ASSESSMENT OF FIRE PERFORMANCE OF ELVEN FLAMEPROOF COMPOSITE

Report: Elven-20230413

Prepared for

Elven Technologies
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OBJECTIVE OF THE WORK

The objective of the project was to evaluate the fire performance of a flameproof composite provided by the customer in a standard lab environment.

PROCEDURES

Standard Test Methods:

ASTM E1354-17 Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products using An Oxygen Consumption Calorimeter.

ASTM E1354-17 Annex A3: Critical Heat Flux Determination using The Oxygen Consumption Cone Calorimeter

ANSI/FM 4910 Section 5 Procedures to Calculate Flammability Data (Optional calculation only)

Sample Assessed:
Material 1: FLAMEPROOF COMPOSITE

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SUMMARY OF RESULTS

Standard ASTM E1354 cone calorimeter tests were conducted for the composite at external heat flux level of 50kW/m^2 to determine the Peak Heat Release Rate (HRR_{peak}) and Average Specific Extinction Area (SEA_{avg}). Procedure described in ASTM E1354 Annex A3 was used to determine the Critical Heat Flux (CHF) of the materials. Additionally, several fire performance parameters were calculated according to ANSI/FM 4910 section 5, including Thermal Response Parameters (TRP) and Fire Propagation Index (FPI). A summary of results is presented in the following Table A.

Table A. Summary of test results

Materials	**CHF** (kW/m^2)	**TRP*** ($kW\text{-}s^{1/2}/m^2$)	**FPI*** ($[m/s^{1/2}]/[kW/m]^{2/3}$)	**HRR_{peak}** (kW/m^2)	**SEA_{avg}** (m^2/kg)
FLAMEPROOF COMPOSITE	20	172	7.89	209	1041

*Note: The ASTM E1354 cone calorimeter test is substantially different from ANSI/FM 4910 fire propagation test described in section 3 in terms of test apparatus, sample dimension, mounting method, and air mixture oxygen concentration. Hence, the calculated parameters in this report should not be treated as comparable to those generated from fire propagation test.

Test methods

This report describes the results of fire performance evaluation of a FLAMEPROOF COMPOSITE provided by client <Elven Technologies> according to ASTM E1354-17 and its Annex A3. Several fire performance parameters were calculated based on ASTM E1354-17 test results and according to ANSI/FM 4910 section 5 calculation equations. The results presented in this report should only be used to describe and assess the fire performance of the specific tested material in response to external heat fluxes under controlled laboratory conditions. The results presented in this report should not be used to describe or assess the fire performance of the lots of same or similar production of the material, nor of other lab or actual fire conditions. All tests were conducted between April 3rd and 10th, 2023 at Laboratories for functional textiles and protective clothing located at Iowa State University, Ames, Iowa.

Tested materials

One type of sample material was received in ready-to-test condition. The samples were conditioned in standard environmental condition (21±1°C, 65±2% RH) for at least 24 hours before testing. Samples were tested within 20 min after taking out from the environmental chamber. Table B summarizes sample material physical properties.

Table B. Summary of sample material physical properties

Materials	**Composition**	**Nominal dimensions** (mm)	**Color**
FLAMEPROOF COMPOSITE	Unknown	100.7 x 100.4 x 5.11	Black

Test setups

- External radiant heat flux: set at 50kW/m^2 for cone calorimeter test; set at 10-30 kW/m^2 for critical heat flux test
- Sample preparation: samples were wrapped of their sides and back with a single layer of heavy-duty aluminum foil to assure face burning only
- Sample mounting: samples were mounted horizontally, with a sample retainer frame but without a wire grid to restrain deformation
- Default exposure time: 20 min if no ignition occurs; flame out time plus 2 min if ignition occurs

Test procedures

For the composite, pilot run was done at 50kW/m^2 heat flux for observation of the history of sample deformation, if happened. Because the composite did not experience deformation (i.e., intumescent), only the retainer frame was used for sample mounting. Then, cone calorimeter tests on the composite were conducted 3 times at 50kW/m^2 external heat flux. The ignition time for these three runs were used as inputs for critical heat flux determination.

Critical heat flux tests were conducted at heat flux starting at 30kW/m^2. The default exposure time was 20 min or until ignition happened. If sample ignited within 20 min, heat flux was decreased and test repeated. If sample did not ignite, the heat flux was increased and test repeated. The heat flux adjustment interval starts at 10kW/m^2, then decreased to 5kW/m^2 and 2kW/m^2. The critical heat flux determined in the test is within ±1kW/m^2, if not specified.

Test results

Detailed cone calorimeter test results and figures are located in Appendix A, detailed critical heat flux test results are located in Appendix B, and sample pictures before and after tests are presented in Appendix C.

Appendix A. Detailed cone calorimeter test results

Client:	Elven Technologies	*Material ID:*	Flameproof composite
Mounting orientation:	Horizontal	*Heat flux:*	50 kW/m^2
Frame retainer:	Yes	*Duct flow:*	24 l/s
Wire grid:	No	*Sample area:*	0.00884 m^2
Spark igniter:	Yes	*Distance to cone:*	25 mm

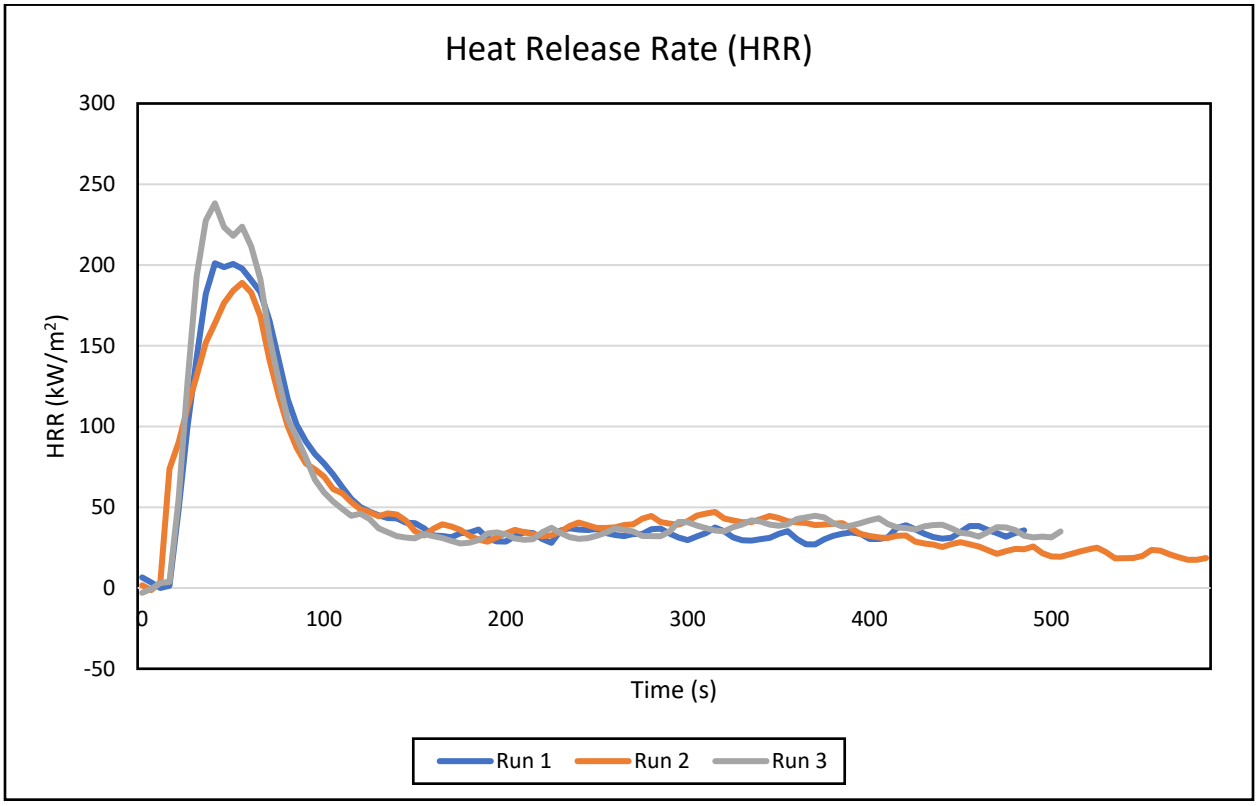
Test ID	t_{ig} (s)	Test duration (s)	C-factor (SI Units)	HRR_{peak} (kW/m^2)	THR (MJ/m^2)	HRR_{60s} (kW/m^2)	HRR_{180s} (kW/m^2)	HRR_{300s} (kW/m^2)
Run 1	18	485	0.0434	201.1	14.5	165.6	89.1	66.9
Run 2	15	585	0.0434	189.0	14.1	149.0	84.0	65.8
Run 3	18	505	0.0434	238.2	15.1	184.9	90.8	68.2
Average	17	525	0.0434	209.4	14.6	166.5	88.0	67.0

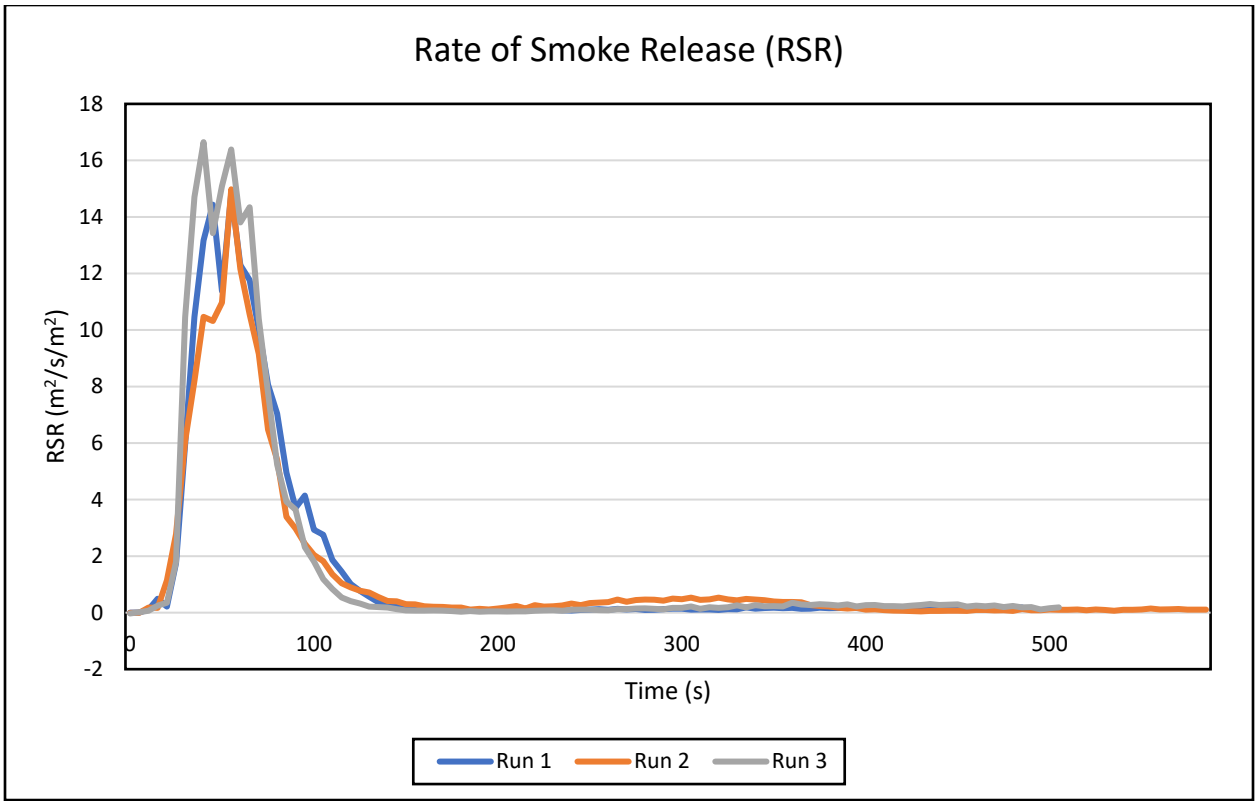
Initial mass (g)	Mass at ignition (g)	Final mass (g)	Mass loss (g)	MLR (g/m^2-s)	10-90 MLR (g/m^2-s)	EHC (MJ/kg)	S_A (m^2/m^2)	SEA (m^2/kg)
35.6	35.6	26.2	9.4	2.2	1.6	20.2	734.7	1032.5
37.4	36.8	27.5	9.9	1.9	1.3	23.0	642.3	1058.5
32.2	31.4	21.8	10.4	2.3	1.8	19.7	781.8	1031.0
35.1	34.6	25.2	9.9	2.1	1.6	21.0	719.6	1040.7

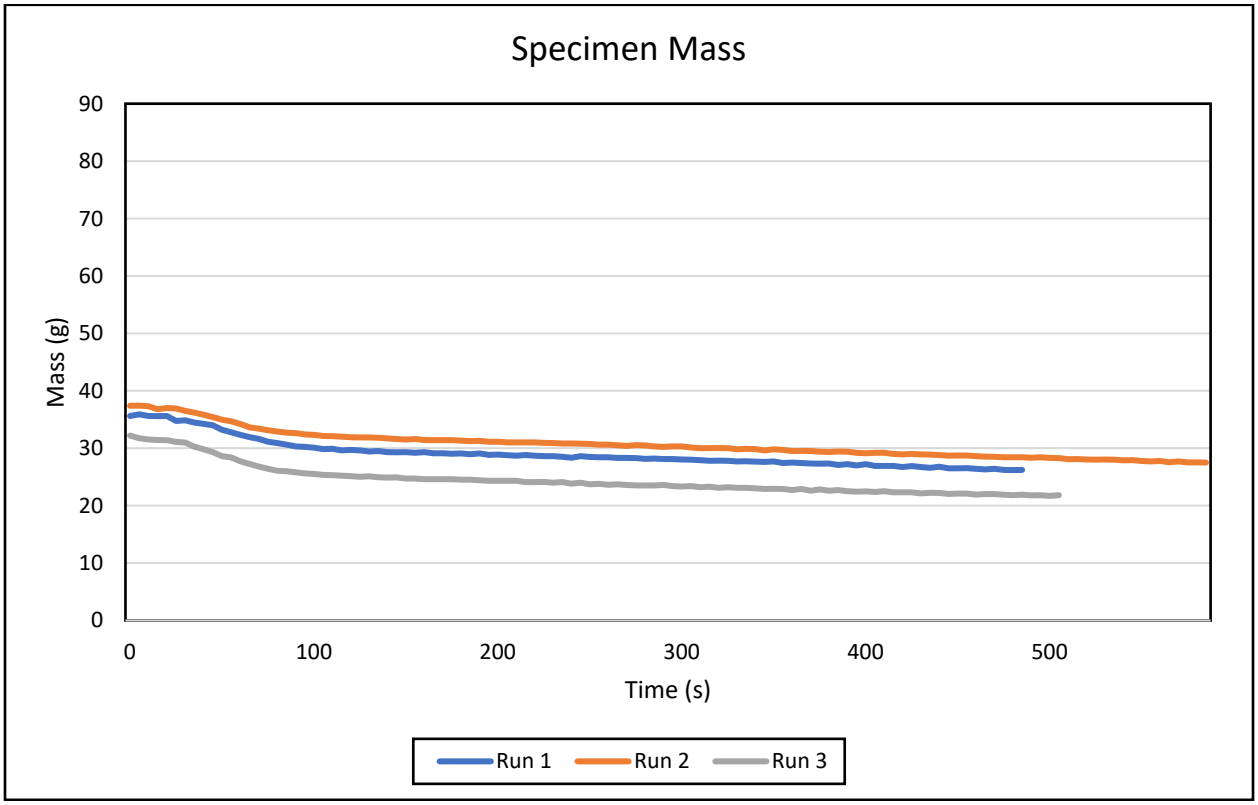
Parameters:

- t_{ig} — Time to ignition for sustained flaming (i.e., flame over specimen surface for at least 4s)
- Test duration — Total test duration (time from the start of test until any signs of combustion cease: 2 min after flame out; mass loss over 1 min period has dropped below 150g/m^2, or until 60 min have elapsed)
- C-Factor — Calibration constant for oxygen consumption analysis (range 0.040-0.046 m$^{1/2}$-kg$^{1/2}$-$K^{1/2}$)
- HRR_{peak} — Peak value of the heat release rate per unit sample area (kW/m^2)
- THR — Total amount of heat released per unit sample area (MJ/m^2)
- HRR_{60s} — Average heat release rate over the first 60s (1 min) after ignition
- HRR_{180s} — Average heat release rate over the first 180s (3 min) after ignition
- HRR_{300s} — Average heat release rate over the first 300s (5 min) after ignition
- Initial mass — Initial mass of the specimen prior to testing (g)
- Mass at ignition — Mass of the specimen at the time of ignition (g)
- Final mass — Mass of the specimen at the end of the test (g)
- Mass loss — Mass loss of the specimen over entire test (g)
- MLR — Average mass loss rate of the specimen per unit area over the test duration (g/m^2-s)
- 10-90 MLR — Average mass loss rate of the specimen per unit area starting 10% mass loss occurred and ending when 90% mass loss occurred (or the end of test if mass loss did not reach 90%)
- EHC — Average effective heat of combustion (ratio of heat release rate to mass loss rate) over the test duration (MJ/kg)
- S_A — Smoke production per unit sample area during the test duration (m^2/m^2)
- SEA — Average specific smoke extinction area (ratio of smoke production to specimen mass loss) over the test duration (m^2/kg)

Figures:


Heat Release Rate (HRR)
300
250
200
150
100
50
0
-50
HRR (kW/m²)
0
100
200
300
400
500
Time (s)
Run 1
Run 2
Run 3


Rate of Smoke Release (RSR)
RSR (m²/s/m²)
18
16
14
12
10
8
6
4
2
0
-2
0
100
200
300
400
500
Time (s)
Run 1
Run 2
Run 3


Specimen Mass
Mass (g)
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
Time (s)
Run 1
Run 2
Run 3

Appendix B. Critical heat flux test results

Table C. Exposed heat flux rates and relative time to ignition

Heat flux	Flameproof composite	
	t_{ig}	$t_{ig}^{-1/2}$
10	NI	
15	NI	
18	NI	
20	178	0.074953169
30	73	0.117041147
50	18	0.23570226
50	15	0.25819889
50	18	0.23570226

Note: NI-Not ignited

Figures below show the inverse square root of the ignition time plotted against the exposed heat flux and the inverse of the slope of the best fit line through the data is the TRP, per ANSI/FM 4910.

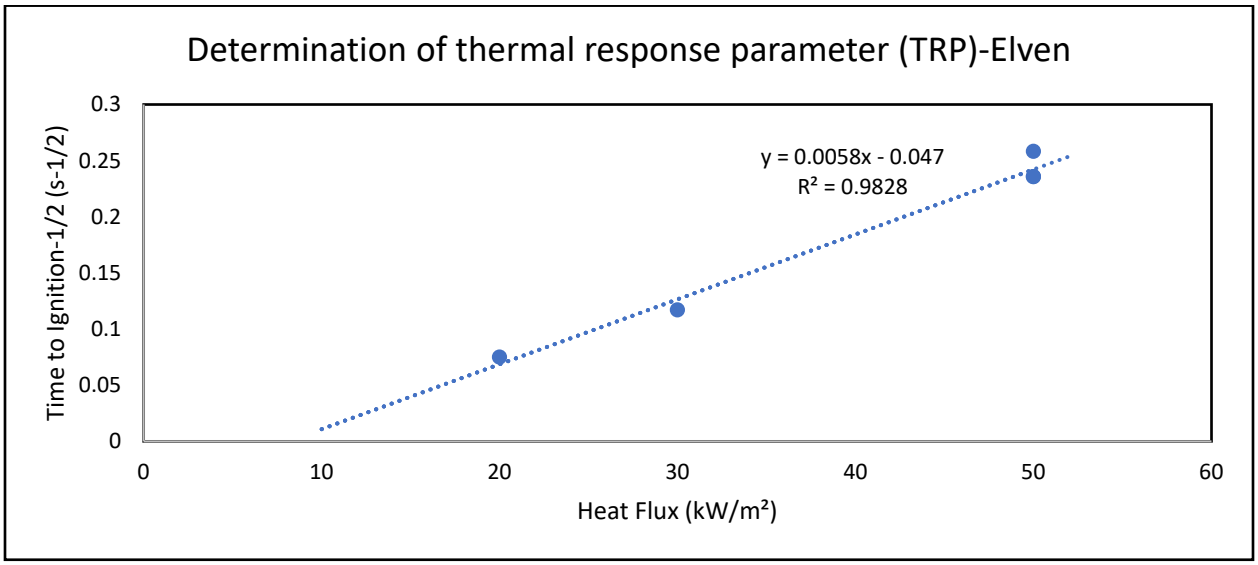


Table D. Calculated results

Materials	CHF (kW/m^2)	TRP* ($kW\text{-}s^{1/2}/m^2$)	FPI* ($[m/s^{1/2}]/[kW/m]^{2/3}$)
Flameproof composite	20	172	7.89

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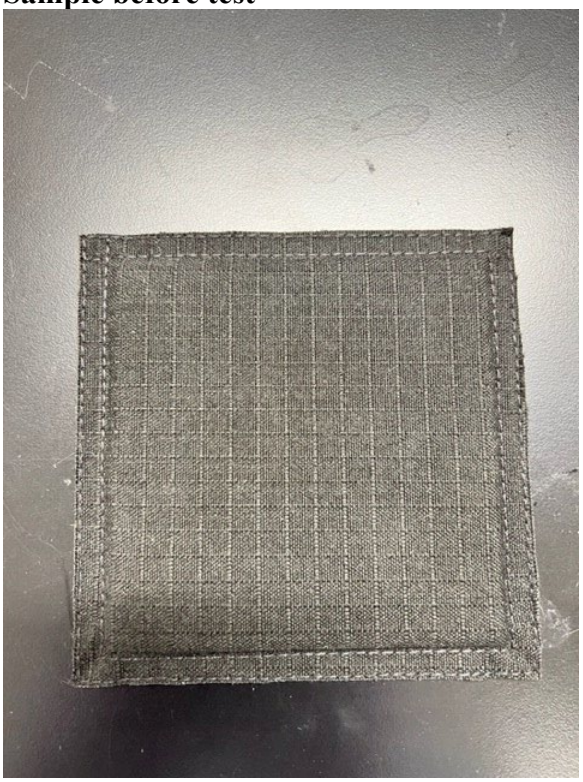
Appendix C. Sample before and after exposure

Sample before test



Sample after 50kW/m^2 exposure

Sample cleaned after exposure