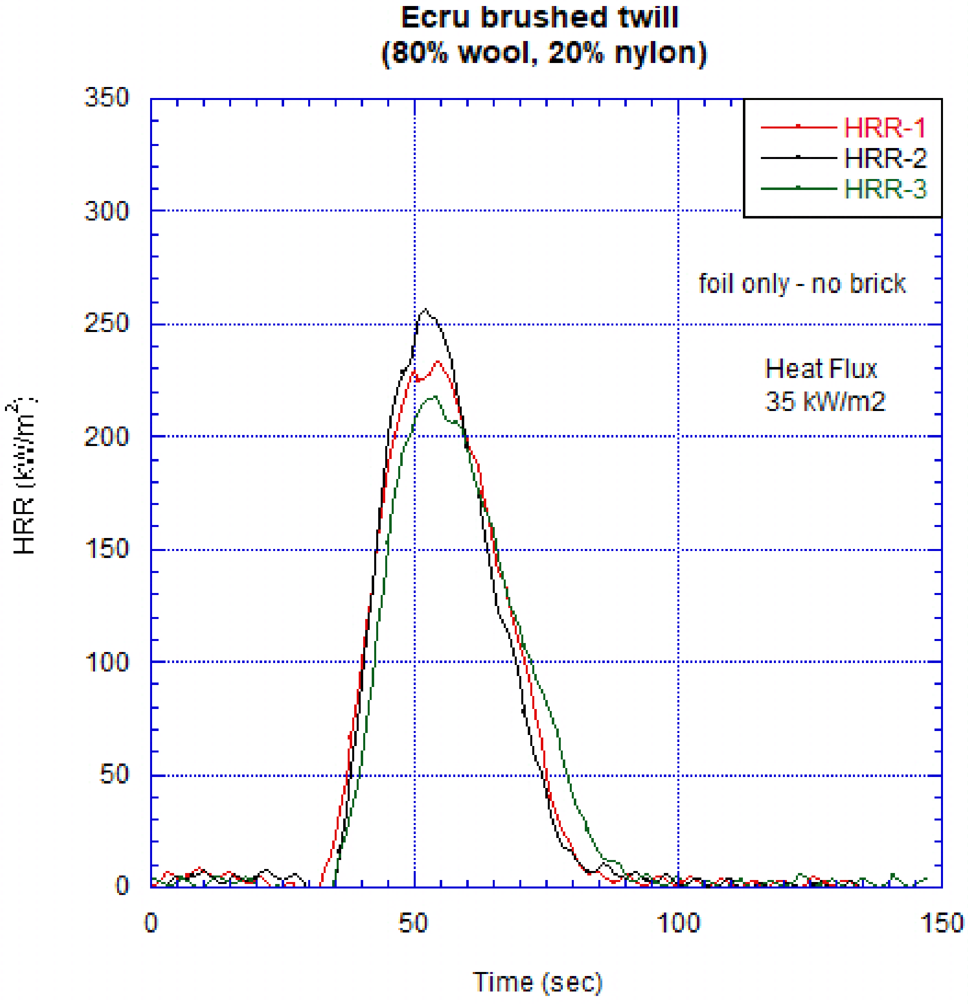




- With ceramic brick (left), and with ceramic wool (right)

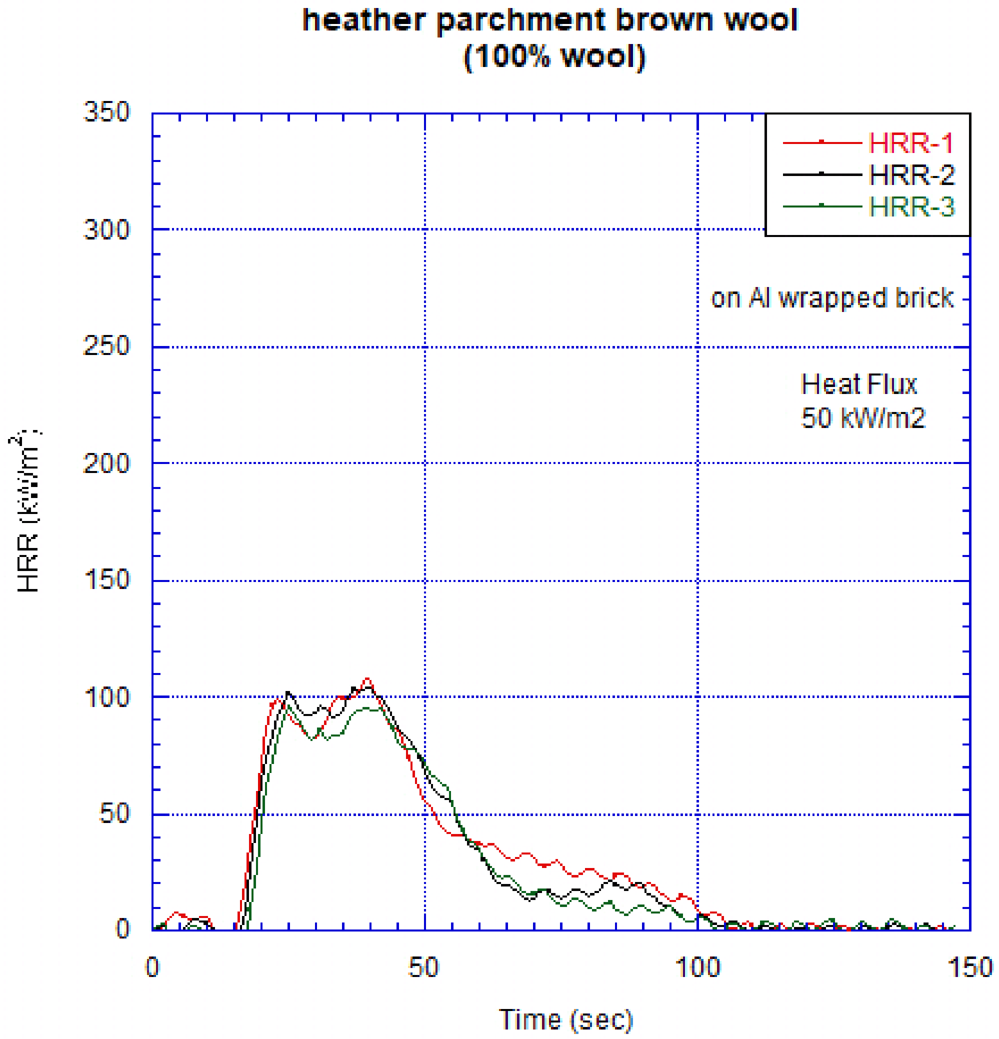
Example 35 kW/m² results

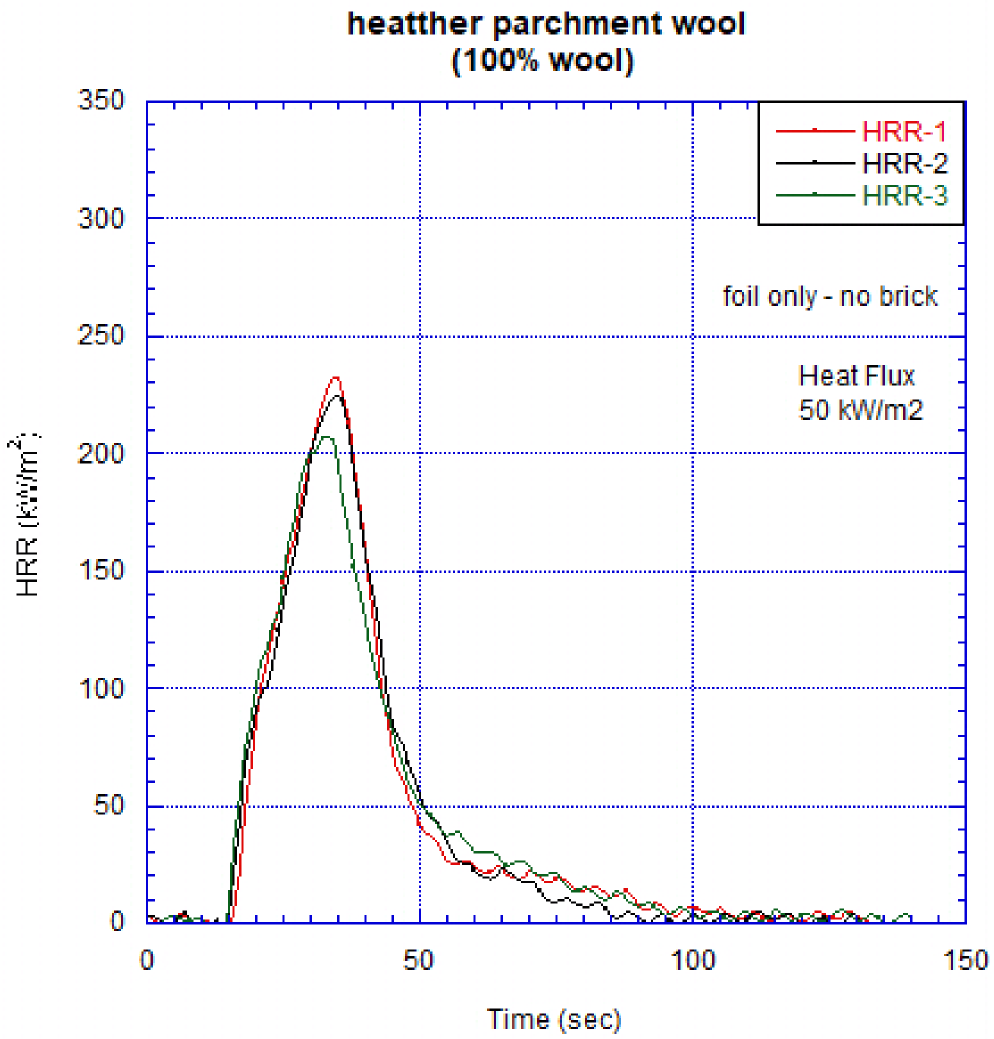




- With ceramic brick (left), and with ceramic wool (right)

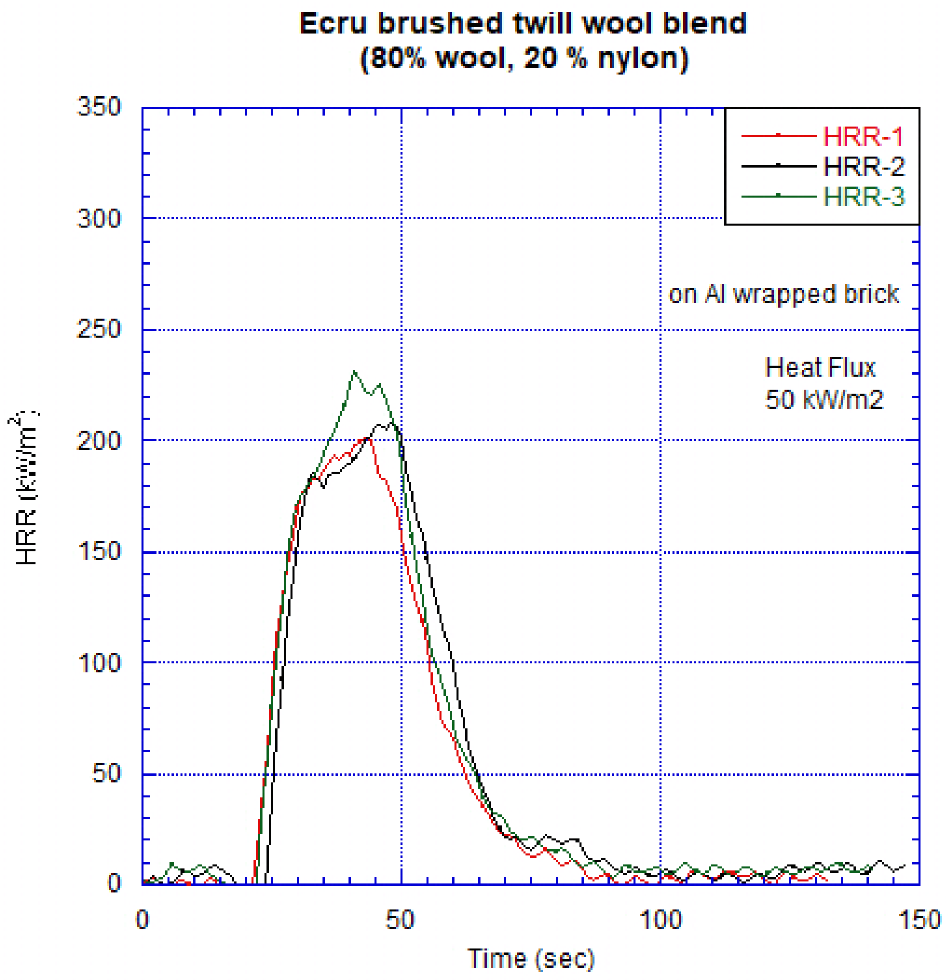
Example 50 kW/m^2 results

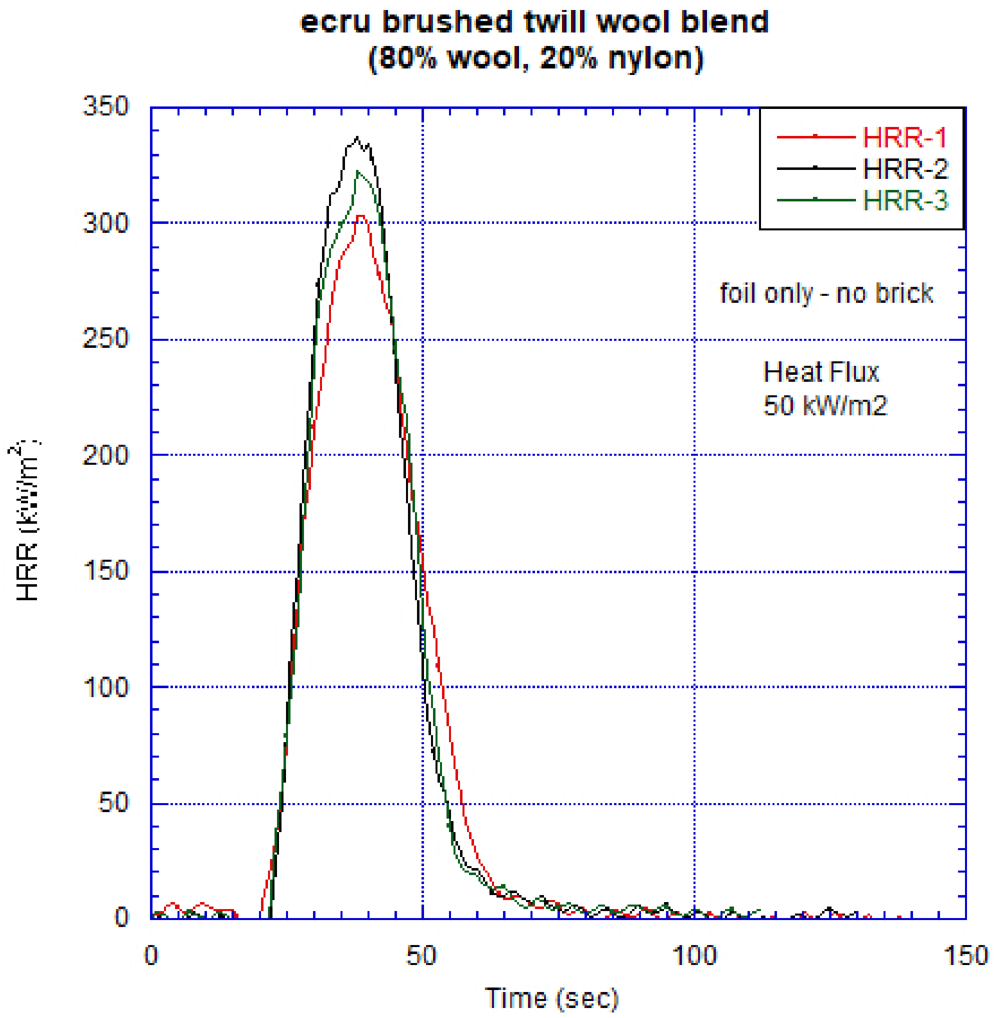




- With ceramic brick (left), and with ceramic wool (right)

Example 50 kW/m^2 results





- With ceramic brick (left), and with ceramic wool (right)

Effect of thermal insulation on heat release

- Backing material clearly affecting heat release measurements.
- Likely cause: ceramic wool stronger thermal insulator than ceramic brick.
  - Thermal brick may be dissipating some heat from the thermally thin sample, effectively lowering the heat flux the fabric is encountering during testing.
- Thermal conductivity measurements on ceramic wool vs. ceramic brick indicate that the thermal brick material (calcium silicate board) is less of a thermal insulator than ceramic wool
  - Ceramic Brick: 0.42 W/m-K
  - Ceramic Wool: 0.04 W/m-K

Heat Release Testing – Fiber Content Effects

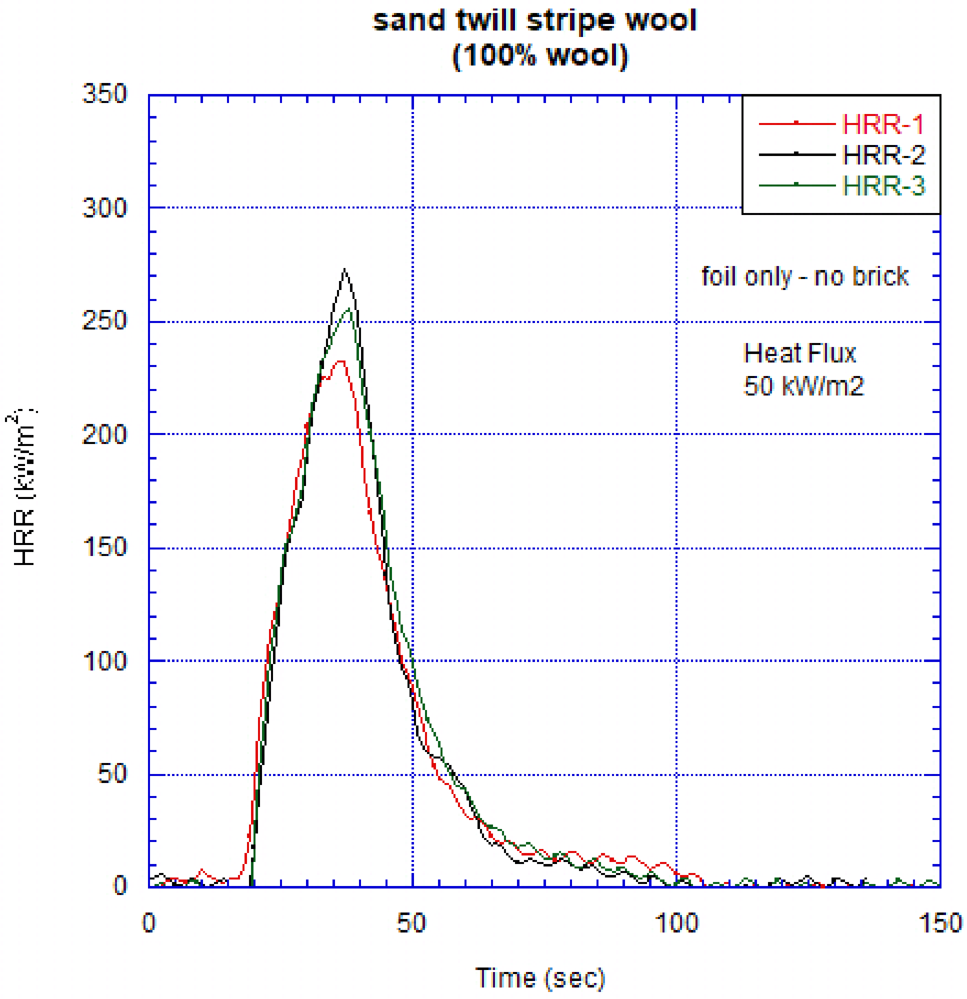
Wool with other fibers

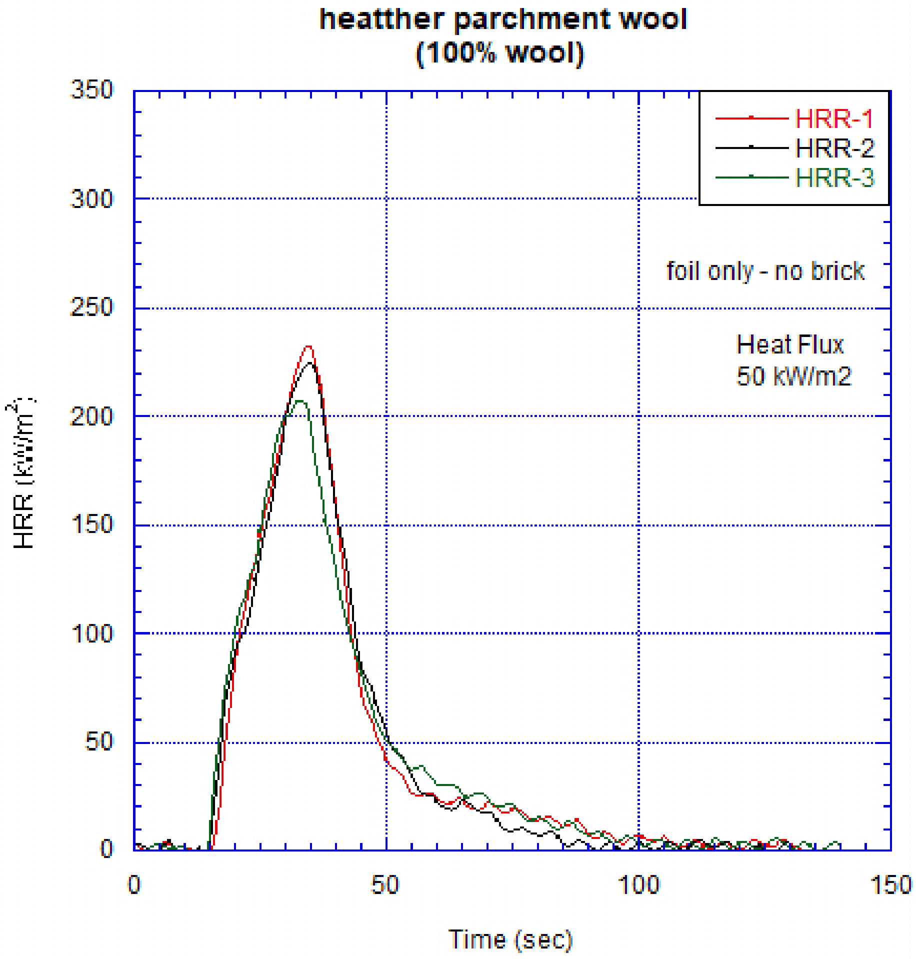
- Six total fabrics studied:
  - Two 100% Wool samples
  - 80% Wool + 20% Nylon
  - 70% Wool + 30% Linen
  - 45% Wool + 55% Cotton
  - 40% Wool + 38% Cotton + 12% Nylon
- With effects of brick and ceramic wool backing known – compared effects of fiber where just ceramic wool backing was used.
- Heat flux effects as expected (lower heat flux of testing = lower heat release)

Heat Release Summary – Fabrics @ 50 kW/m^2

Sample Description	Sample Thickness (mm)	Time to ignition (s)	Peak HRR (kW/m2)	Time to Peak HRR (s)	Average HRR (kW/m2)	Starting Mass (g)	Total Mass Loss (g)	Weight % Lost (%)	Total Heat Release (MJ/m2)	Total smoke Release (m2/m2)	Avg. Effective Heat of Comb. (MJ/kg)	MARHE (kW/m2)
100% wool	0.9	13	233	36	77	3.8	3.0	80.4	6.1	48	17.58	101
	0.9	14	273	37	95	3.7	3.0	80.4	6.0	40	17.62	104
	0.9	13	256	38	101	3.9	3.1	81.6	6.2	42	17.35	104
Average Data	0.9	13	254	37	91	3.8	3.1	80.8	6.1	43	17.52	103
100% wool	1.0	10	233	34	81	2.6	2.5	95.4	5.2	49	18.21	96
	1.0	9	225	35	91	2.7	2.5	92.5	5.1	53	18.30	96
	1.0	9	207	32	80	2.7	2.5	92.3	5.2	46	18.38	93
Average Data	1.0	9	222	34	84	2.7	2.5	93.4	5.2	49	18.30	95
80% wool	1.3	15	303	39	149	3.5	2.7	76.8	6.8	82	22.55	122
20% nylon	1.3	14	337	38	139	3.6	2.8	77.7	7.0	79	22.23	130
	1.3	15	323	38	144	3.4	2.5	72.7	6.9	80	24.18	127
Average Data	1.3	15	321	38	144	3.5	2.6	75.8	6.9	80	22.99	126
70% wool	0.3	7	137	21	41	1.5	1.3	81.7	2.3	7	15.77	59
30% linen	0.3	7	154	20	45	1.5	1.3	88.1	2.5	12	16.00	60
	0.3	8	139	22	47	1.5	1.4	88.9	2.5	13	16.02	58
Average Data	0.3	7	143	21	44	1.5	1.3	86.2	2.4	11	15.93	59
45% wool	0.6	9	166	24	70	2.3	2.2	92.7	3.6	12	14.83	76
55% cotton	0.6	8	175	24	70	2.4	2.2	93.7	3.7	9	14.71	77
	0.6	9	181	28	70	2.3	2.1	92.2	3.6	12	15.02	77
Average Data	0.6	9	174	25	70	2.3	2.2	92.9	3.6	11	14.85	76
40% wool	0.9	10	232	26	81	2.2	1.8	81.4	4.2	35	20.36	100
38% cotton	0.9	10	267	25	81	2.2	1.9	84.9	4.2	40	19.76	106
12% nylon	9.0	10	247	27	84	2.2	1.9	87.2	4.3	35	19.86	105
Average Data	3.6	10	249	26	82	2.2	1.9	84.5	4.2	37	19.99	104

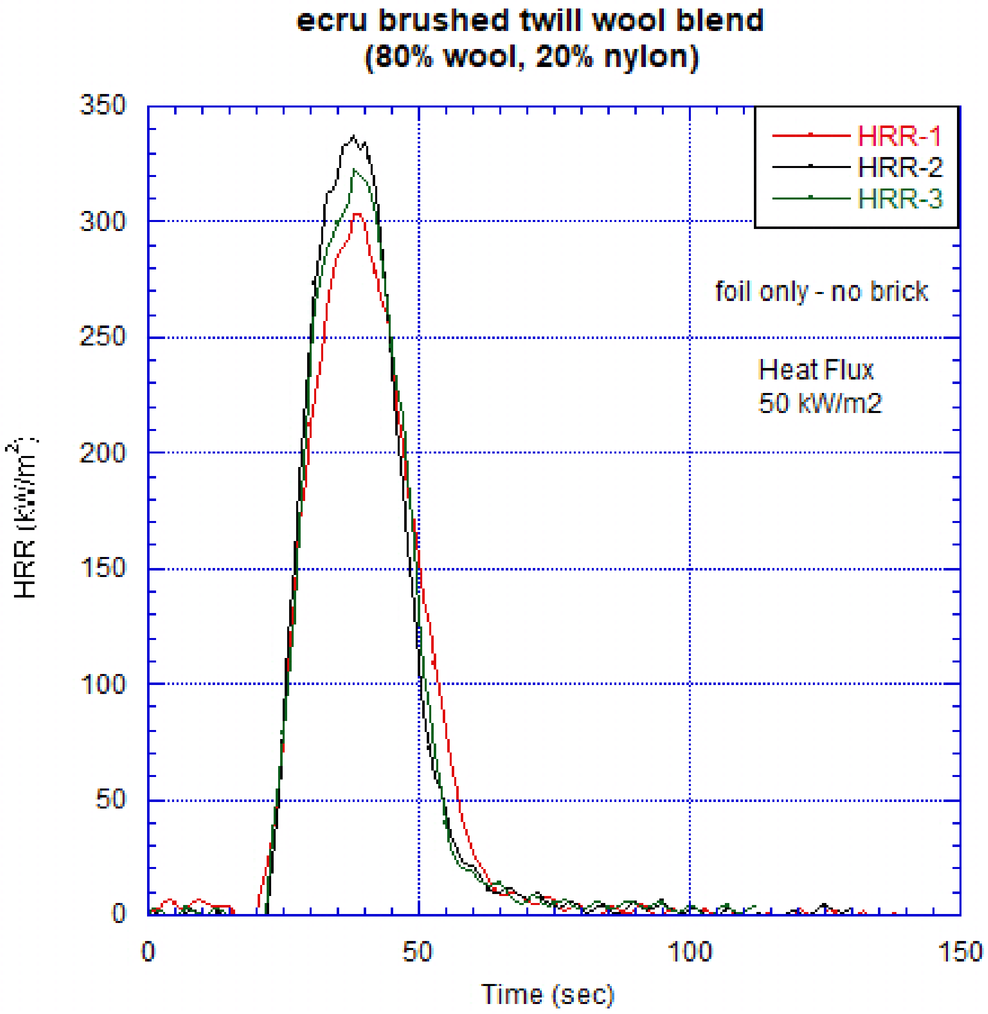
50 kW/m^2 Heat Flux Data

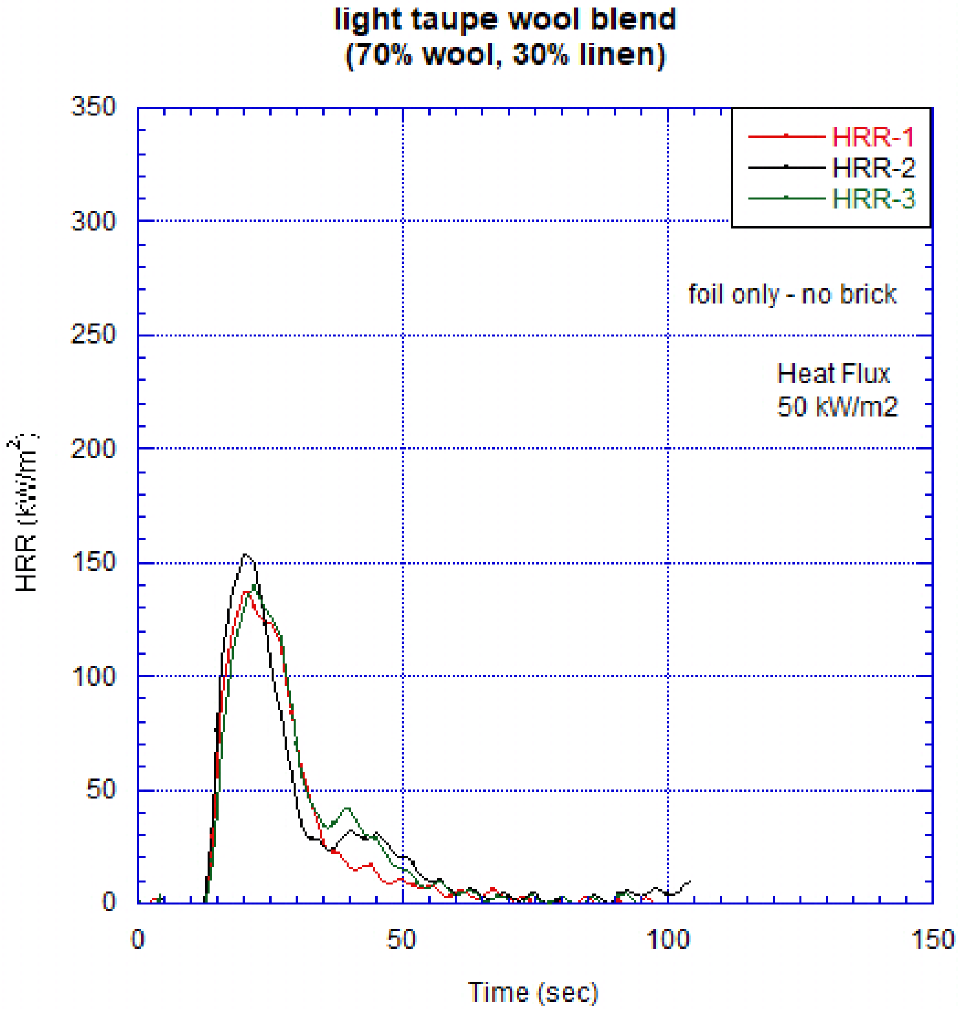




- 100% wool (sand twill stripe – left) and 100% wool (heather parchment)

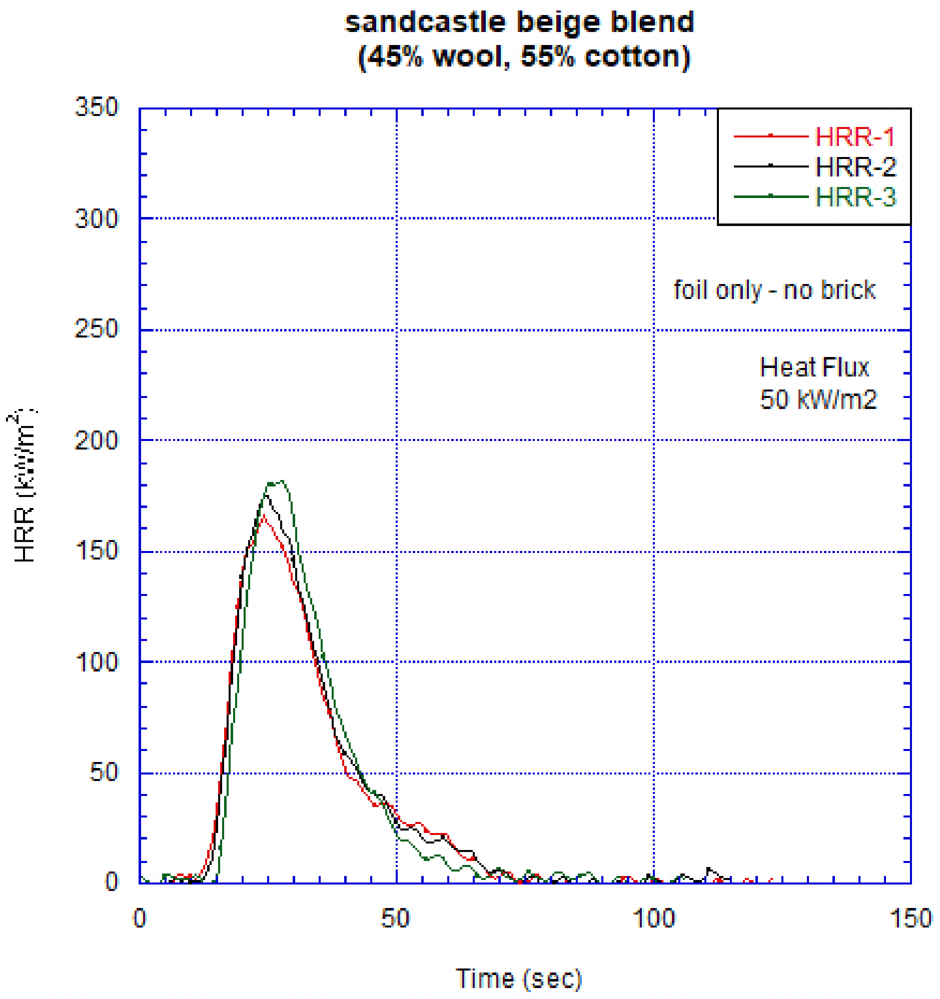
50 kW/m² Heat Flux Data

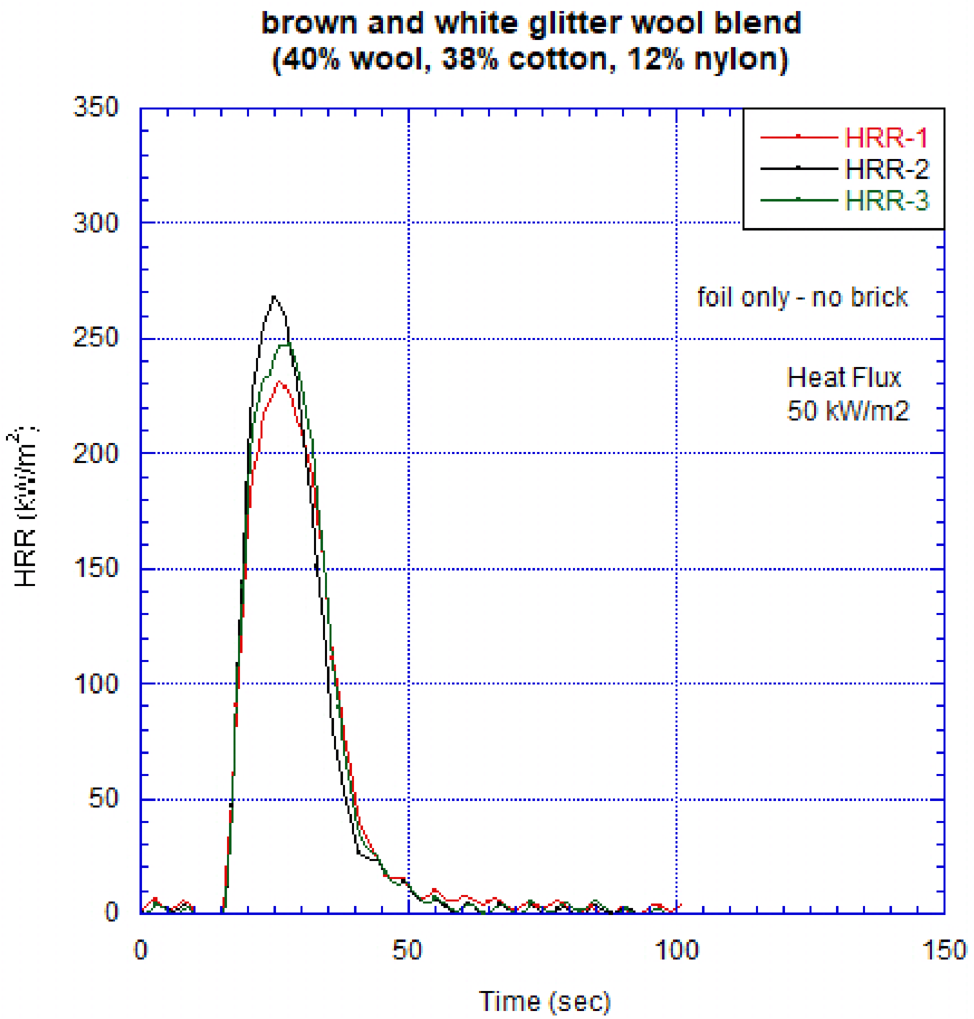




- 80% Wool, 20% nylon (left); 70% Wool, 30% linen (right)

50 kW/m² Heat Flux Data





- 45% Wool, 55% Cotton (left); 40% Wool, 38% Cotton, 12% Nylon

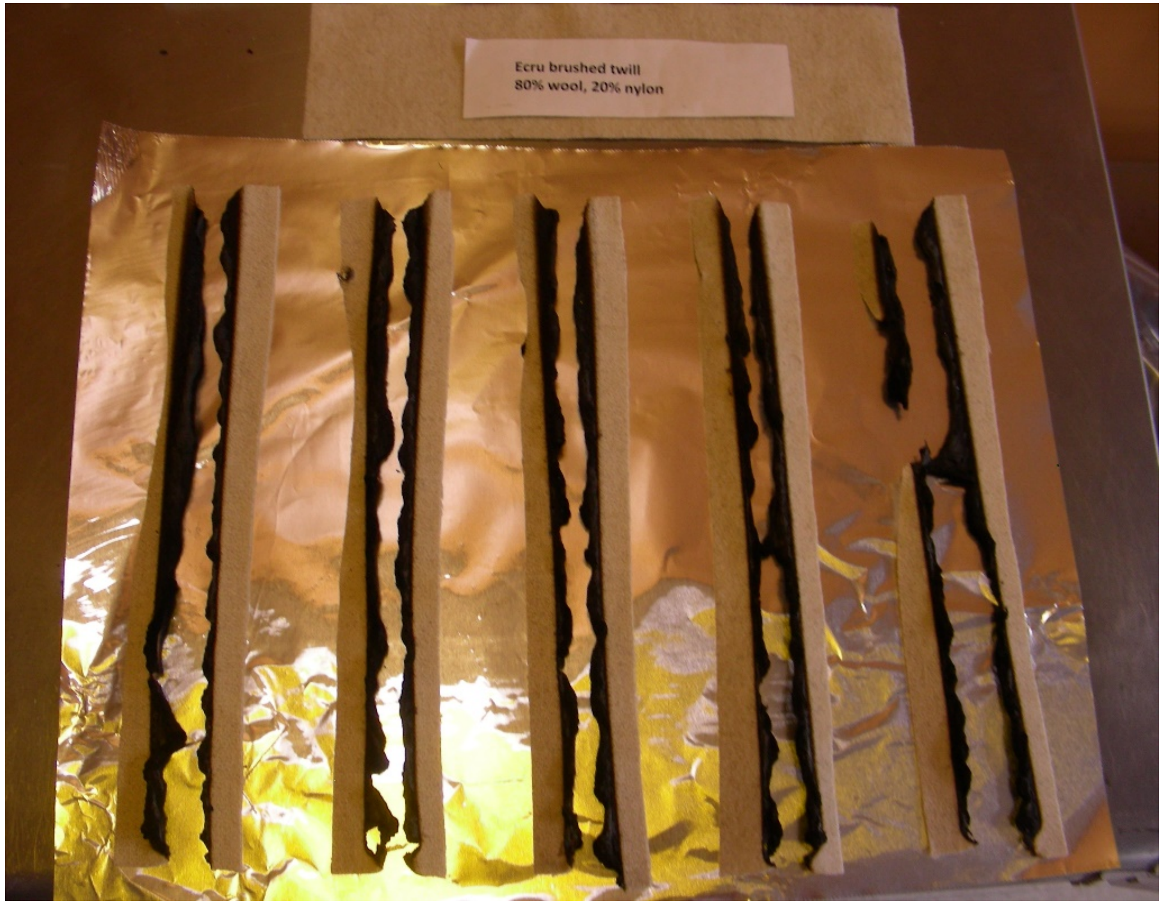
ASTM D6413 Vertical Burn Testing

- All materials burned the full length of the fabric tested, but with different burn rates and burn times.

Sample	Flame Extinguishing Time (sec)	Time to 1st Drip (sec)	Burn Rate (in/sec)	Afterglow Time (sec)
Sand Twill Wool (100% Wool)	53	43, 56, 36, none, none	0.23	None
Heather Parchment (100% Wool)	43	None	0.29	None
Ecru Brushed Twill (80% Wool, 20% Nylon)	44	None	0.28	None
Light Taupe Blend (70% Wool, 30% Linen)	13	None	0.96	12, 11, 6, 14, 15
Sandcastle beige blend (45% Wool, 55% Cotton)	27	None	0.45	2, 4, none, 2, none
Brown and white glitter stripe (40% Wool, 38% Cotton, 12% Nylon)	22	None	0.55	none, 2, 2, none, none

Vertical Burn Results - Wool

- Burn rates fairly similar and wool melted back as expected.
- Similar behavior seen with Nylon and Wool



100% Wool (left), 80% Wool, 20% Nylon (right)

Vertical Burn Results – Wool & Cellulosic

- Burn rates different with linen and cotton
- Cotton remained behind – ladder structure – probably effect of weaving process

45% Wool / 55% Cotton (left), 70% Wool, 30% Linen (right)

Conclusions

Sample Backing Effects

- While ceramic brick provides a good flat surface for testing fabrics, it may be underreporting heat release due to differences in thermal conductivity vs. the standard ceramic wool.
- Assuming the fabric can be kept from deforming, testing with ceramic wool would be preferred.
  - Note – what the fabric is actually bonded to in the real world would be a better indicator of its contribution to heat release.
- The modified cone calorimeter test (ASTM E1740) effectively measures thin films (soundproofing carpet, wallpaper) when adhered/bound to another substrate, much as was done in this experiment with the ceramic brick. One should assume the backing material is just as important to flammability performance and consistency of backing material is critical to heat release comparisons in ASTM E1354, ASTM E1354, and other heat release tests.

Fiber Effects on Wool Heat Release

- While commercial fabrics are highly variable in composition:
  - 100% wool fabrics from two different vendors pretty close to one another in heat release.
  - Adding nylon to wool causes heat release to increase.
  - Adding cotton or linen to wool causes heat release to decrease.
  - Cellulosic + wool fiber flammability may merit further studies to further reduce heat release for other fire risk scenarios (vehicle seating, blast, etc.)
  - Cellulosic fibers with wool increase burning rate, but decrease burning time.

Acknowledgements

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Questions?