Evaluation of Containment Boxes as a Fire Mitigation Method in Elevated Oxygen Conditions

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Background and Scope

- Flight avionics boxes are applied throughout the International Space Station (ISS)
- Avionics boxes are an efficient means of containing required materials within an enclosure.
  - Potential strategy for isolating flammable materials
  - Use of wider variety of materials
  - Protecting temperature sensitive equipment (such as Li-Ion battery containing items)
- Assessment of a fire breach and propagation
  - Perform realistic scenario
  - Perform conservative/worst case scenario
  - Evaluate general containment
  - Assess propagation potential (external maximum temperatures)

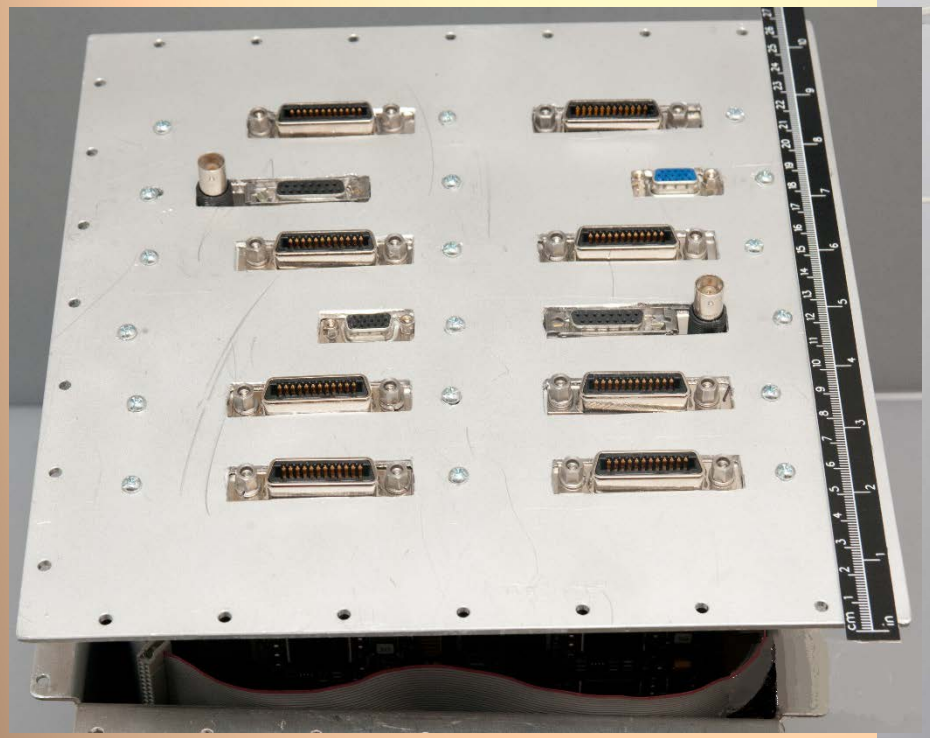
Approach

- Simulated avionics box
  - Worst case/thinnest cross section (case material)
  - No forced ventilation
  - Simulated enclosure vents (non-direct vent path)
- Worst case environment
  - 40% Oxygen concentration
  - 101.3 kPa (14.7 psia) cabin pressure
  - Procedure:
    - Vacuum chamber
    - Backfill with premixed gas
    - Stabilize for 15 min. before test
- Propagation potential
  - Witness plates located above feed-throughs (buoyancy)
  - Measure external surface temperatures

Simulated Avionics Box

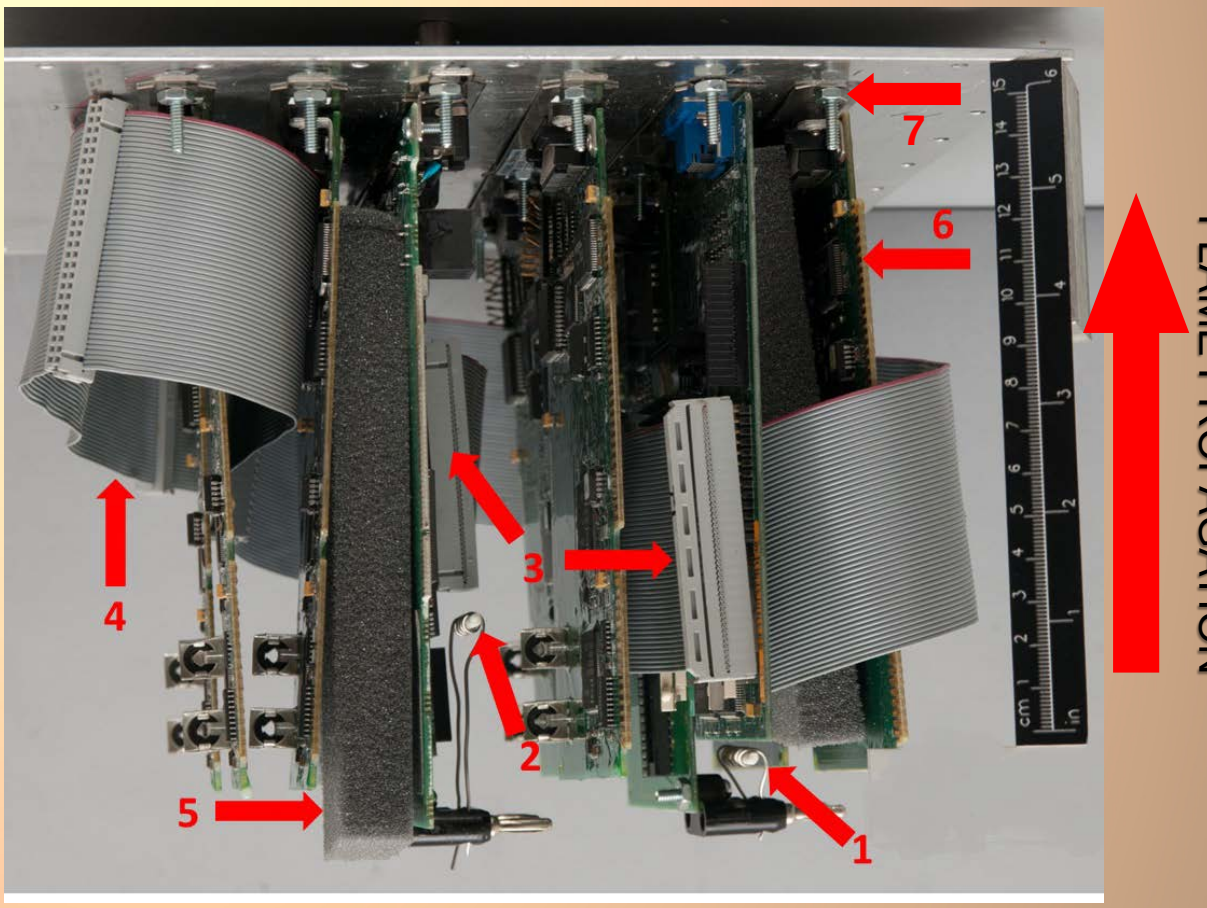
- Physical Dimensions:
  - 15.14L (923.4 in3)
  - 23.9 x 23.9 x 29 cm (9 x 9 x11.4 in.)
  - Actual thinnest wall thickness- 0.38 cm (0.150 in.) wall thickness
  - Wall Thickness – 0.25cm (0.1 in.) < 0.38 cm (0.150 in.) (actual)
- Key Features
  - Simplified analogous vents – tortuous path
  - PCB feed-throughs
  - Upward flame prop. orientation (analogous to NASA STD Test 1)
  - Not hermetically sealed, gas can readily flow in/out
- All tests performed using the same simulated avionics box

Assembled Test Article

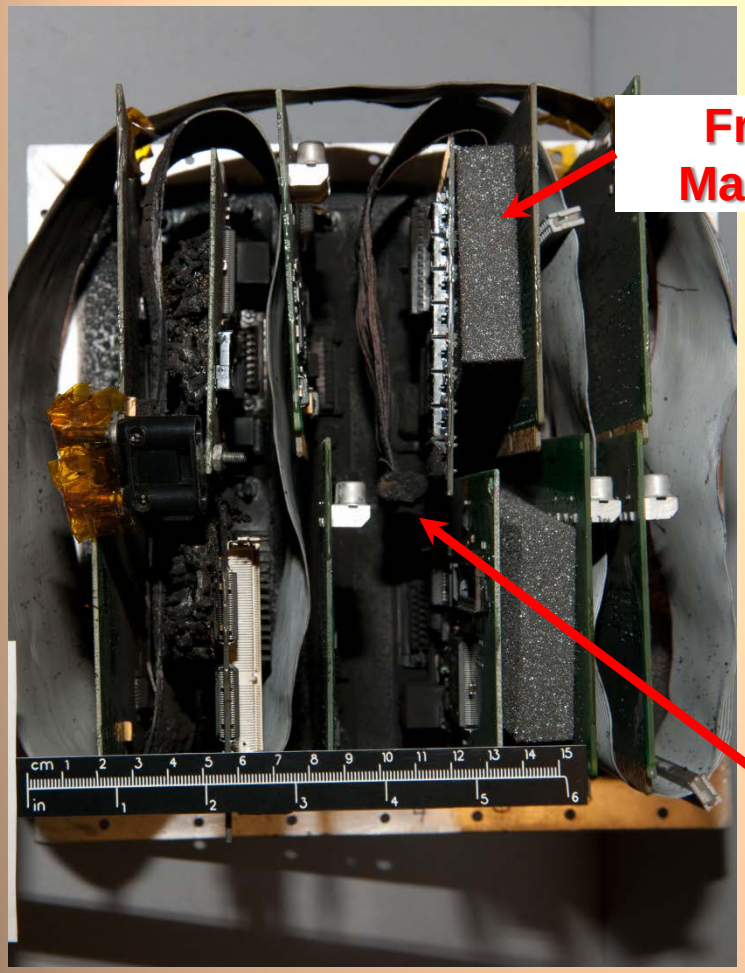


Realistic Scenario

1. Igniter Location 1
2. Igniter Location 2
3. Ribbon cable connector
4. Ribbon cable
5. Polyurethane foam
6. PCB Board
7. PCB Feed-through

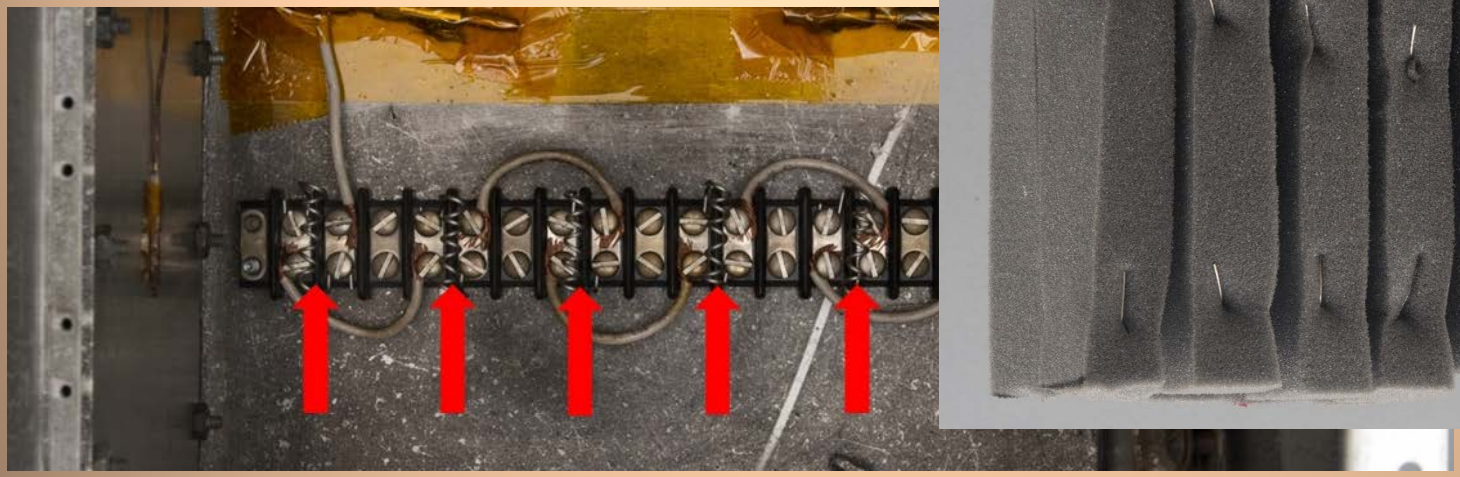


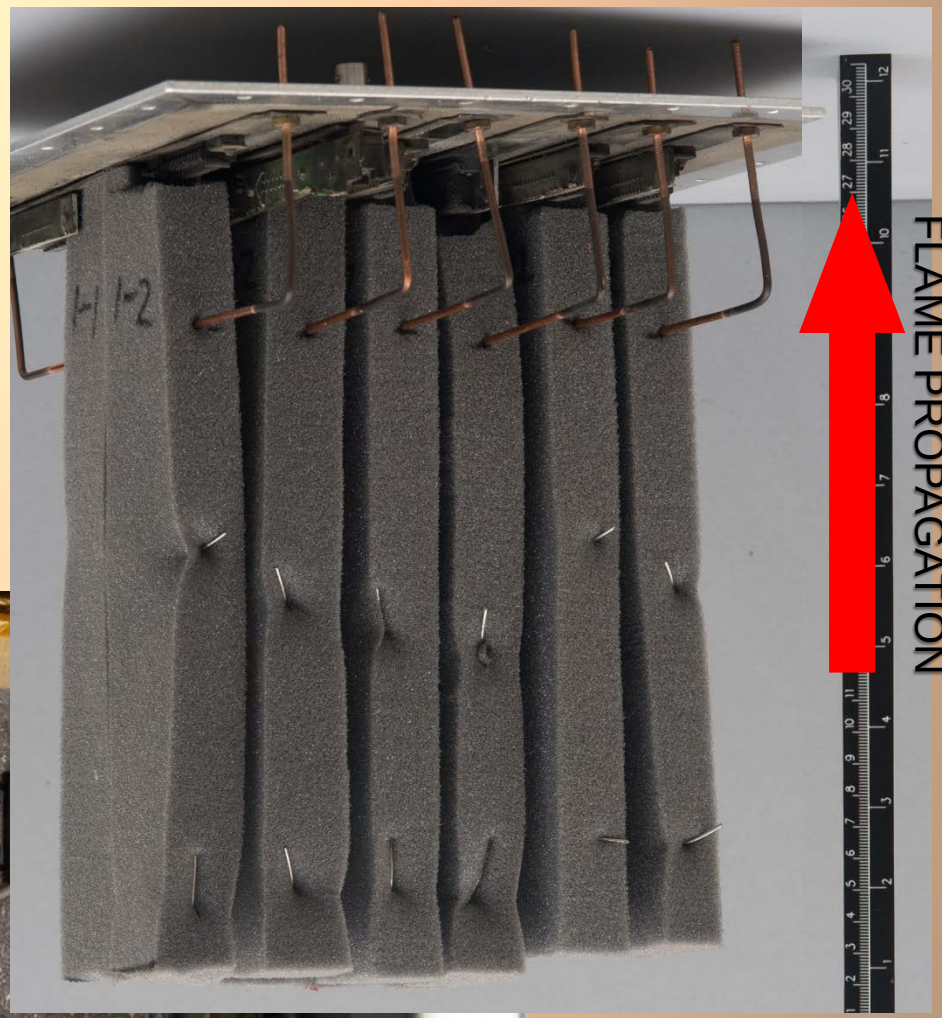
Realistic Scenario: Posttest



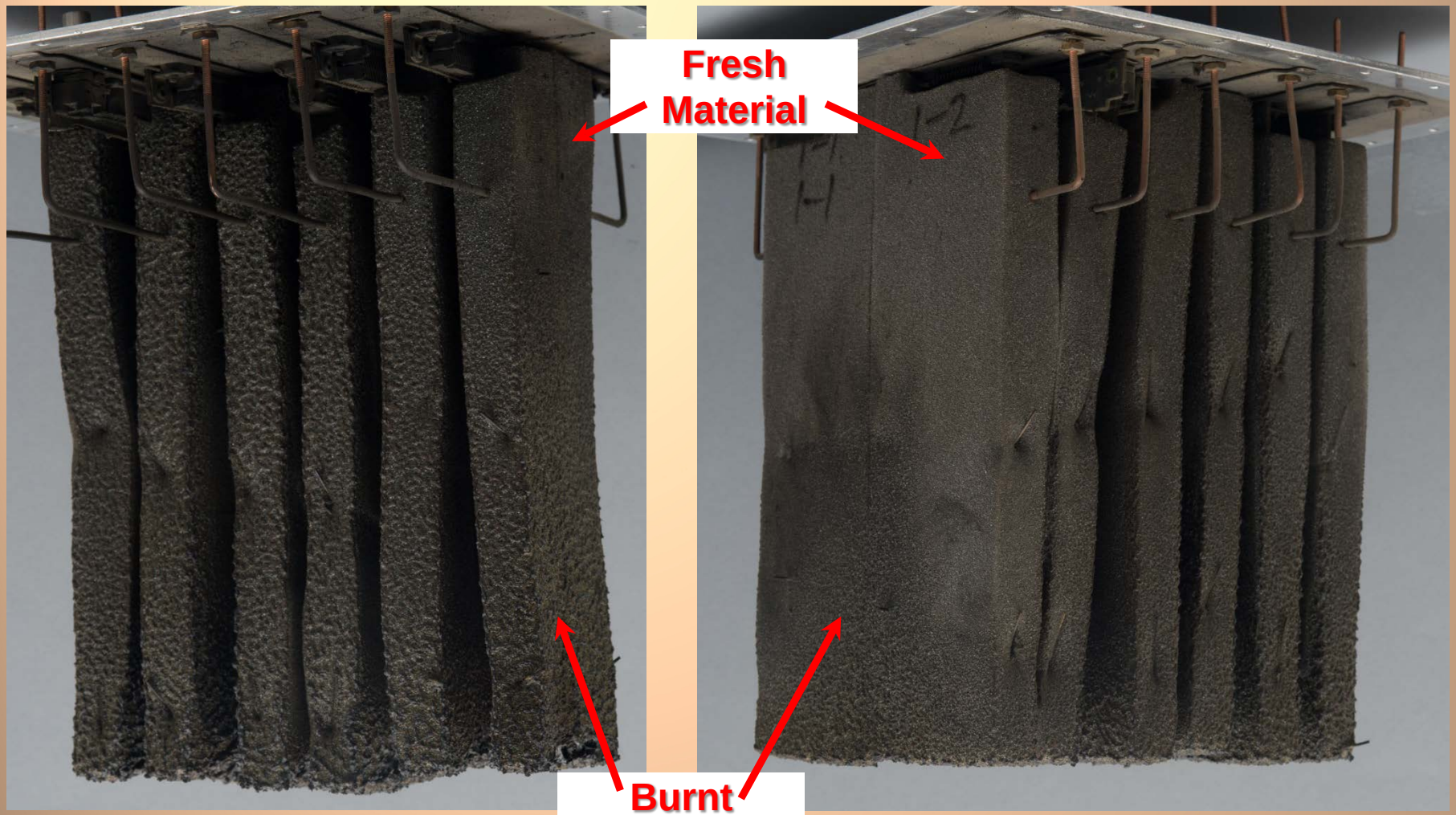
Severe Scenario

1. Vary Packing Density – neglecting foam density
   - 60% Free Volume
   - 80% Free Volume
2. Oxygen consumption concern → Hotwire ign.
3. Constant length and thickness → vary width
4. 6 rows of two Samples
5. 6 hot wire igniters



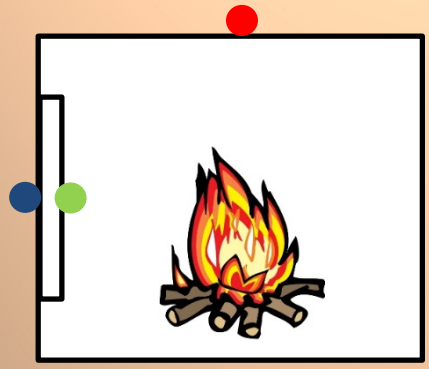


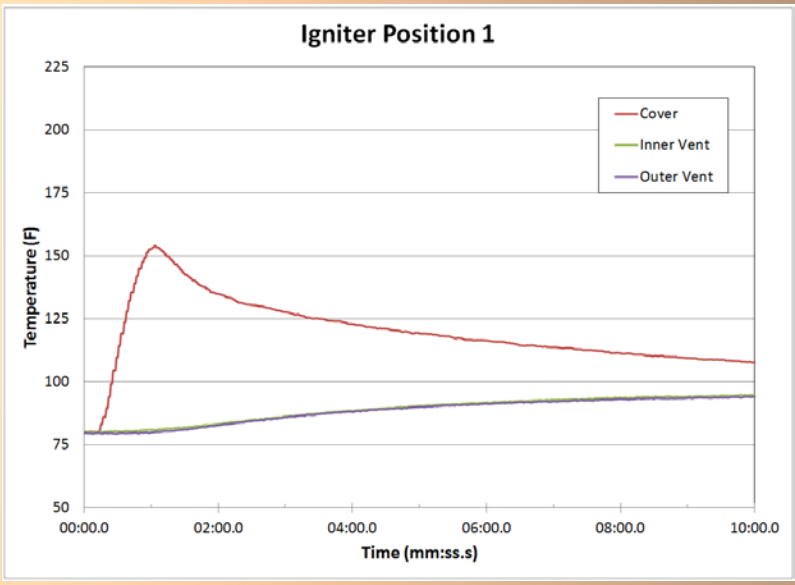
Severe Scenario: Posttest

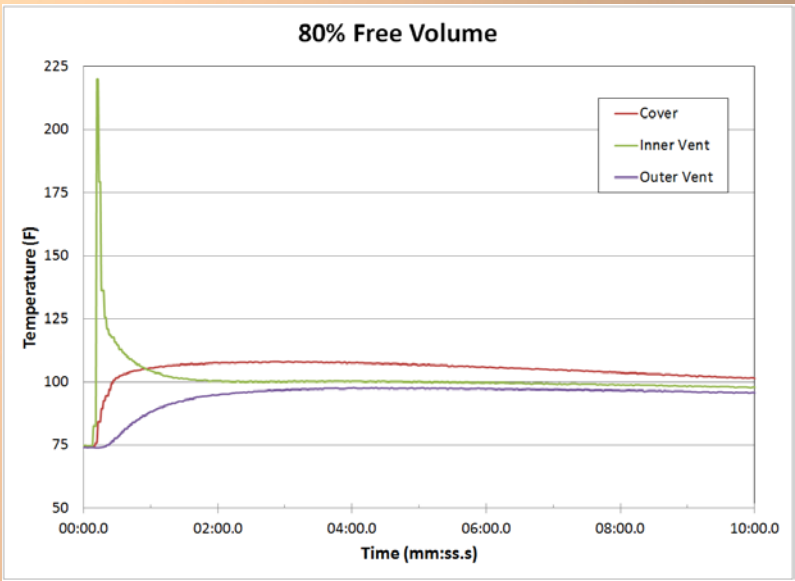


Results

- Self-extinguishment occurred in all cases
  - No observed breach flames
  - No propagation to witness plates
- Smoke observed exiting through feed-throughs
- Maximum Sustained Peak temperatures ~ 150F
  - Low risk as potential overheat source
  - Conservative scenario, bouyancy







Results

	Pretest			Posttest			Posttest Deltas		
	O_2 (% vol.)	Mass g	CO_2 (% vol.)	O_2 (% vol.)	Mass g	CO_2 (% vol.)	O_2 (% vol.)	Mass g	CO_2 (% vol.)
Realistic Scenario 1	40.10	246.66	0.00	39.90	240.89	0.08	-0.20	-5.77	0.08
Realistic Scenario 2	40.15	240.89	0.00	40.02	234.04	0.08	-0.13	-6.85	0.08
60 Percent Free Volume	40.30	189.63	0.00	40.10	185.92	0.08	-0.20	-3.71	0.08
80 Percent Free Volume	40.30	96.89	0.00	40.10	92.03	0.08	-0.20	-4.86	0.08

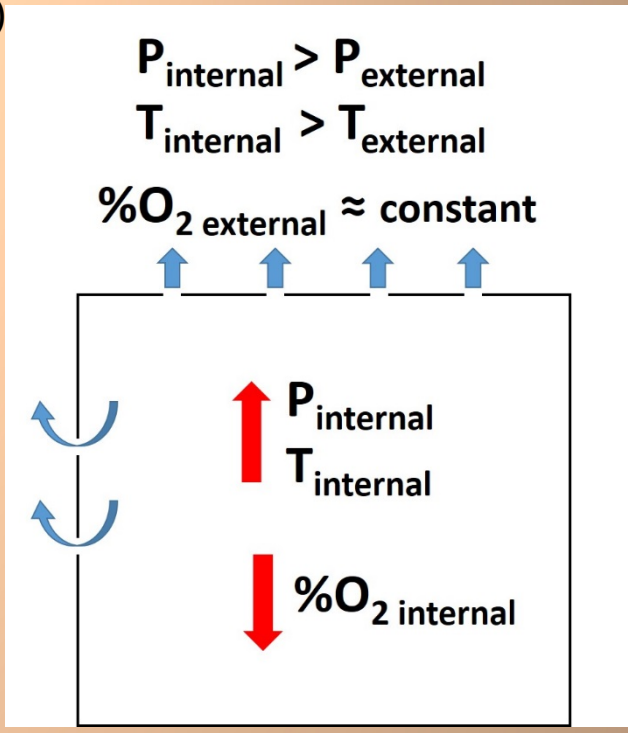
- Simplified Model - Assumptions
  - % O2 within enclosure = $MOC_{Polyurethane}$ @ 14.7 psia(19%)
  - % O2 outside enclosure remains constant
  - Posttest atmosphere fully mixed
- Calculated estimate ~ ***40.08 %*** O2 for tests using foam

$$V_{free\ volume} = V_{chamber} - V_{enclosure}$$

$$V_{O2,free\ volume} = \%_{O2}^{o} * V_{free\ volume}$$

$$V_{O2,enclosure} = \%_{O2}^{f,enclosure} * V_{enclosure}$$

$$\%_{O2}^{f} = \frac{(V_{O2,enclosure} + V_{O2,free\ volume})}{V_{chamber}}$$

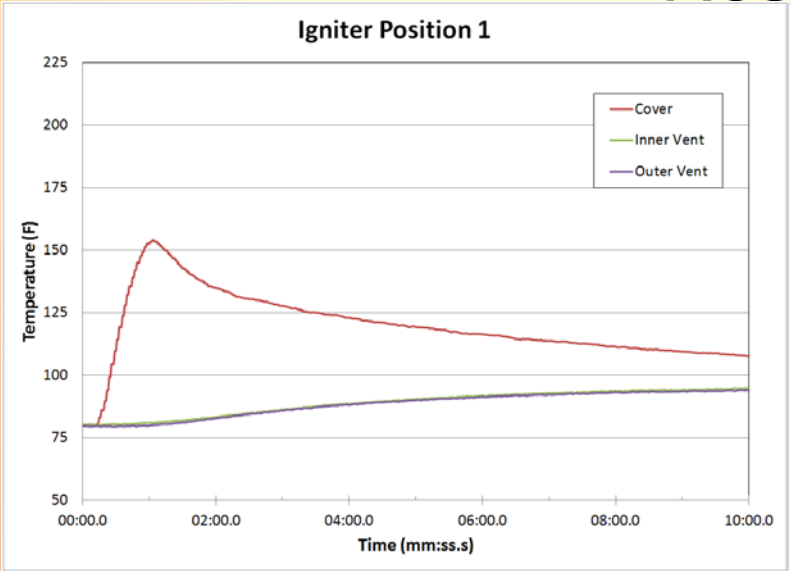


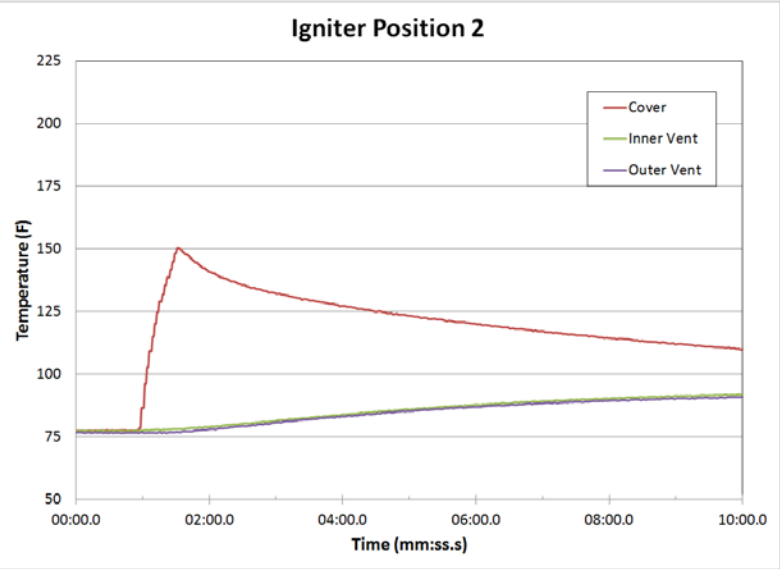
Conclusions

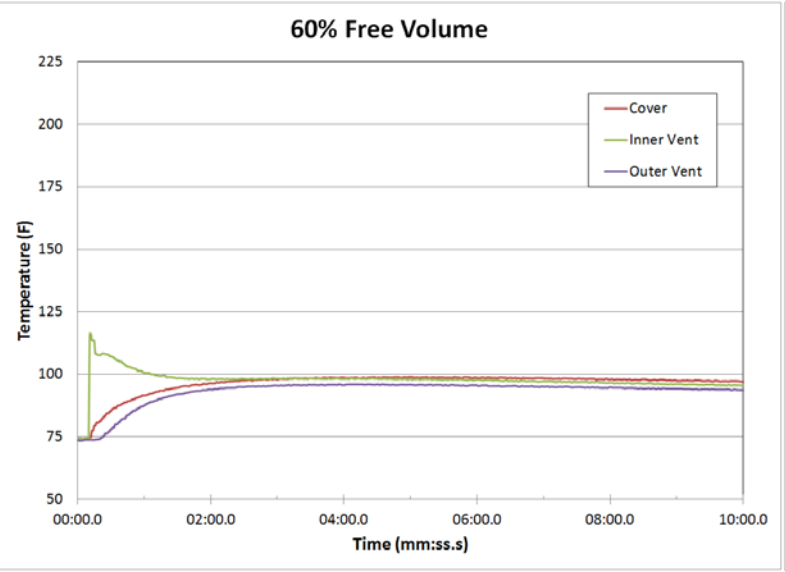
- Enclosure prevented:
  - Propagation to adjacent material (PMMA Witness plates)
  - Flame breaching
  - Excessive surface temperatures despite being thinner than current design
- Observations
  - Smoke observed emanating from PCB feed-throughs
  - Oxygen depletion within enclosure → extinguishment
  - Positive pressure inhibit the replenishing of fresh oxygen
- Note: all tests present here were performed w/out forced ventilation. Units with forced air convective cooling may behave differently.

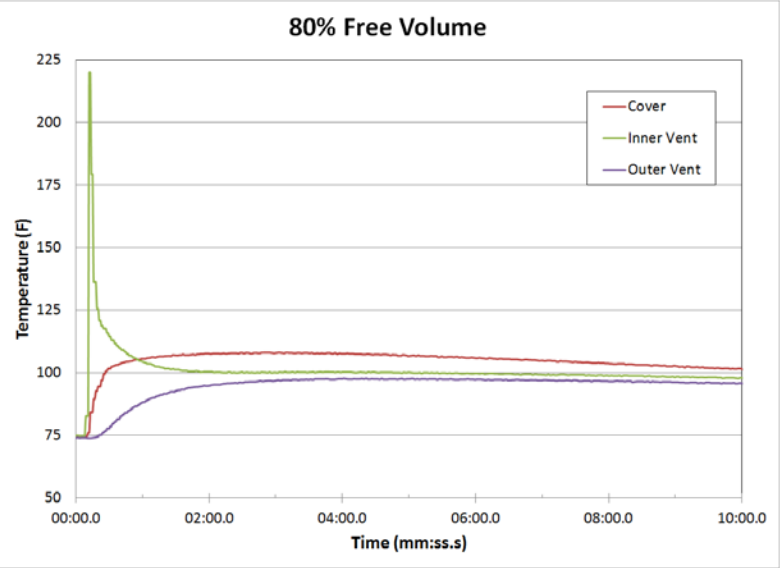
Back-up Slides

Results


Igniter Position 1
Temperature (F)
225
200
175
150
125
100
75
50
00:00.0
02:00.0
04:00.0
06:00.0
08:00.0
10:00.0
Time (mm:ss.s)
Cover
Inner Vent
Outer Vent


Igniter Position 2
Temperature (F)
225
200
175
150
125
100
75
50
00:00.0
02:00.0
04:00.0
06:00.0
08:00.0
10:00.0
Time (mm:ss.s)
Cover
Inner Vent
Outer Vent


60% Free Volume
Temperature (F)
225
200
175
150
125
100
75
50
00:00.0
02:00.0
04:00.0
06:00.0
08:00.0
10:00.0
Time (mm:ss.s)
Cover
Inner Vent
Outer Vent


80% Free Volume
Temperature (F)
225
200
175
150
125
100
75
50
00:00.0
02:00.0
04:00.0
06:00.0
08:00.0
10:00.0
Time (mm:ss.s)
Cover
Inner Vent
Outer Vent