Will It Support a Self-Propagating Fire?

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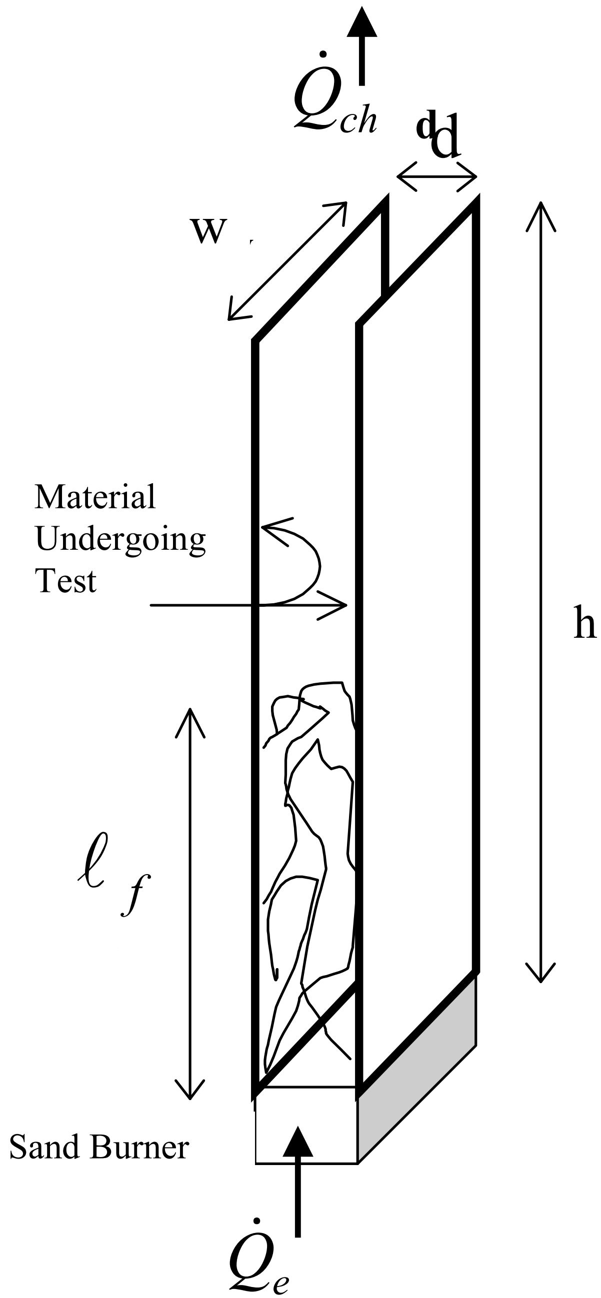
Regulators Desire

- Simple Tests
- Models Requiring a Minimum of Inputs
- Clear Pass/Fail Results

Researchers Seek Understanding



Will the Fire Resistive Material Support a Self-Propagating Fire for a Given Exposure Fire $\dot{Q}_e$?

A Quasi-Steady Model
for the
Parallel Panel Test.

Model Assumptions

1. Heat Release per Unit Volume $\dot{q}'''_{ch} = const = 2000\ kW/m^3$

2. Flame Volume and Height $V_f = l_f wd$ $\ell_f = \dfrac{V_f}{wd} = \dfrac{\dot{Q}_{ch}}{\dot{q}'''_{ch} wd}$

3. Area of Sidewalls $A_{sw} = 2\ell_f w$

   Total Flame Area $A_f = 2\ell_f w + 2\ell_f d + 2wd$

4. Heat Transfer to Walls $\dfrac{\dot{Q}_{sw}}{\dot{Q}_{ch}} = \dfrac{A_{sw}}{A_f}\chi$

5. Flame Heat Flux $\dot{q}''_f = \dot{Q}_{sw} / A_{sw}$

6. Fuel Mass Flux $\dot{m}'' = \left(\dot{q}''_f - \dot{q}''_{loss}\right)/L$

7. Conservation of Energy $\dot{Q}_{ch} = \dot{Q}_e + \Delta H_{ch} A_{sw} \dot{m}''$

Non-Dimensionalization

$$\dot{Q}_{ch} = \dot{Q}_e + \left(\dot{q}''_f - \dot{q}''_{loss}\right) A_{sw} \Delta H_{ch} / L$$

$$\dot{Q}_{ch} = \dot{Q}_e + \dot{Q}_{ch} \chi \left(\frac{A_{sw}}{A_f}\right) \frac{\Delta H_{ch}}{L} - \dot{q}''_{loss} A_{sw} \frac{\Delta H_{ch}}{L}$$

$$\frac{\dot{Q}_{ch}}{\dot{q}'''_{ch} w^2 d} = \frac{\dot{Q}_e}{\dot{q}'''_{ch} w^2 d} + \frac{\dot{Q}_{ch} \chi}{\dot{q}'''_{ch} w^2 d} \left(\frac{A_{sw}}{A_f}\right) \frac{\Delta H_{ch}}{L} - \frac{\dot{q}''_{loss} A_{sw}}{\dot{q}'''_{ch} w^2 d} \frac{\Delta H_{ch}}{L}$$

Fire Size $$\zeta_f = \frac{\ell_f}{w} = \frac{\dot{Q}_{ch}}{\dot{q}'''_{ch} w^2 d}$$

Exposure Fire Size $$\zeta_e = \frac{\dot{Q}_e}{\dot{q}'''_{ch} w^2 d}$$

Surface Heat Loss $$\gamma_{loss} = \frac{\dot{q}''_{loss}}{\dot{q}'''_{ch} d}$$

Parallel Panel Aspect Ratio $$\alpha = d / w$$

Combustion Heat Gain $$\Gamma = \frac{\Delta H_{ch}}{L}$$

Scaling the Aspect Ratio

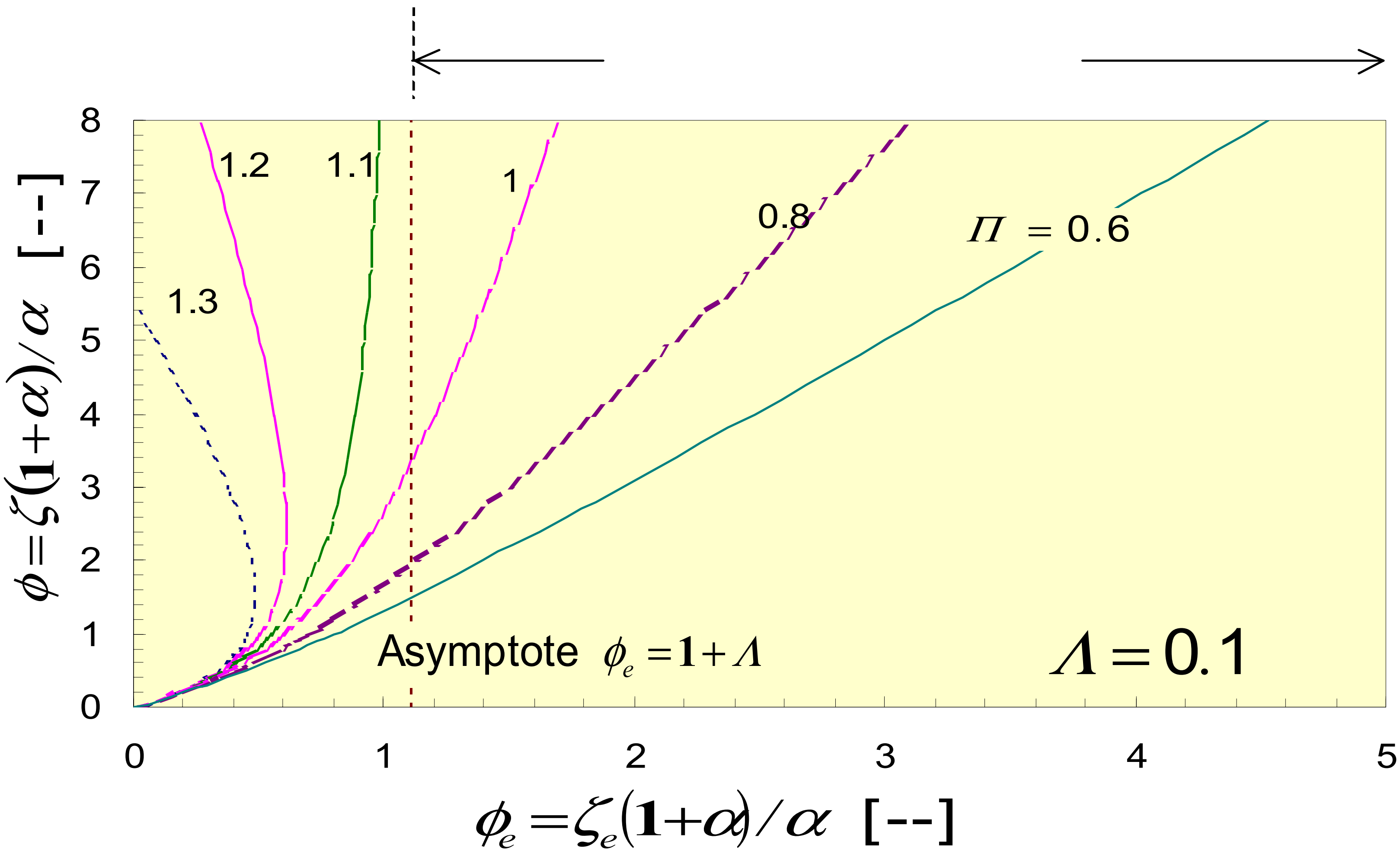
Scaled Fire Size $\phi = \zeta_f (1+\alpha)/\alpha$

Scaled Exposure Fire Size $\phi_e = \zeta_e (1+\alpha)/\alpha$

Scaled Flame Heat Flux $\Pi = \dfrac{\chi\Gamma}{1+\alpha}$

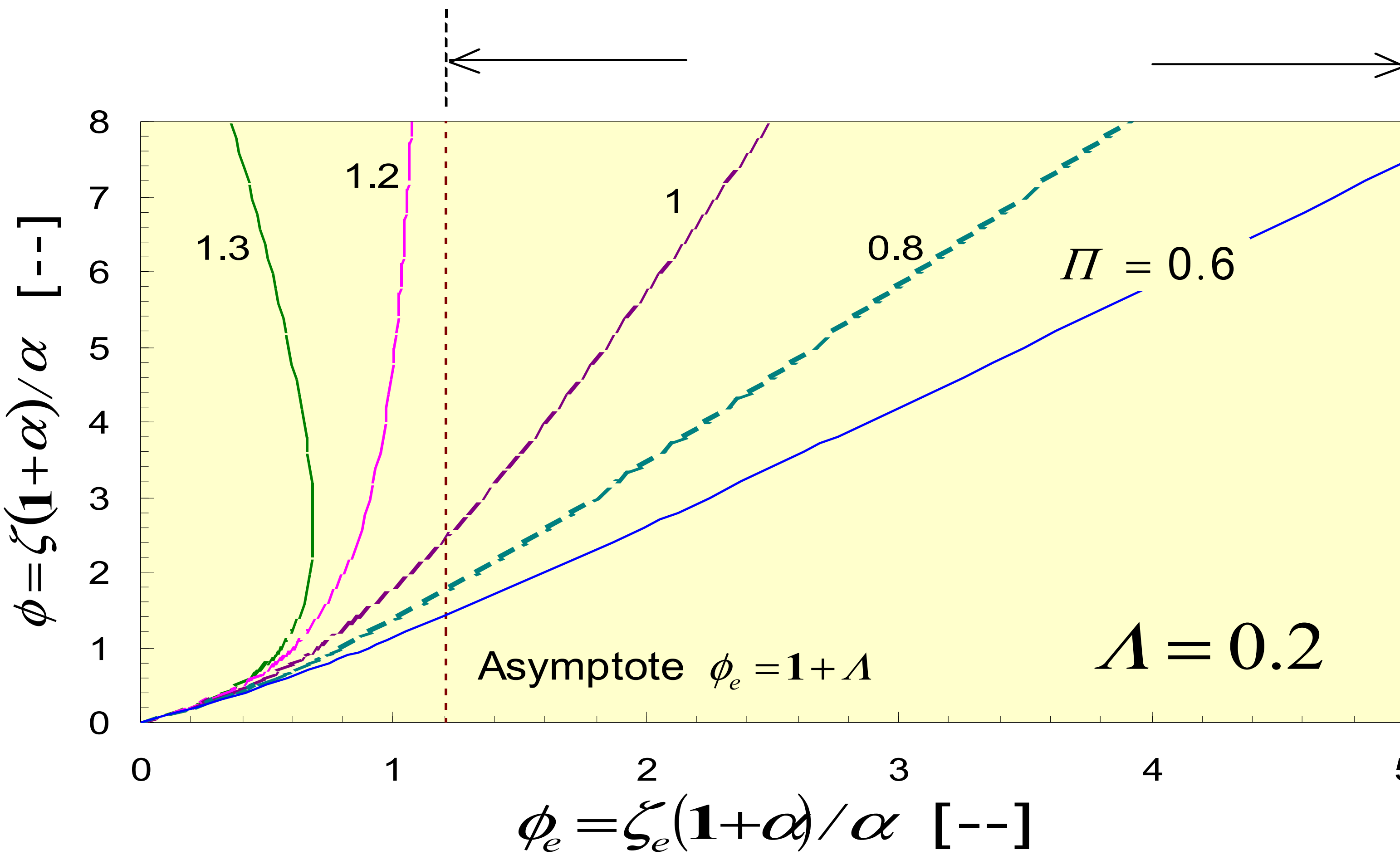
Scaled Heat Loss $\Lambda = 2\Gamma\gamma_{loss}$

Governing Equation $\phi = \phi_e + \dfrac{\phi^2 \Pi}{\phi + 1} - \Lambda\phi$



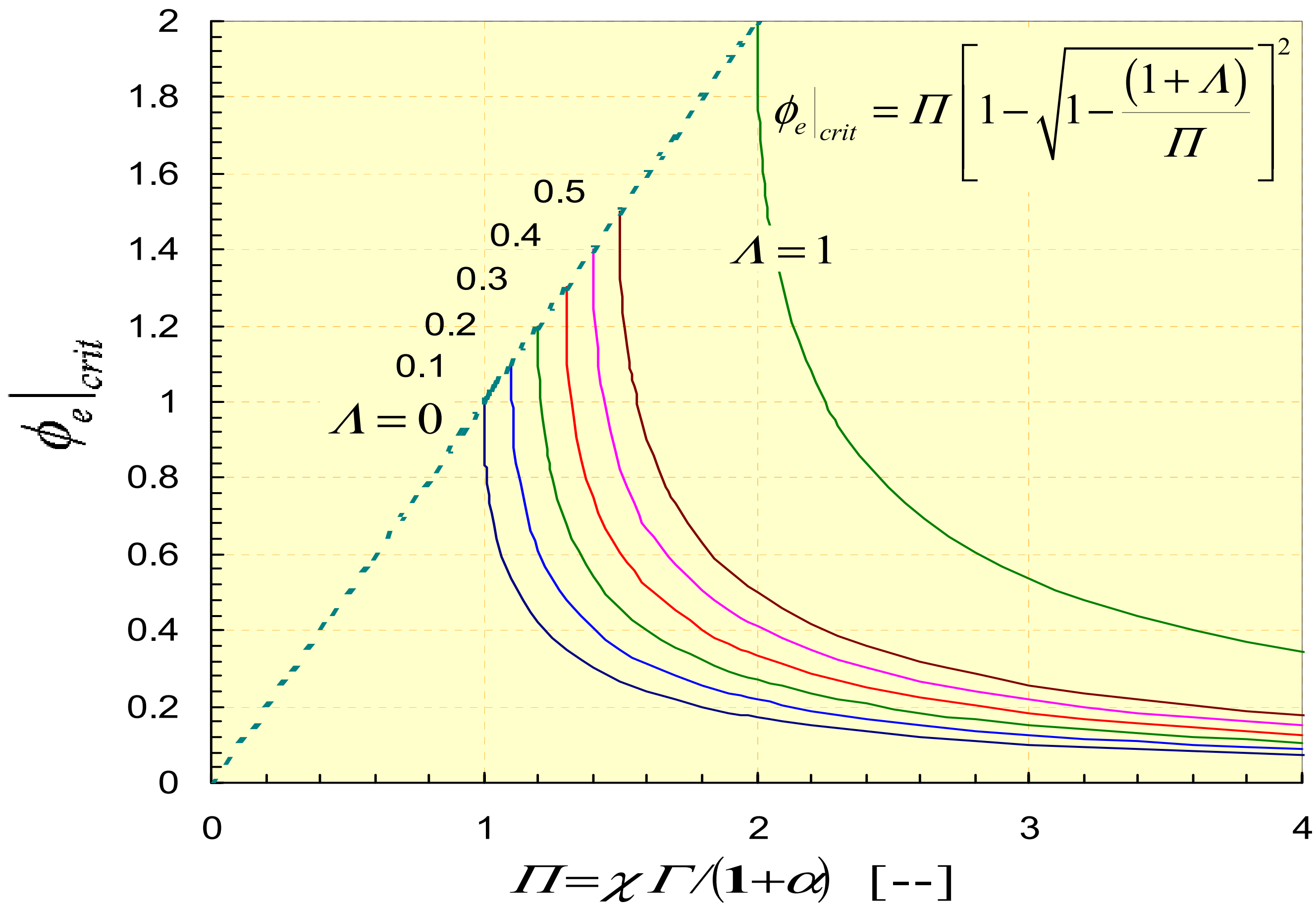
Scaled Fire Size vs. Scaled Exposure Fire Size

for Various Scaled Flame Heat Fluxes
and a Fixed Scaled Heat Loss $\Lambda = 0.1$



Scaled Fire Size vs. Scaled Exposure Fire Size

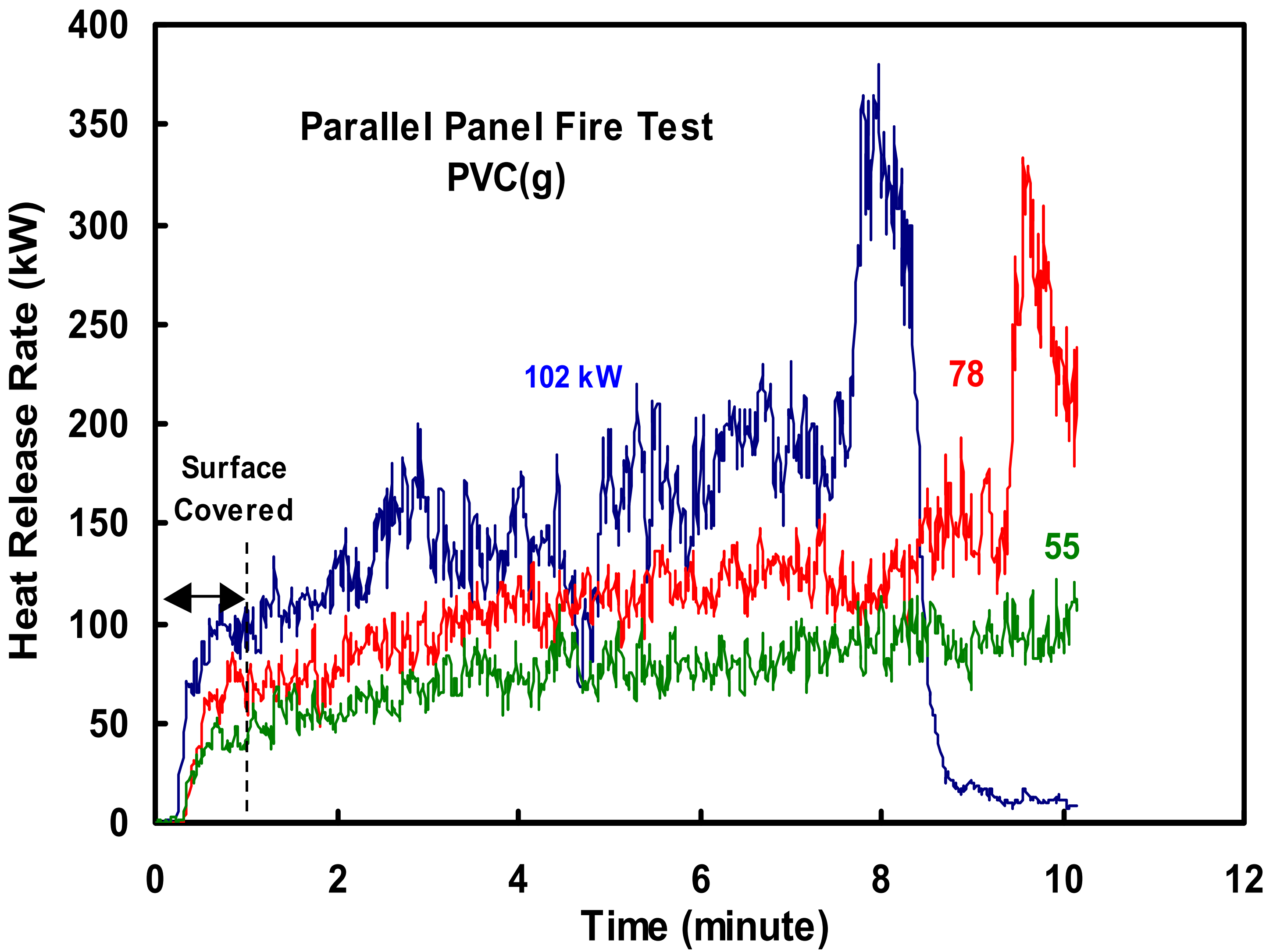
for Various Scaled Flame Heat Fluxes
and a Fixed Scaled Heat Loss $\Lambda = 0.2$



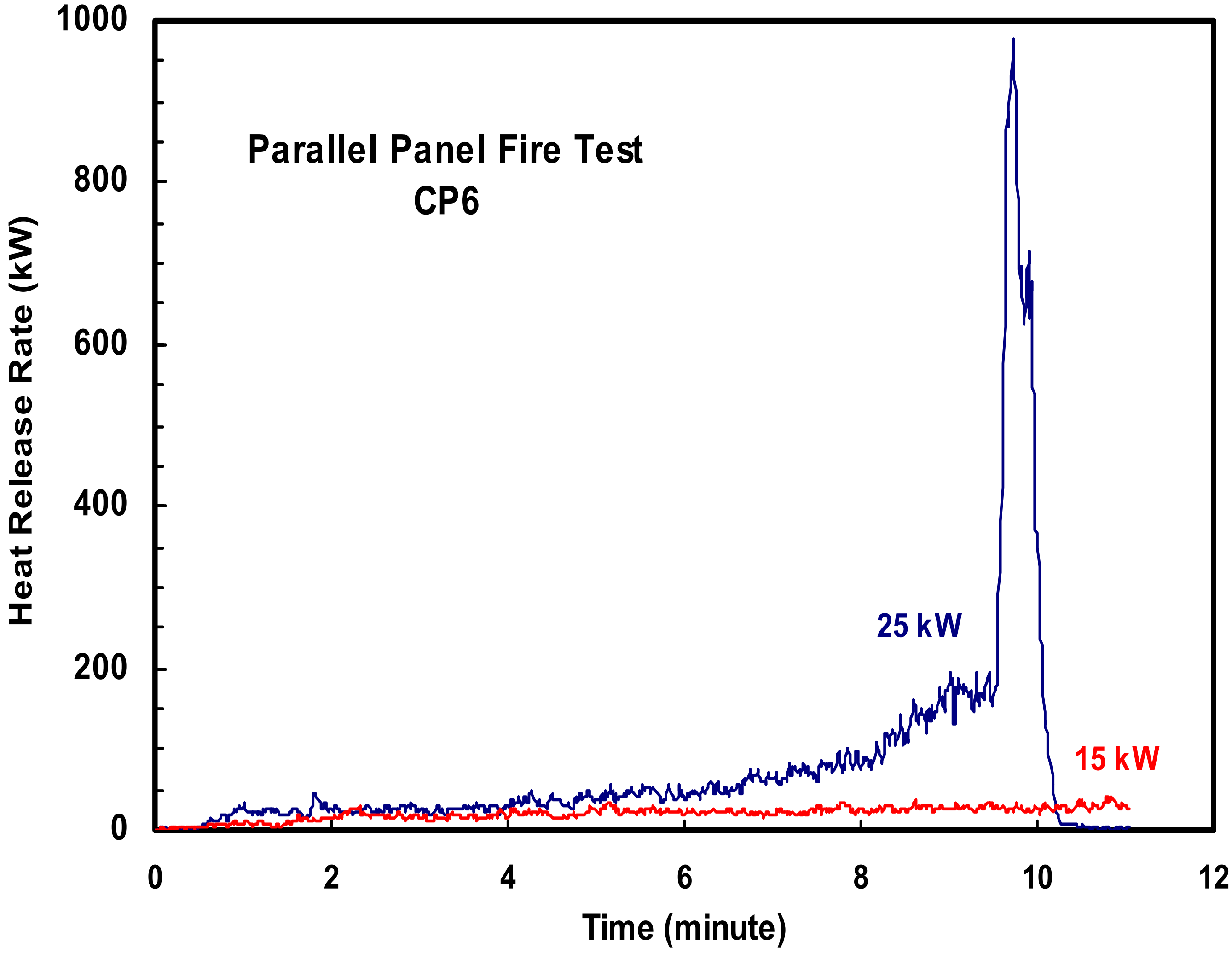
Critical Scaled Exposure Size Leading to Run Away Fire Growth

T_s

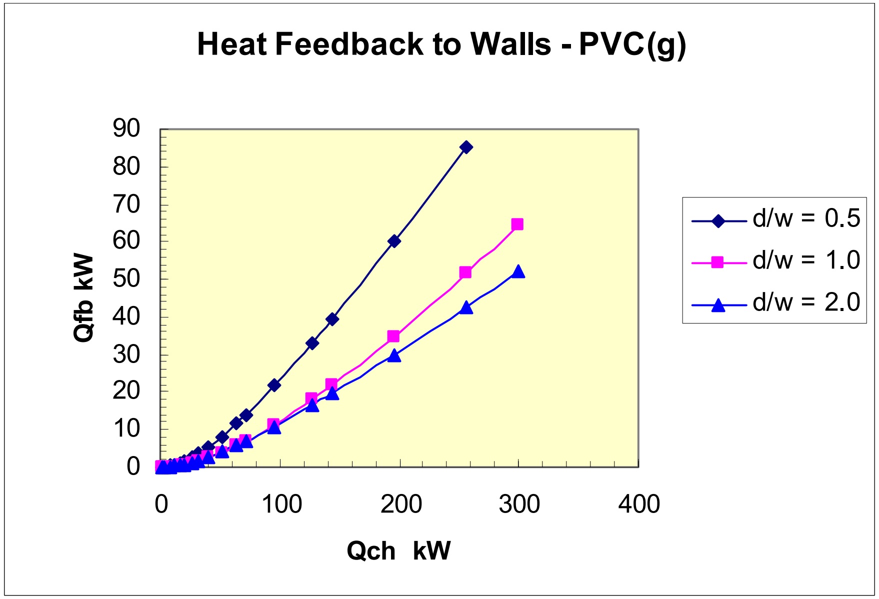
Property	**Symbol**	**Unit**	**PMMA**	**PVC(g)**	**CP-6**
Heat of Combustion	ΔH_{ch}	kJ/g	24.9	7.0	19.0
Heat of Gasification	L	kJ/g	1.61	2.63	5.9
Heat Gain	$\Gamma = \Delta H_{ch} / L$	[--]	15.5	2.66	3.22
Surface Heat Loss	$\dot{q}''_{loss}$	kW/m^2	10.7	12.5	18.4
Surface Temperature	T_s	K	658	685	755
Surface Enthalpy	$C_p (T_s - T_\infty)$	kJ/g	0.46	0.48	0.57
B-Number	$B = \left[\Delta H_{air} - C_p (T_s - T_\infty)\right] / L$	[--]	1.57	0.96	.41
Blockage	$\chi = \ln(1 + B) / B$	[--]	0.60	0.70	0.84
Smoke Yield	$y_s = \dot{g}_{smoke} / \dot{g}_{fuel-vaporized}$	[--]	.02	0.116	0.090
Surface Loss	$\gamma_{loss} = \dfrac{\dot{q}''_{loss}}{\dot{q}'''_{ch} d} \quad for \quad d = 0.3 \quad m,$ $\dot{q}'''_{ch} = 2000 \quad kW / m^3$	[--]	0.017	0.0208	0.0307
Scaled Heat Flux	$\Pi = \dfrac{\chi \Gamma}{1 + \alpha} \quad for \ \alpha = 0.5$	**[--]**	**6.2**	**1.24**	**1.8**
Scaled Heat Loss	$\Lambda = 2 \Gamma \gamma_{loss}$	**[--]**	**0.53**	**0.11**	**0.20**

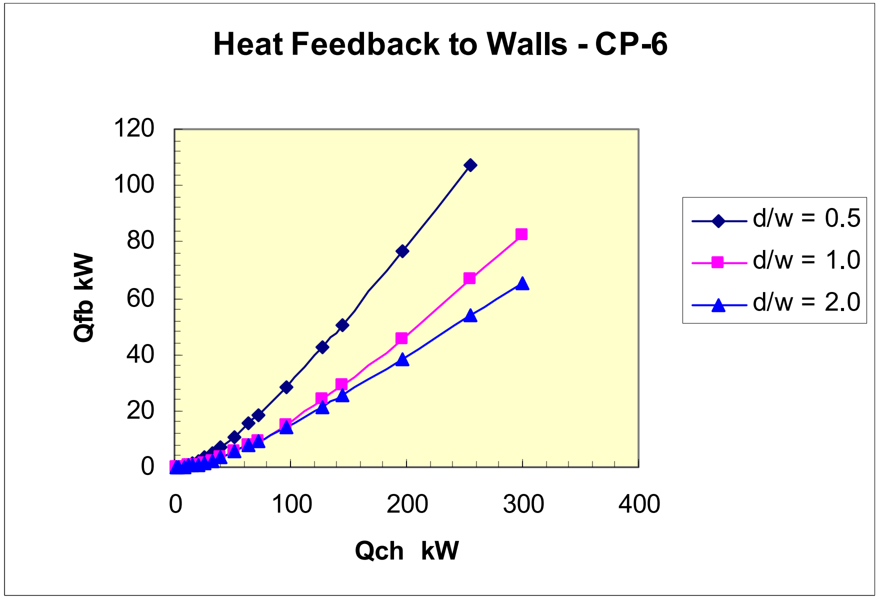


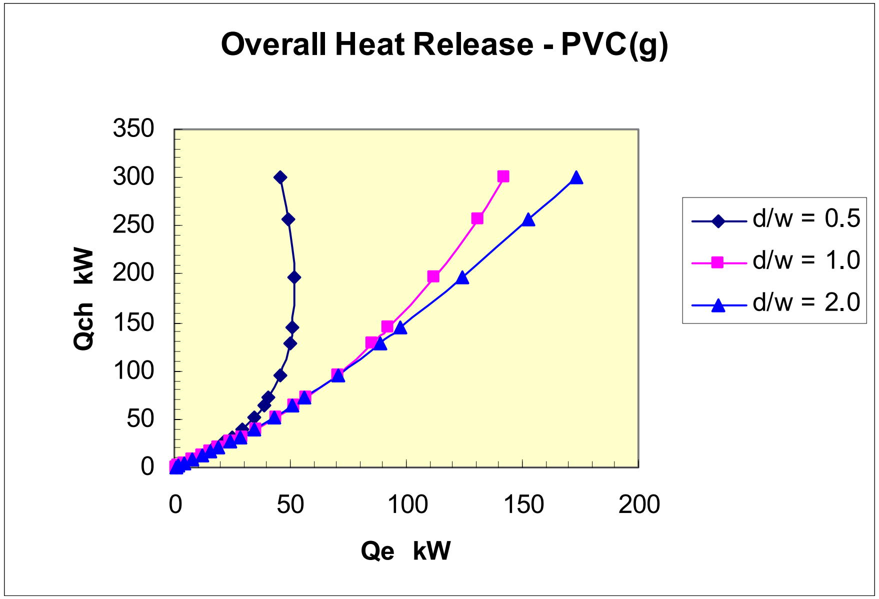
Parallel Panel Fire Test
PVC(g)
Heat Release Rate (kW)
Time (minute)
Surface
Covered
102 kW
78
55
0
50
100
150
200
250
300
350
400
0
2
4
6
8
10
12

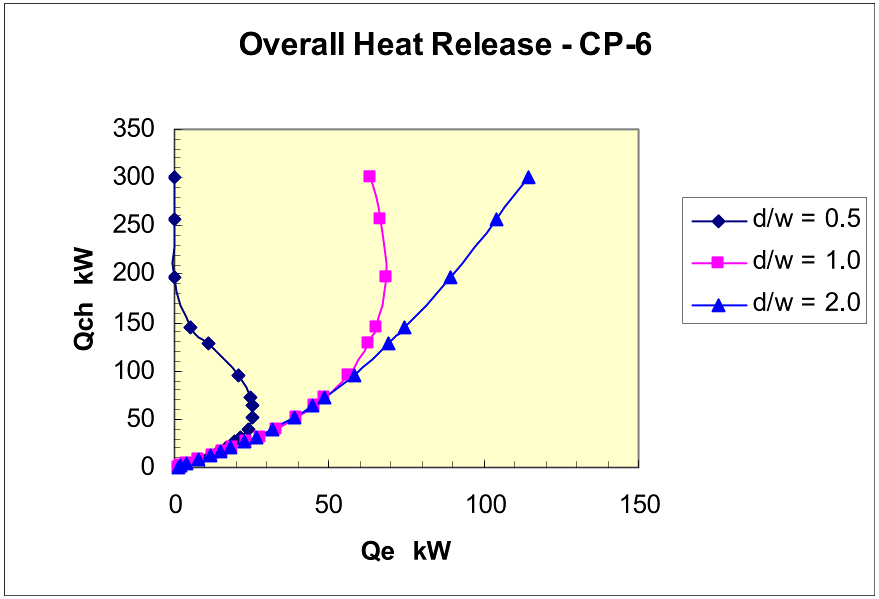


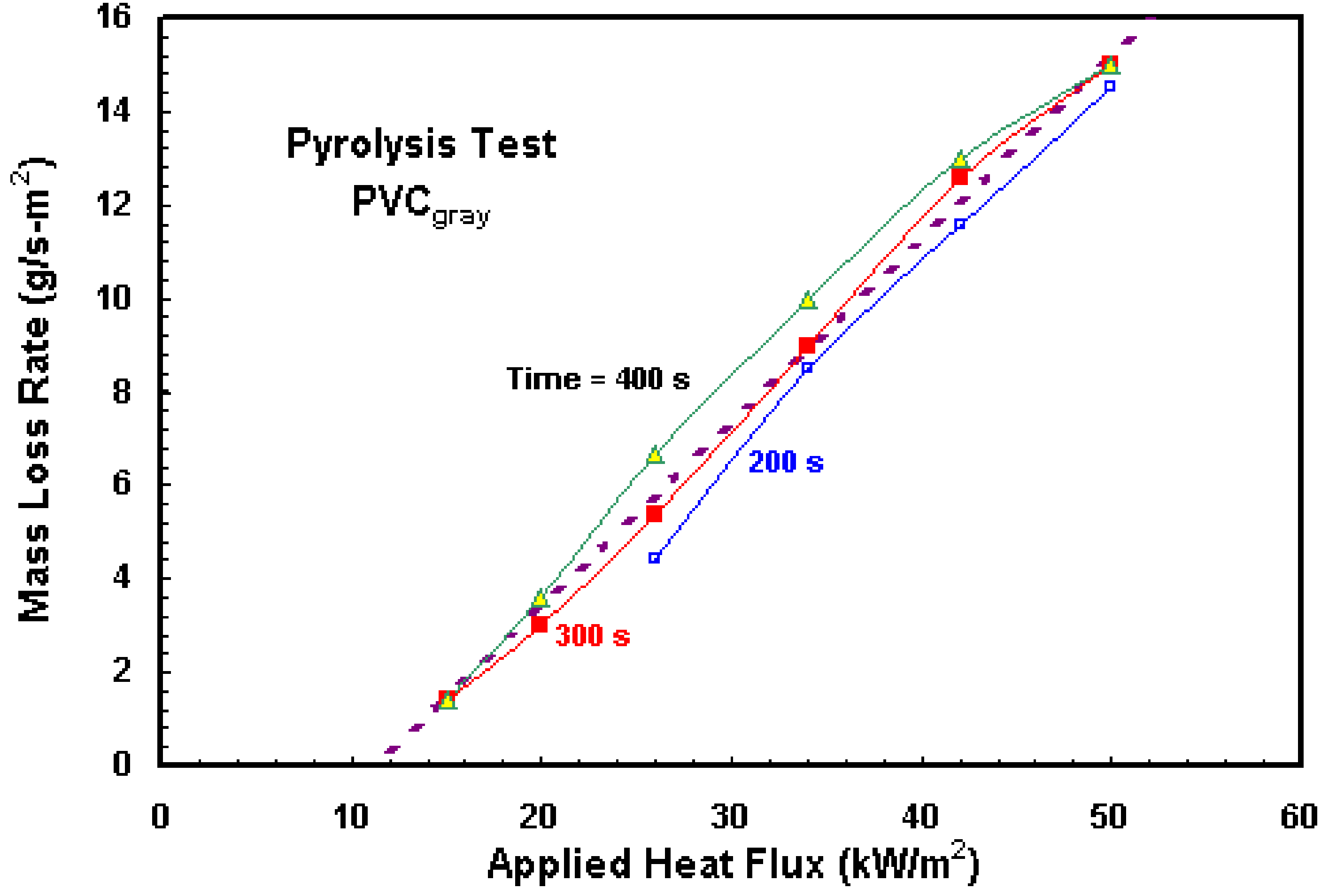
Parallel Panel Fire Test
CP6
Heat Release Rate (kW)
Time (minute)
25 kW
15 kW
0
200
400
600
800
1000
0
2
4
6
8
10
12


Heat Feedback to Walls - PVC(g)
Qfb kW
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
Qch kW
d/w = 0.5
d/w = 1.0
d/w = 2.0

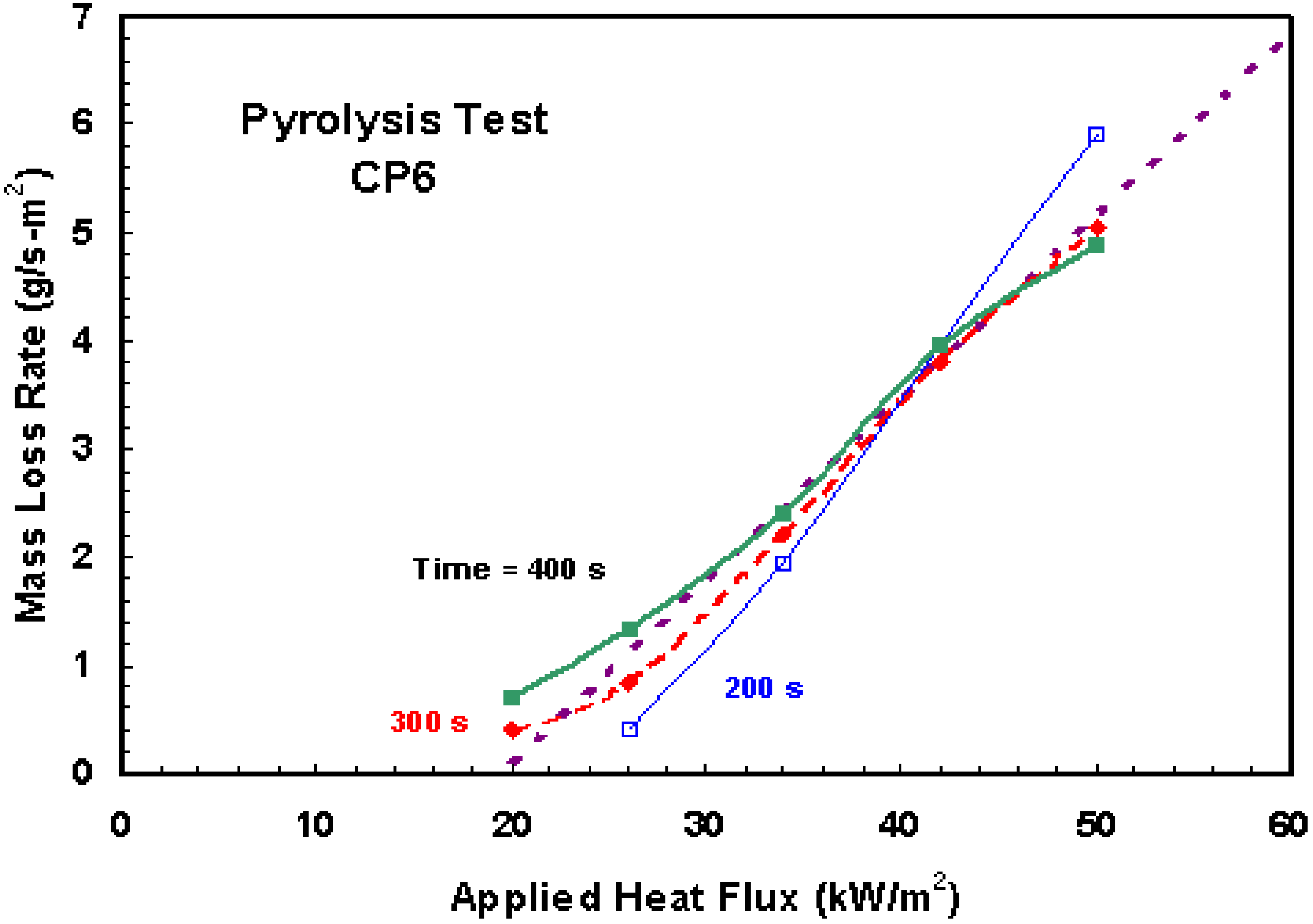

Heat Feedback to Walls - CP-6
Qfb kW
120
100
80
60
40
20
0
0
100
200
300
400
Qch kW
d/w = 0.5
d/w = 1.0
d/w = 2.0


Overall Heat Release - PVC(g)
Qch kW
350
300
250
200
150
100
50
0
0
50
100
150
200
Qe kW
d/w = 0.5
d/w = 1.0
d/w = 2.0


Overall Heat Release - CP-6
Qch kW
350
300
250
200
150
100
50
0
0
50
100
150
Qe kW
d/w = 0.5
d/w = 1.0
d/w = 2.0



Pyrolysis Test
PVC gray
Time = 400 s
300 s
200 s
Mass Loss Rate (g/s-m²)
Applied Heat Flux (kW/m²)
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60


Pyrolysis Test
CP6
Time = 400 s
300 s
200 s
Mass Loss Rate (g/s-m²)
Applied Heat Flux (kW/m²)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60