



Flame Spread Experiments and Next Steps

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2021 IAFSS Symposium Workshop: MaCFP Condensed Phase
April 23, 2021

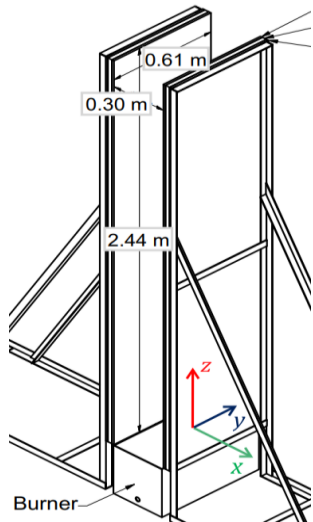
Large-scale experiments on the cast black PMMA that are currently in progress



- Flame spread on a corner wall formed by two $146 \times 50 \text{ cm}^2$ panels of PMMA
- 7 tests were performed thus far at



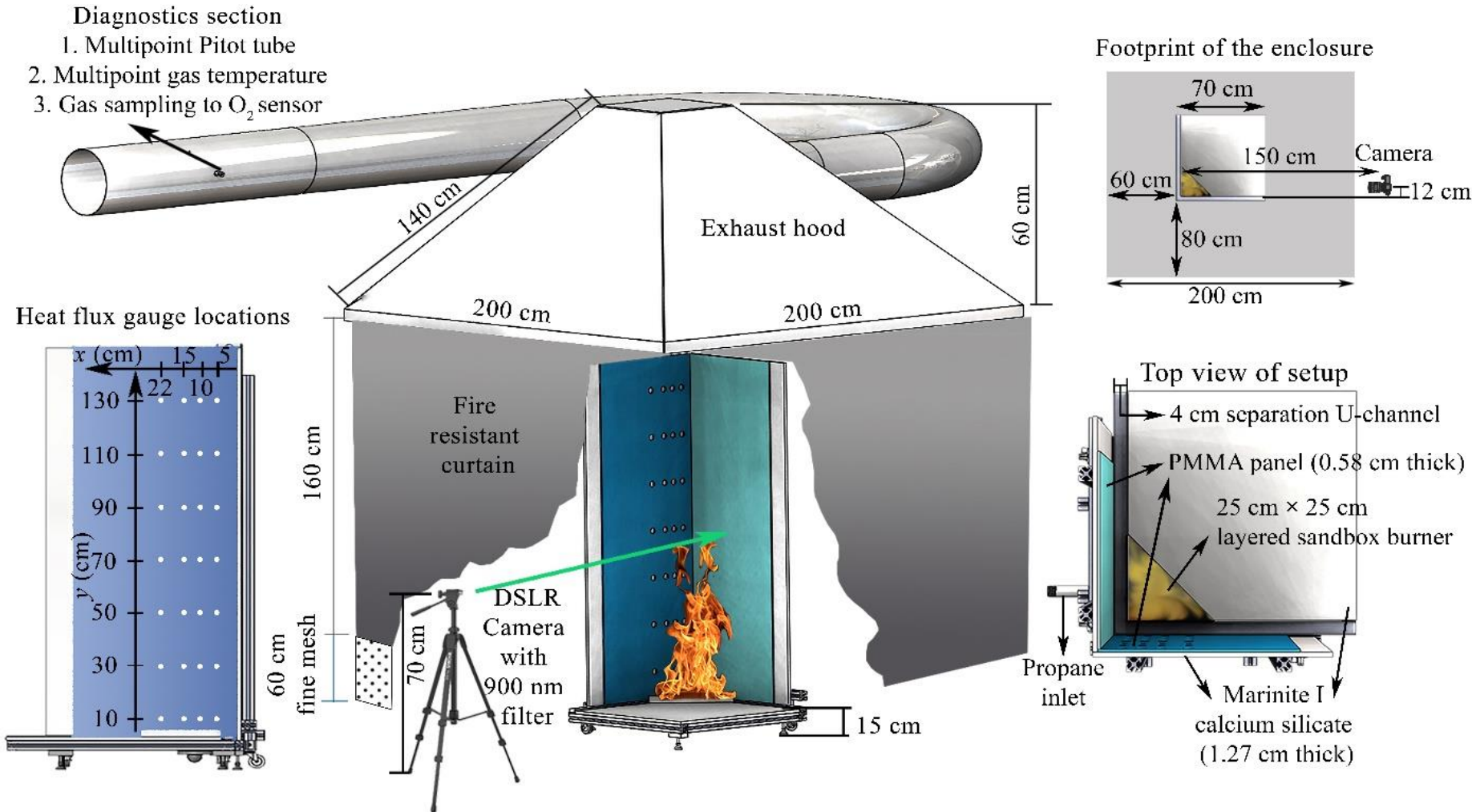
; they are supported by



- Flame spread on parallel panels lined with $245 \times 60 \text{ cm}^2$ sheets of PMMA
- 6 tests were performed thus far at

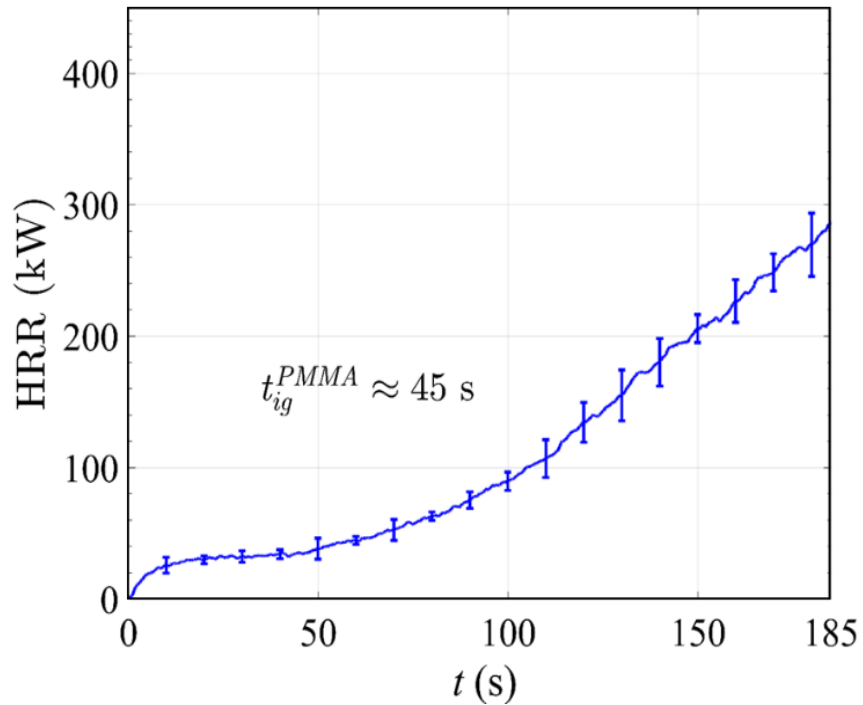


Experimental setup to study flame spread on a corner wall



- Key Diagnostics:**
1. Fast-response (13 s) heat release rate (HRR) measurement
 2. Flame heat flux with water-cooled gauges positioned in 28 locations distributed over the PMMA surface
 3. Monochromatic, 900 nm, video of the spreading flame using DSLR camera with a linear sensor response

Results of HRR measurements



$$\text{HRR} = E \cdot A \cdot C_f^e \left(2\Delta P \left(\frac{P_a M_e}{T_e R} \right) \right)^{0.5} \frac{M_{O_2}}{M_e} \left(\frac{X_{O_2}^{m,0}}{1 + X_{O_2}^{m,0} r_{H_2O}^0} - X_{O_2}^t \right)$$

$$X_{O_2}^t = \frac{X_{O_2}^m}{1 + \gamma \left(\frac{X_{O_2}^{m,0}}{(1 - X_{O_2}^{m,0}) + X_{O_2}^m} - X_{O_2}^m \right) + r_{H_2O}^0 X_{O_2}^m}$$

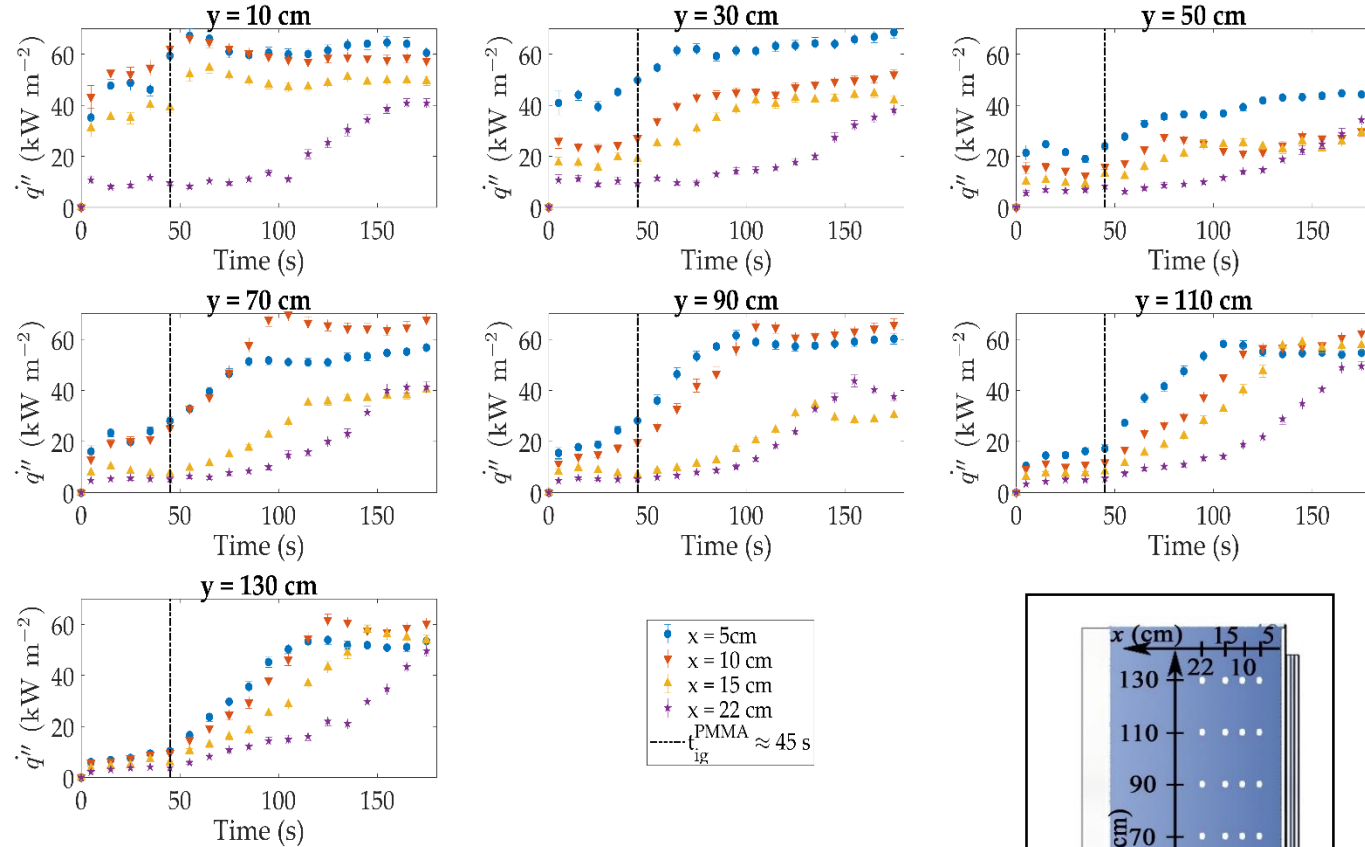
$$r_{H_2O}^0 = \left(\frac{P_a}{(RH^0/100)P_{H_2O}^v} - 1 \right)^{-1} \frac{1}{X_{O_2}^{m,0}}$$

For details, see: <https://doi.org/10.1016/j.polymdegradstab.2020.109433>

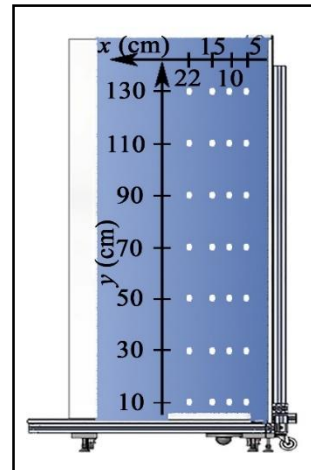


Results of flame heat flux measurements

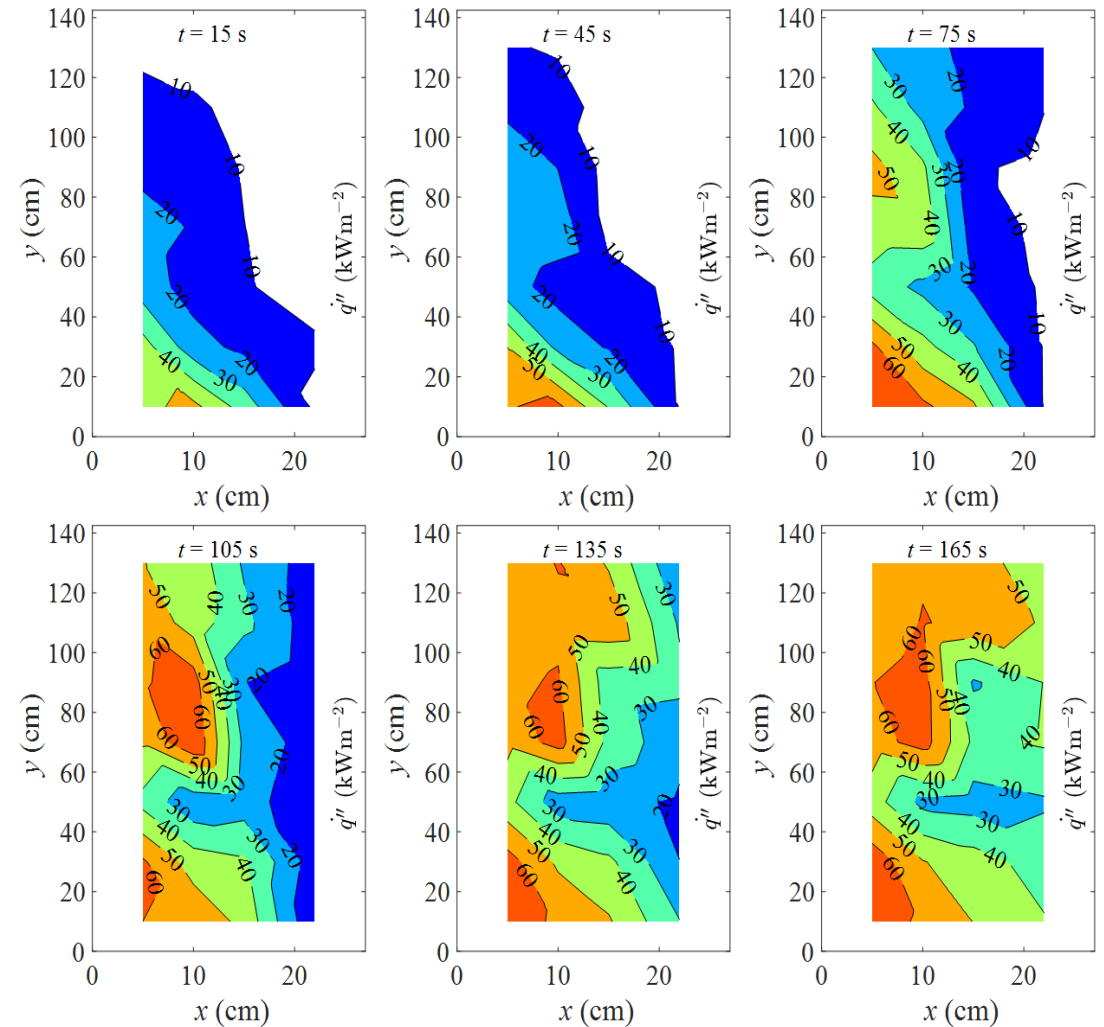
Temporally resolved:



Uncertainty $\approx 10\%$

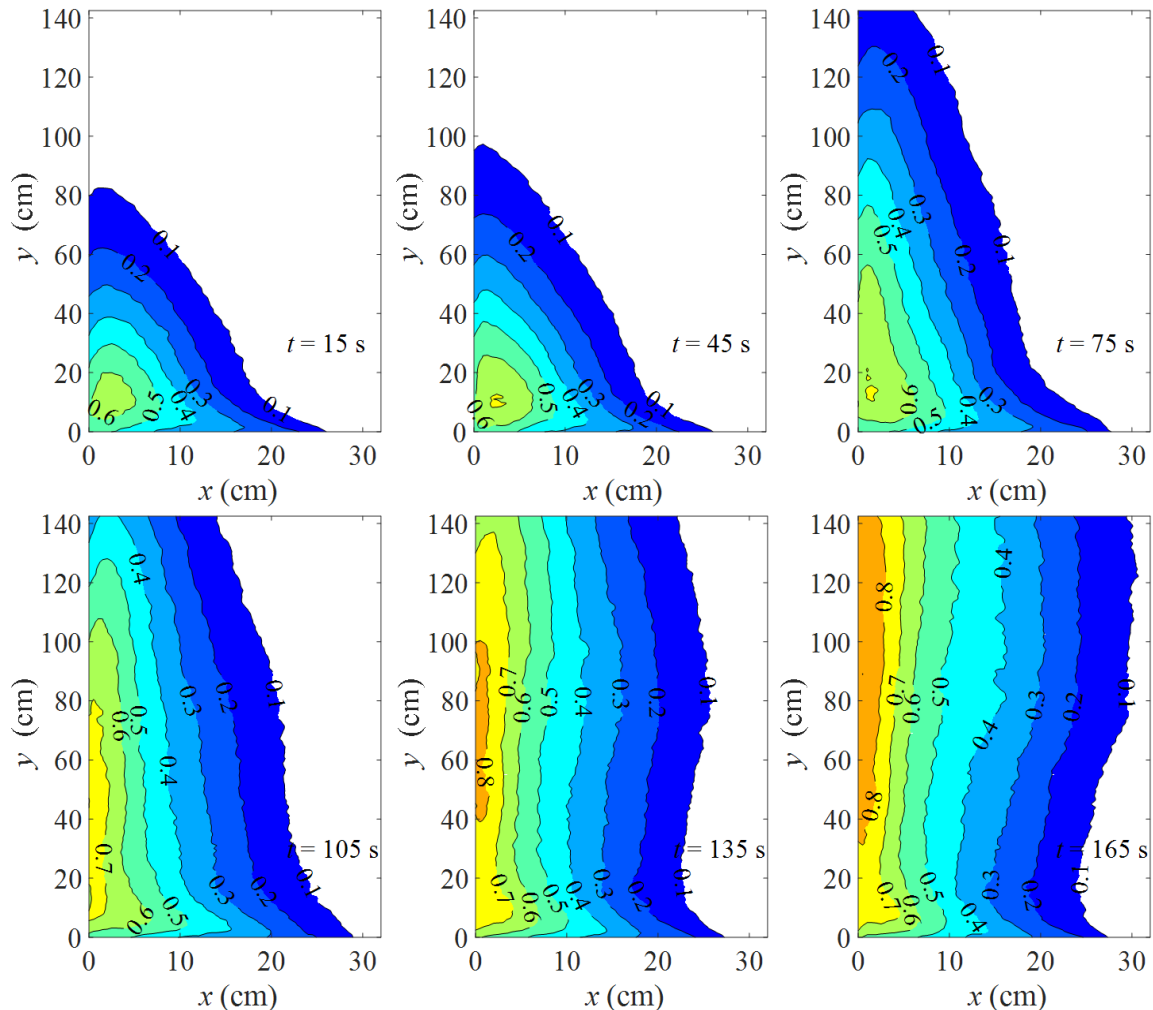


Spatially resolved:



Results of flame imaging

10 s averaged relative intensities of 900 nm flame emissions projected onto a PMMA panel surface



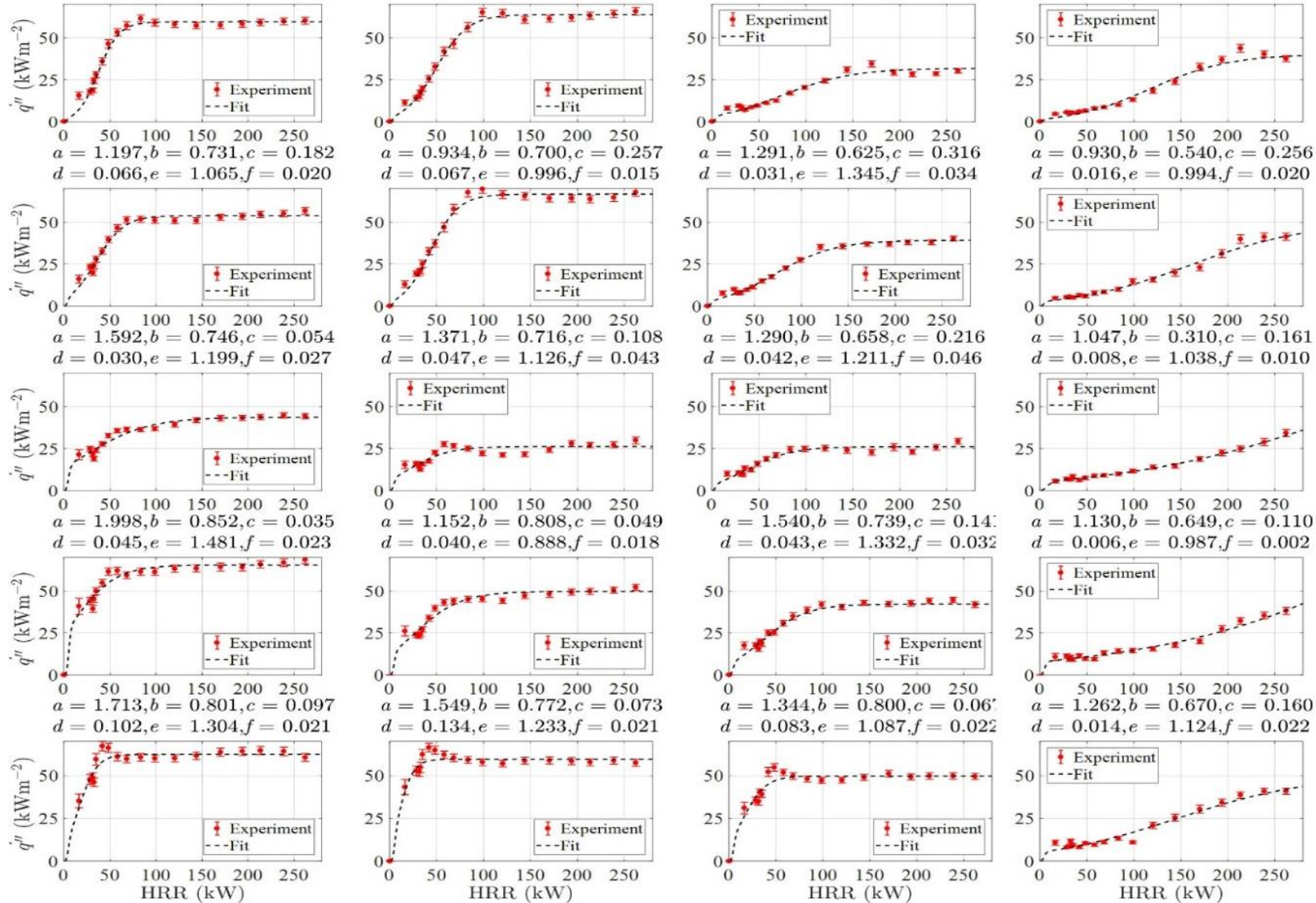
$$I_{900 \text{ nm}}^{\text{cam}}(x, y) \propto \int_s \left(k_{900 \text{ nm}}^{\text{soot}}(s) I_{900 \text{ nm}}^{\text{b}}(T) - k_{900 \text{ nm}}^{\text{soot}}(s) I_{900 \text{ nm}}(s) \right) ds$$

$$(x_s, y_s, z_s) = (x, y, 0) + \frac{s}{\sqrt{(12-x)^2 + (70-y)^2 + 150^2}} \cdot (12 - x, 70 - y, 150)$$

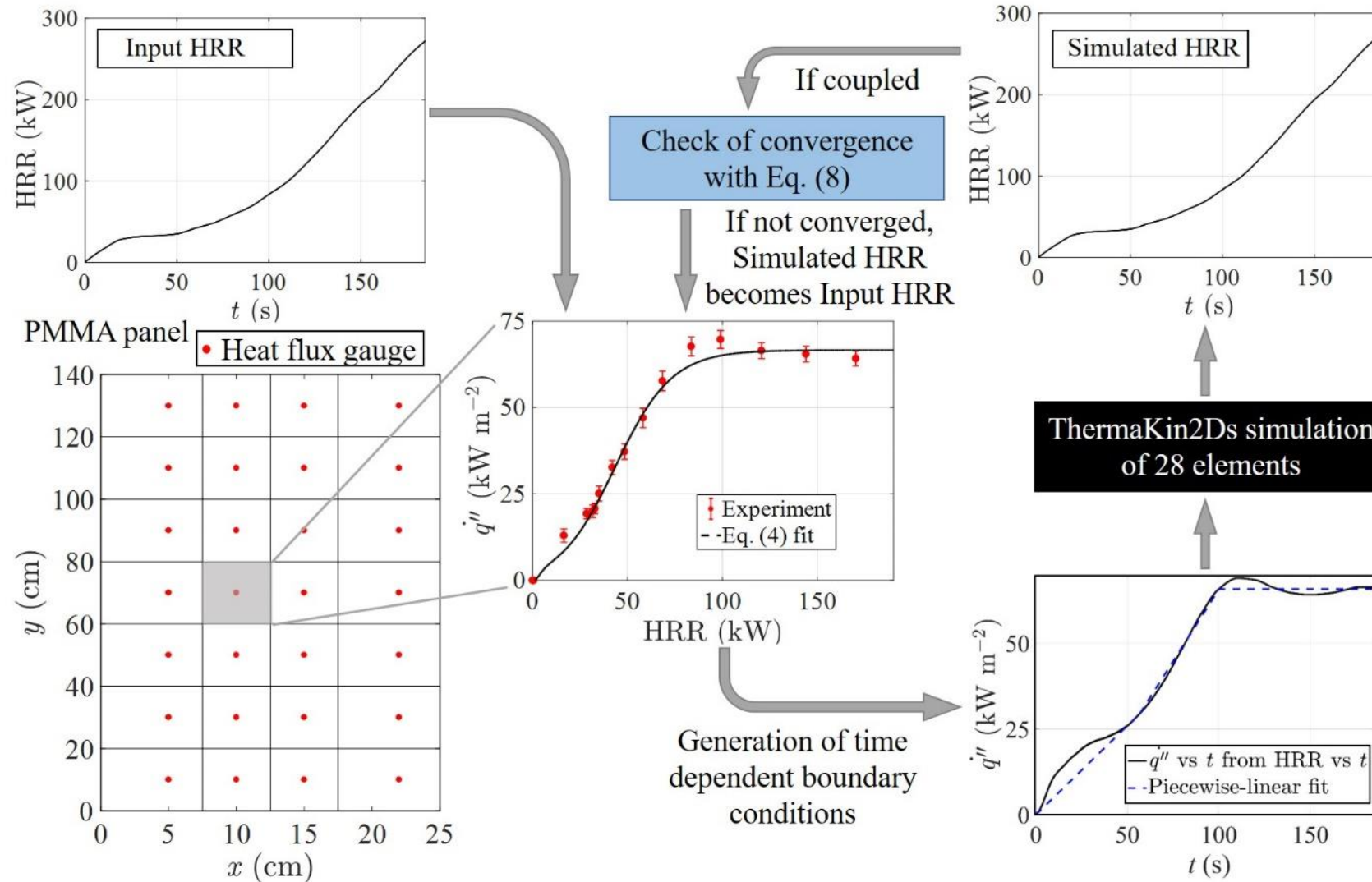
$k_{900 \text{ nm}}^{\text{soot}}$ is the extinction coefficient that includes effects of absorption and scattering by soot and is related to the local soot volume fraction

For details, see: <https://doi.org/10.1016/j.polymdegradstab.2020.109433>

Further analysis: relationship between flame heat flux and HRR

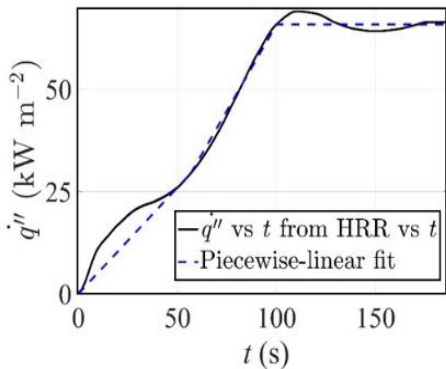


Further analysis: connection with pyrolysis model



Prediction of HRR

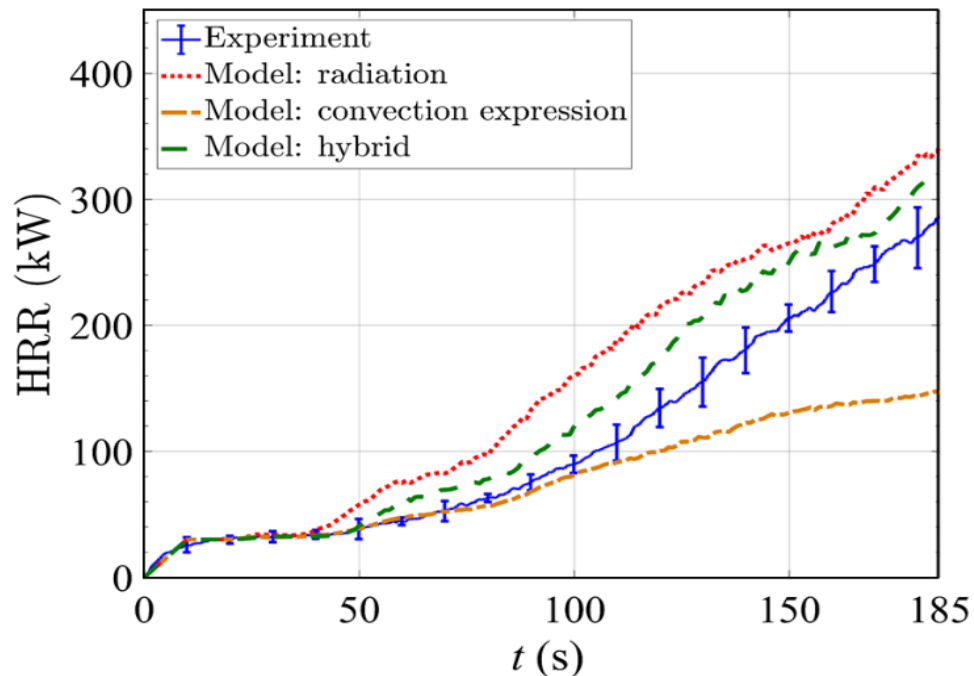
Front surface boundary conditions (two limiting cases):



Flame heat flux is radiative $\Rightarrow \dot{q}''_{net} = \epsilon \dot{q}'' - \epsilon \sigma \langle T_{solid}^4 \rangle_{(averaged\ over\ absorption\ depth)}$

Flame heat flux is convective $\Rightarrow \dot{q}''_{net} = h(T_{flame} - T_{surf}) - \epsilon \sigma \langle T_{solid}^4 \rangle_{(averaged\ over\ absorption\ depth)}$

$$T_{flame}(t) = \frac{\dot{q}''}{h} + T_{gauge}; \quad h = \frac{\dot{q}''_{MAX}}{T_{flame}^{MAX} - T_{gauge}}$$



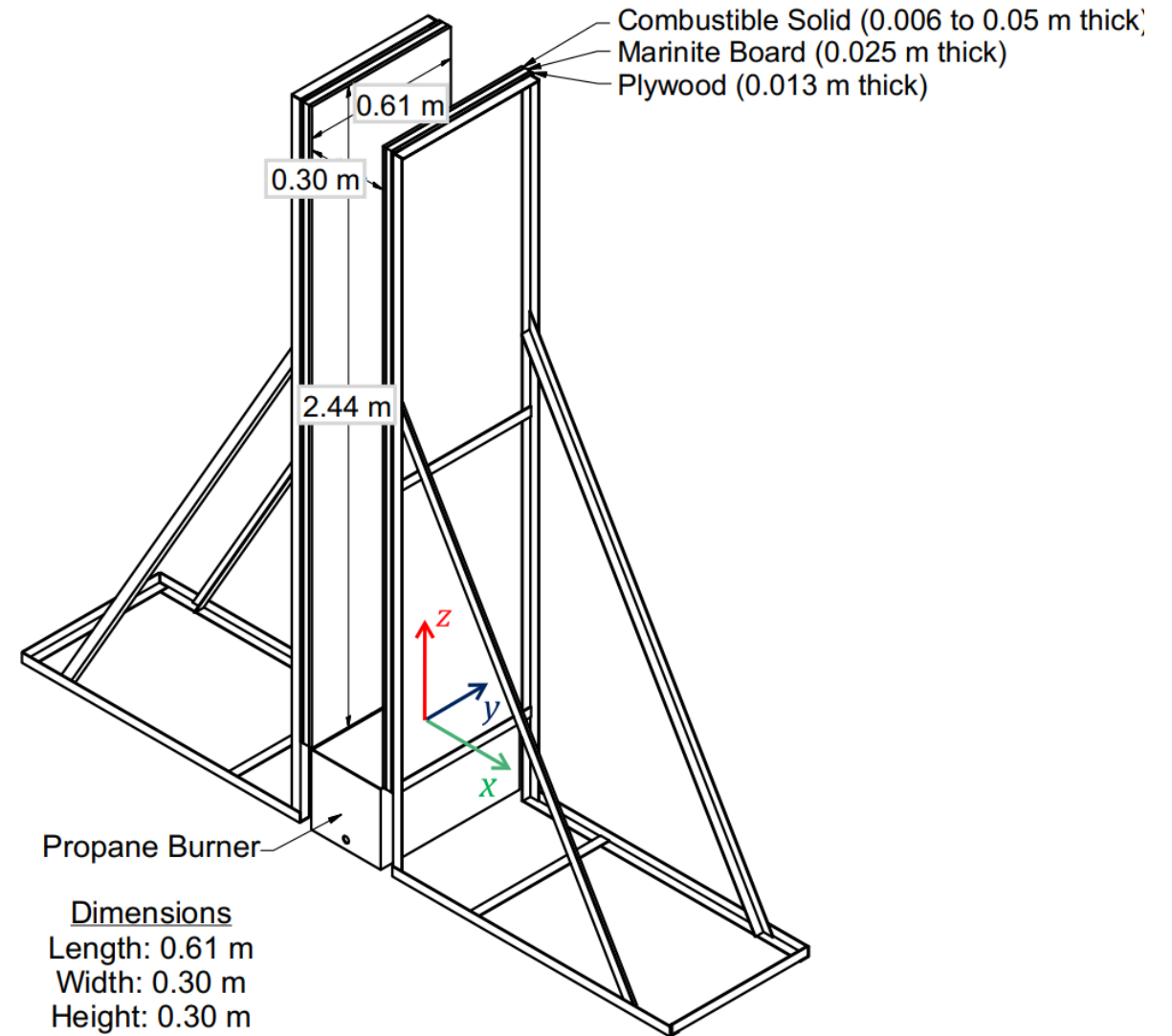
For further details, see Poster 69 and

<https://doi.org/10.1016/j.polymdegradstab.2020.109433>

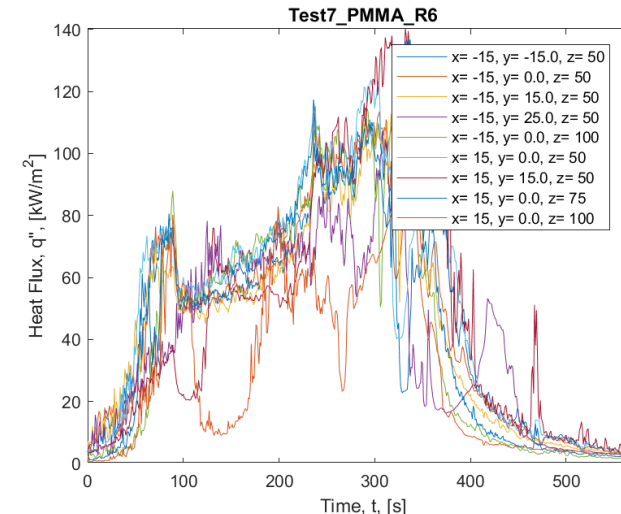
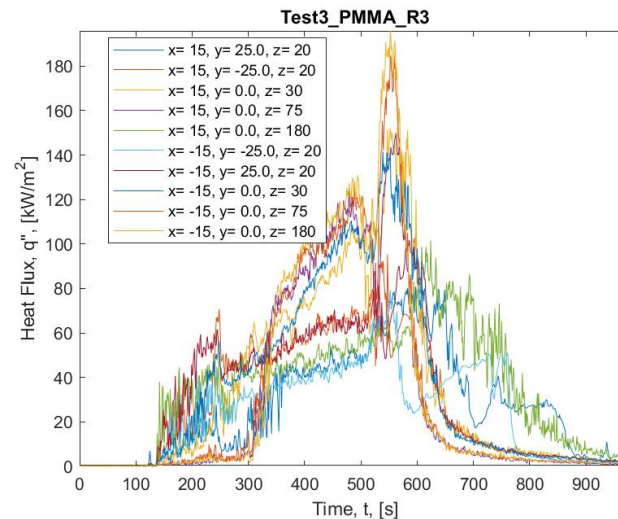
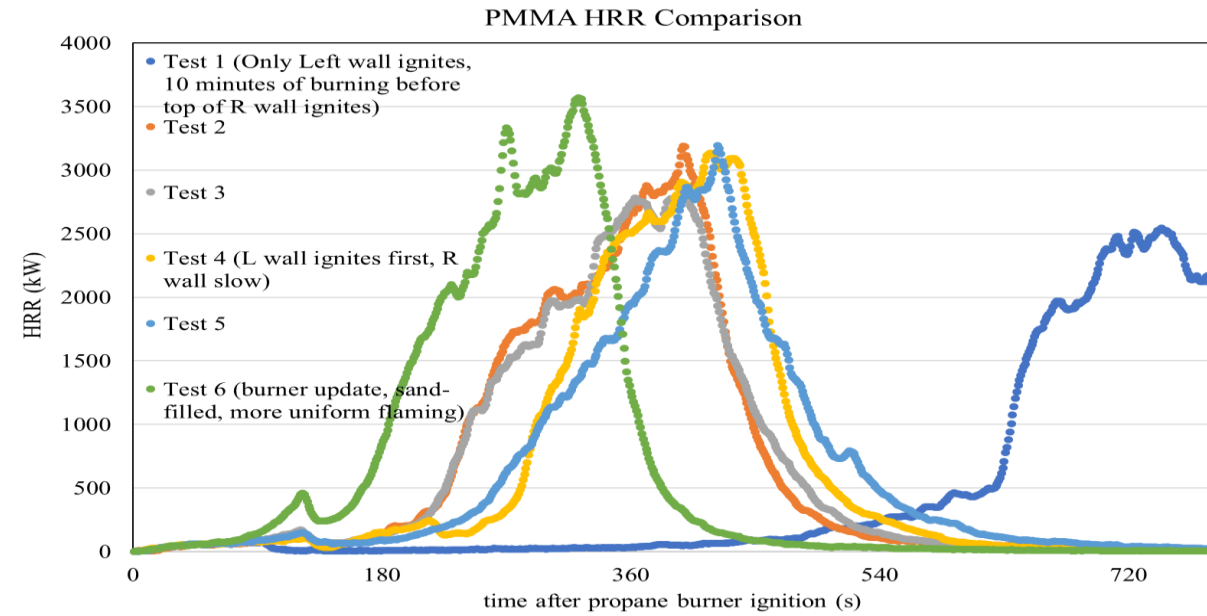
Future work: measurement of the radiative portion of flame heat flux

Parallel panel experimental setup

- Ignitability and flame spread
 - Sample size: 2.45 m tall, 0.6 m wide
 - Panel Separation: 0.3 m
- Burner:
 - Fire Size: 60 kW
 - Dimensions: 0.6 m by 0.3 m
 - Fill designed for uniform gas flow
 - Ceramic insulation blanket, 2.5 cm at top
 - Sand, 7.5 cm
 - Pea gravel, 20 cm base
- Measurement Data
 - CO, CO₂, O₂, Soot and HRR
 - Flame to surface heat flux at 9 heights, 4 horizontal locations



Results obtained thus far



Measurements from the full-scale parallel panel experiments shown here were obtained by the National Institute of Standards and Technology (NIST), an agency of the US government, and are not subject to copyright in the USA. Not all of the measurement data presented here has been through a formal review process and it should therefore be considered as pre-decisional draft results.

The Matl-db repository

- Processing /preparation for Github repository, Matl-db
 - Internal data review (NIST)
 - Evaluate ability to merge measurement data from unique tests
- Follow format of existing large-scale measurement data on macfp-db
 - README.md file
 - Global Measurements (time, HRR, Y_i)
 - Local Measurements (heat flux at location: x, y, z)

The screenshot shows the GitHub interface for the repository 'MacCFP / macfp-db'. The repository has 11 watches, 17 stars, and 23 forks. The current view is the 'Code' tab, showing the file path 'macfp-db / Wall_Fires / FM_Vertical_Wall_Flames / Experimental_Data /'. A commit history table is displayed, listing files added, modified, or removed with their commit messages and dates. Below the table, the 'README.md' file is open, showing the title 'FM vertical wall fire data' and a description of the experimental data.

File	Commit Message	Time
..		
.gitignore	add FM_Vertical_Wall_Flames	5 years ago
C3H6_Flame_Radiance.csv	FM Vertical Wall Flames: Commit preliminary NIST results and scripts.	4 years ago
C3H6_Soot_Depth.csv	FM Vertical Wall Flames: Commit preliminary NIST results and scripts.	4 years ago
C3H6_T_Gas_at_771mm.csv	remove ^M from text files	17 months ago
C3H6_T_Thermocouple_at_771mm....	remove ^M from text files	17 months ago
C3H6_Total_Heat_Flux.csv	remove ^M from text files	17 months ago
FM_Vertical_Wall_Flames_dataplot_i...	FM_Vertical_Wall_Flames: More NIST results.	4 years ago
Other_Fuel_Total_Heat_Flux.csv	remove ^M from text files	17 months ago
README.md	Update README.md	4 years ago

FM vertical wall fire data

The experimental data are summarized in the following .csv files, which include soot depth at different elevation locations and fuel flow rates for propylene, uncorrected and corrected temperature profiles at $Z = 771$ mm with different fuel flow rates for propylene, flame outward radiance at different elevation locations and fuel flow rates for propylene, and total heat flux at different fuel flow rates for methane, ethane, ethylene and propylene. Those data have been published in Refs. 1 and 2.

Detailed description of the .csv files are

The Matl-db repository

- Example output file:
 - Global measurement quantities
 - Time-resolved data
 - Standard format
 - Quantified uncertainties

Time	HRR	Oxygen	CO2	CO	Ksmoke	Exhaust	Mass	Flow	Rate
[s]	[kW]	[vol %]	[vol %]	[vol %]	[l/m]	[kg/s]			
0	0.95	0.2094	0.0004	-9.00E-07	0	16.364			
1	0.27	0.2094	0.0004	-9.00E-07	0	16.295			
2	2.38	0.2094	0.0004	-1.40E-06	0	16.296			
3	3.94	0.2094	0.0004	-1.20E-06	0	16.283			
4	5.11	0.2094	0.0004	-1.00E-06	0	16.2			
5	10.3	0.2094	0.0005	-8.00E-07	0	16.251			
6	11.8	0.2094	0.0005	-5.00E-07	0	16.22			
7	13.9	0.2094	0.0005	-6.00E-07	0	16.31			
8	16.9	0.2094	0.0005	-7.00E-07	0	16.388			
9	17.5	0.2094	0.0005	-8.00E-07	0	16.369			
10	21.7	0.2094	0.0005	-9.00E-07	0	16.276			
11	23.7	0.2093	0.0005	-5.00E-07	0.001	16.347			
12	26.7	0.2093	0.0005	-7.00E-07	0.001	16.327			
13	28.3	0.2093	0.0005	-1.00E-06	0	16.319			
14	25.7	0.2093	0.0005	-1.00E-06	0.001	16.381			
15	27.9	0.2093	0.0005	-1.20E-06	0.001	16.265			
16	29.2	0.2093	0.0005	-7.00E-07	0.001	16.328			
17	32.6	0.2093	0.0005	-9.00E-07	0.001	16.227			
18	34.1	0.2093	0.0005	-8.00E-07	0.001	16.176			
19	34.3	0.2093	0.0005	-6.00E-07	0.001	16.089			
20	33.9	0.2093	0.0005	-7.00E-07	0.001	16.101			
21	34.9	0.2093	0.0005	-8.00E-07	0.001	16.119			
22	36.1	0.2093	0.0005	-7.00E-07	0.001	16.132			
23	40.2	0.2093	0.0005	-5.00E-07	0.001	16.145			
24	43.2	0.2093	0.0005	-5.00E-07	0.001	15.957			
25	41.6	0.2093	0.0005	-4.00E-07	0.001	16.081			
26	41.5	0.2093	0.0005		0	0.001	16.046		
27	44.8	0.2093	0.0005	-2.00E-07	0.002	16.137			
28	45.4	0.2093	0.0005	-6.00E-07	0.002	16.205			
29	47.6	0.2093	0.0006	-4.00E-07	0.002	16.308			
30	51	0.2092	0.0006	-8.00E-07	0.002	16.374			