Inaccessible Area Fire Tests on Composite Structure

Presented to: 8th Triennial International Aircraft Fire & Cabin Safety Research Conference

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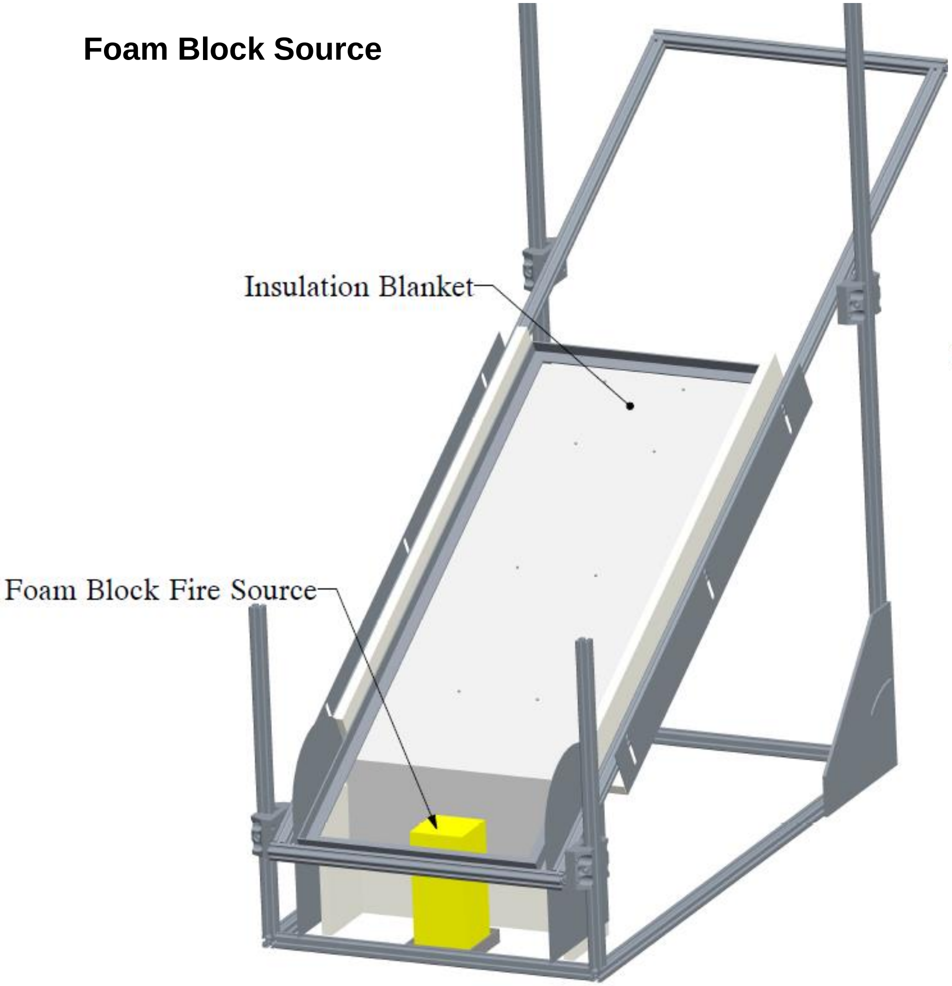
Federal Aviation Administration

Introduction

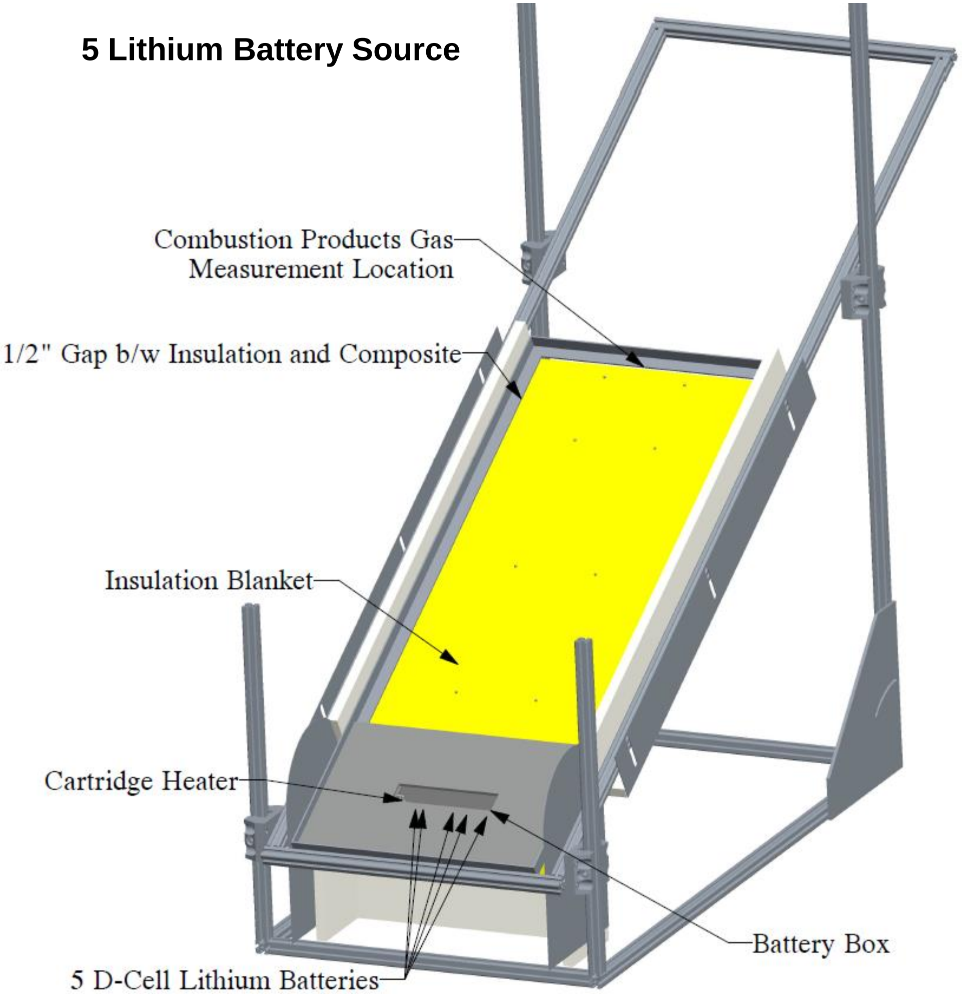
- **Tests were performed to determine the influence of a variety of configurational factors on inboard flame propagation of composite fuselage panels**
  - Insulation-panel spacing
  - Heat retention near panel surface
  - Outboard surface heat loss
  - Fire source strength
- **CFRP panels were procured for this testing**
  - 0.1” thickness
  - Quasi-isotropic tape layup, single outer ply of woven fabric
  - 350°F cure toughened epoxy

Test Configurations

Foam Block Source

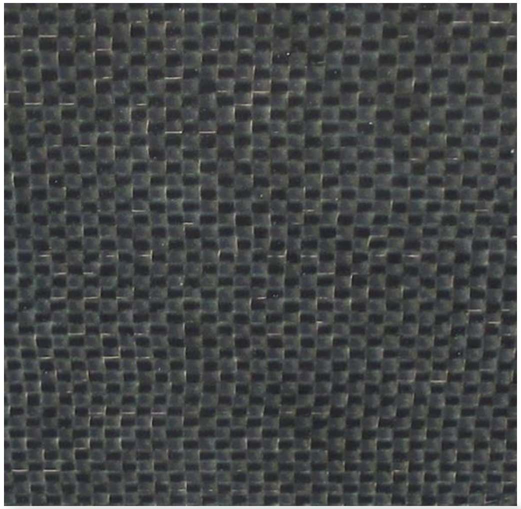


5 Lithium Battery Source



Test Results

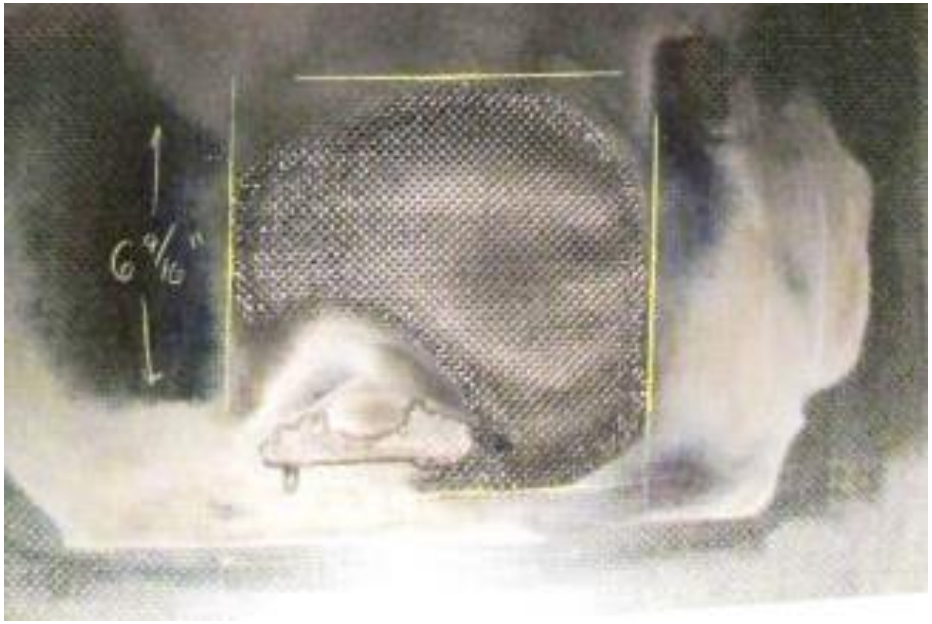
- **Flat Panel Tests**
  - Under certain conditions, the foam block fire source can cause the CFRP panel to propagate the fire and completely burn
    - Sample-insulation distance critical (approx ½”)
    - Foam block fire box area insulation and airflow also critical to direct all heat towards sample and develop flow up and along CFRP panel
- **Simulated Structure and Panel Tests**
  - Three dimensional geometry of CFRP stringers and frames add complexity
  - After many iterations and variations of the panel-insulation spacing, full length propagation was achieved
- **Simulated Primary Lithium Battery Powered Electronic Locator Transmitter (ELT) failure adjacent to CFRP panel**
  - Higher intensity fire source
  - Able to get full length flame propagation
- **Exterior surface cooling tests**
  - Water spray cooling of exterior surface was more than adequate to prevent flame propagation in all scenarios where full propagation was found under static ambient exterior surface conditions



Test Matrix: Foam Block Ignition Source

Date	Test Name	Configuration	Insul. Dist.	Burn Length	Burn Width
1/22/2015	Baseline	Std. Config.	n/a	6.5625	6.6875
1/22/2015	Insulation 1	Insul Pressed Tightly to Skin	0	0	0
1/26/2015	Insulation 2	Insul Pressed Tightly to Skin	0	7.5	15.25
1/27/2015	Insulation 3	Insul slightly further from skin	0.5	10	15
1/27/2015	Insulation 4	Insul further from skin	1	9.25	6.25
1/28/2015	Insulation 5	Insul closer, added gasket	0.5	46	12
3/4/2015	Insulation 6	Insulation 5 w/water cooling	0.5	0	0
3/9/2015	Insulation 7	repeat of insulation 6	0.5	0	0
3/17/2015	Insulation 8	CFRP with frames	0.5	46	12
3/19/2015	Insulation 9	CFRP with frames & water cooling	0.5	3	3
3/24/2015	Insulation 10	CFRP frames & stringers	0.5	16	14
3/27/2015	Insulation 11	CFRP frames & stringers (flipped panel)	1	2	5
4/2/2015	Insulation 12	CFRP frames & stringers	1	8	7
4/2/2015	Insulation 13	CFRP frames & stringers (flipped panel)	1	9	8
4/2/2015	Insulation 14	CFRP frames & stringers (sealed w/RTV)	1	7	4
4/30/2015	Insulation 15	CFRP frames & stringers (flipped panel+RTV)	0.5	8	5
4/30/2015	Insulation 16	CFRP frames & stringers (sealed w/RTV)	0.5	33.5	14
5/28/2015	Insulation 17	Insulation 16 w/water cooling	0.5	9	9.75

Test: Baseline – No Insulation



Burn Area: $6\,{}^{9}/_{16}$ " L × $6\,{}^{11}/_{16}$ " W

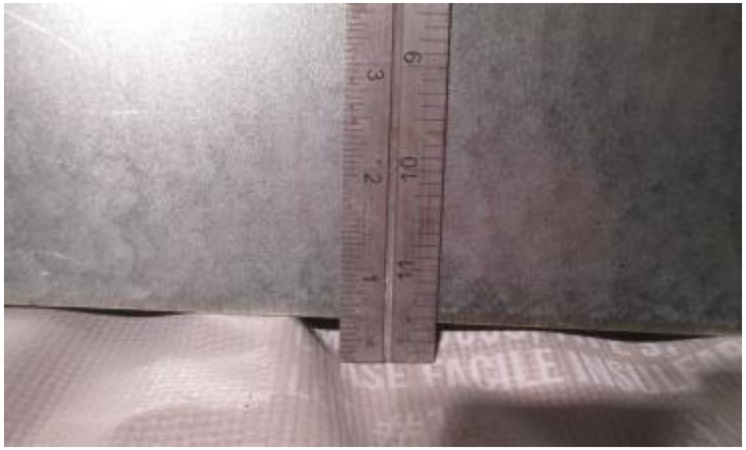
Test: Insulation 2
Insulation Pressed Tightly Against Panel

Before

After

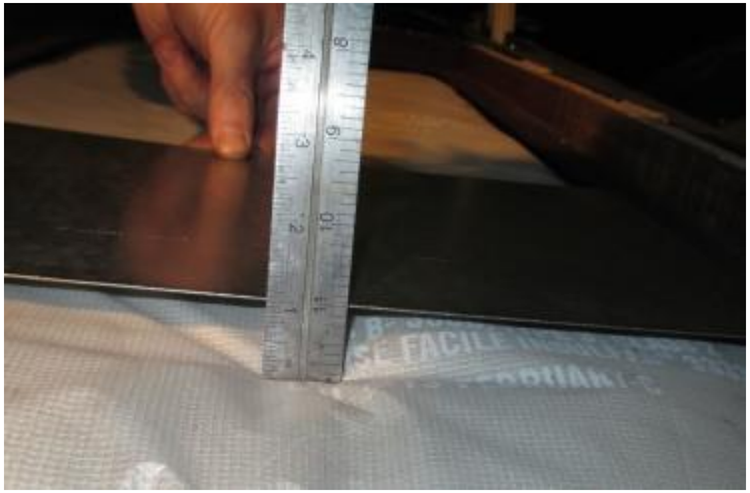
Burn Area: $7\,{}^{1}/_{2}\text{" L} \times 15\,{}^{1}/_{4}\text{"}W$

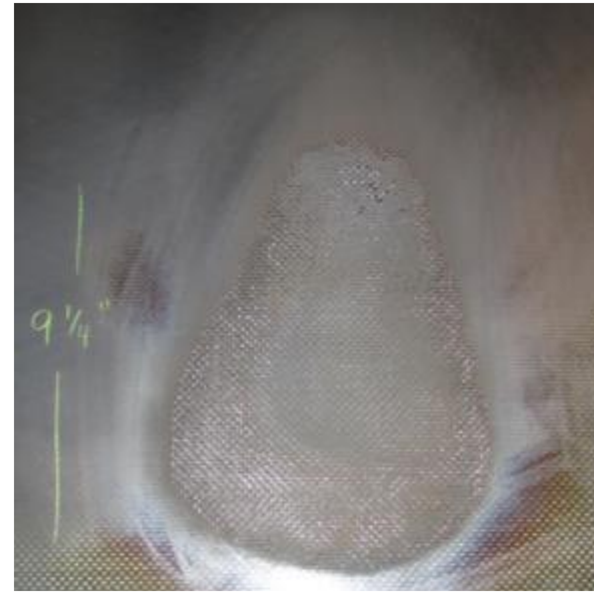
Test: Insulation 3
Insulation Approximately ½" From Panel



Burn Area: 10" L × 15" W

Test: Insulation 4
Insulation Approximately 1” From Panel





Burn Area: $9\,{}^{1}/_{4}$ " L × $6\,{}^{1}/_{4}$ "W

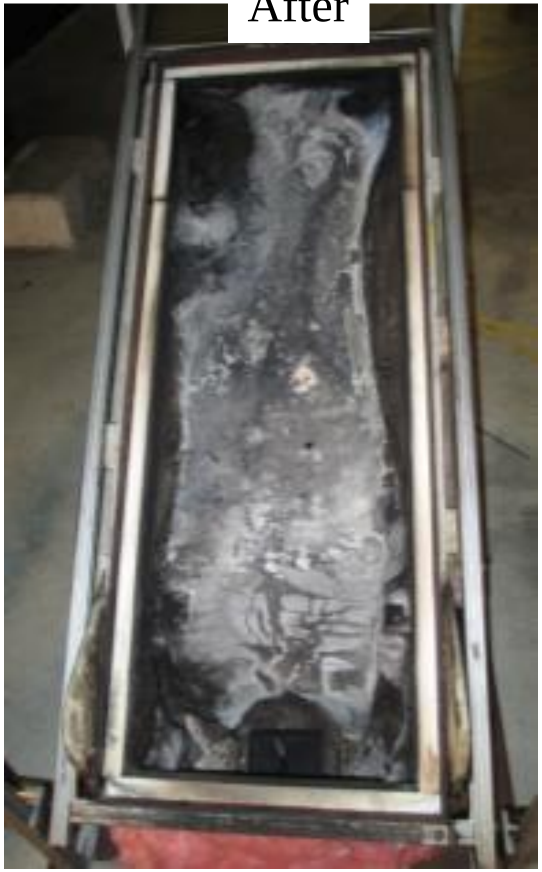
Before

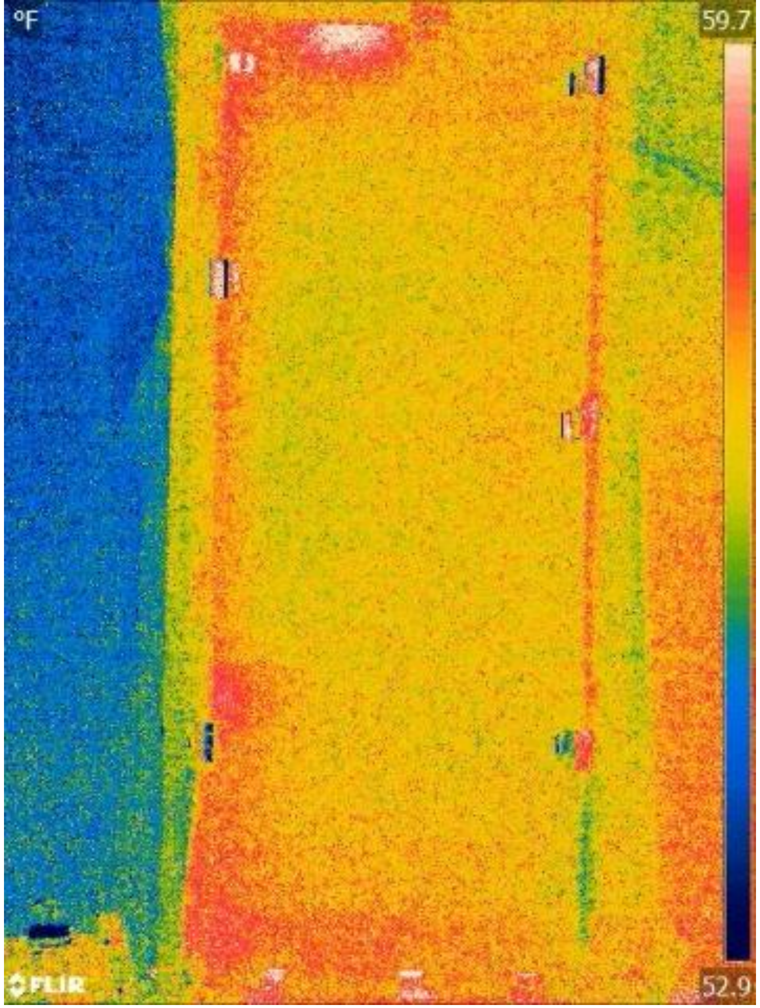
After

Test: Insulation 5
Insulation Approximately .5” From Panel
Installed gasket b/w frame and sample, sealed off leaks

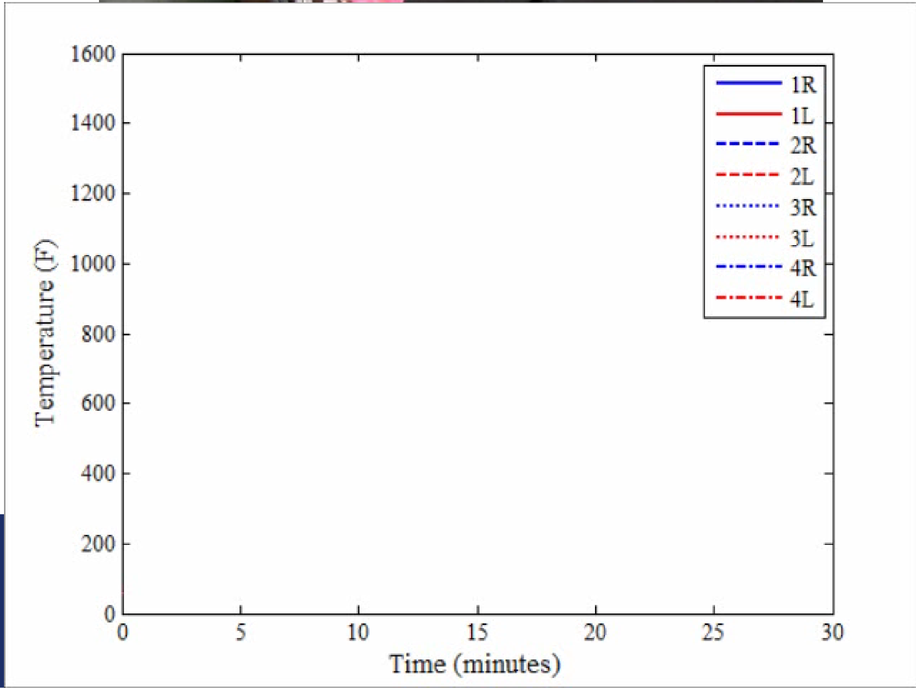
Before

After

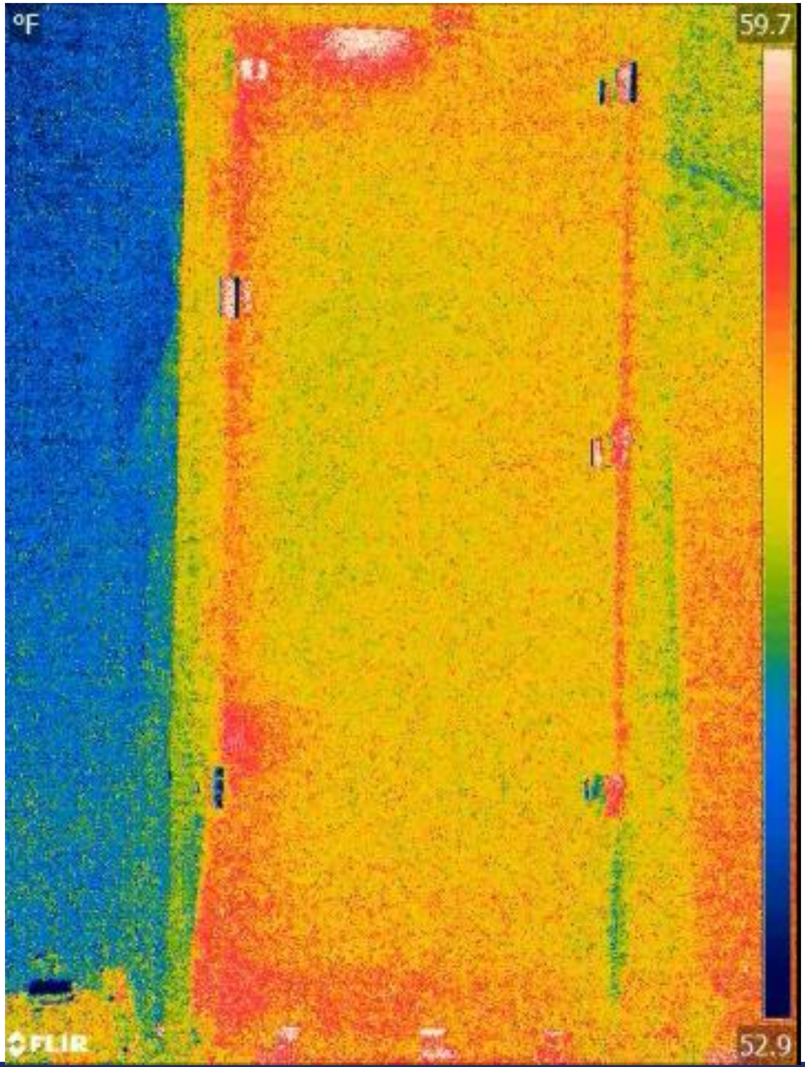




Burn Area: 46 " L × 15"W

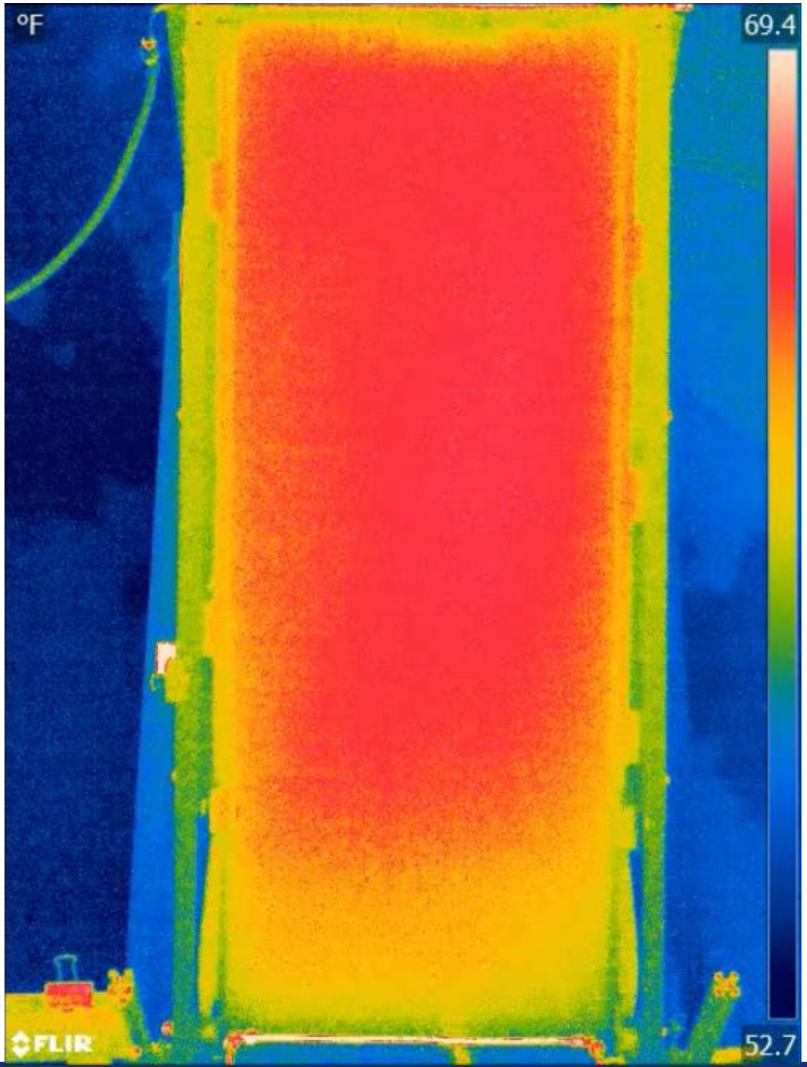


Static Ambient Backside
55°F Air
8x Play Speed



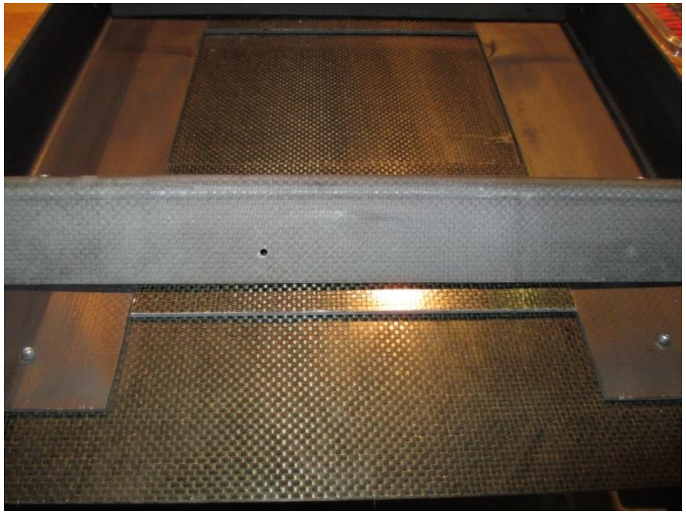
Insulation 5

Backside Cooling
1.33 GPM Water @ 55°F
8x Play Speed

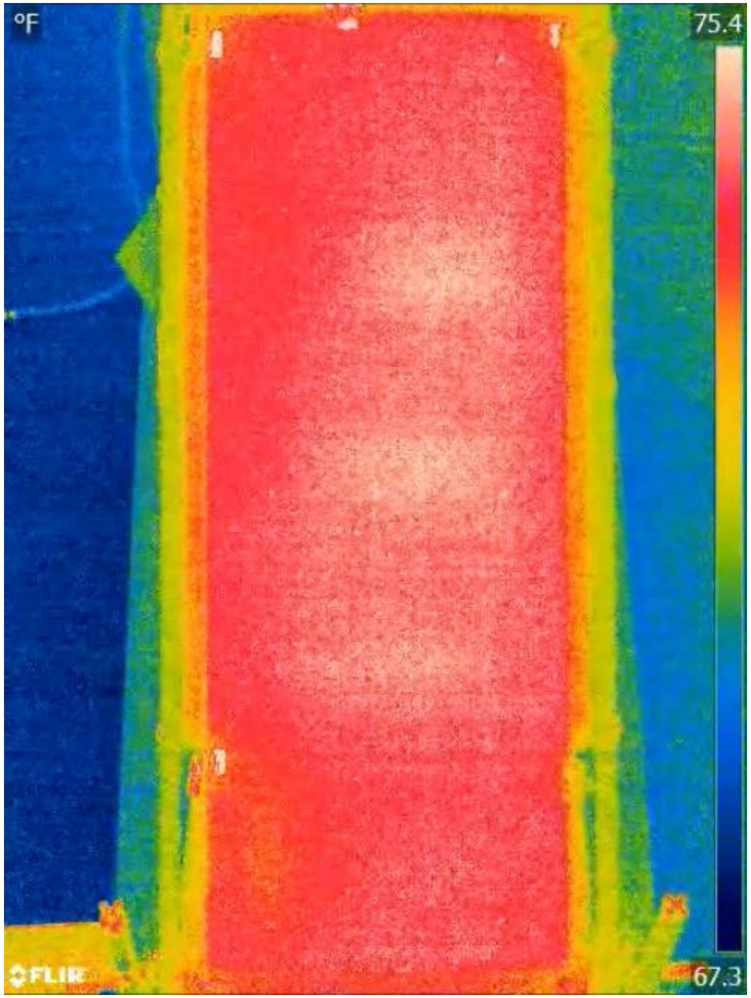


Insulation 6

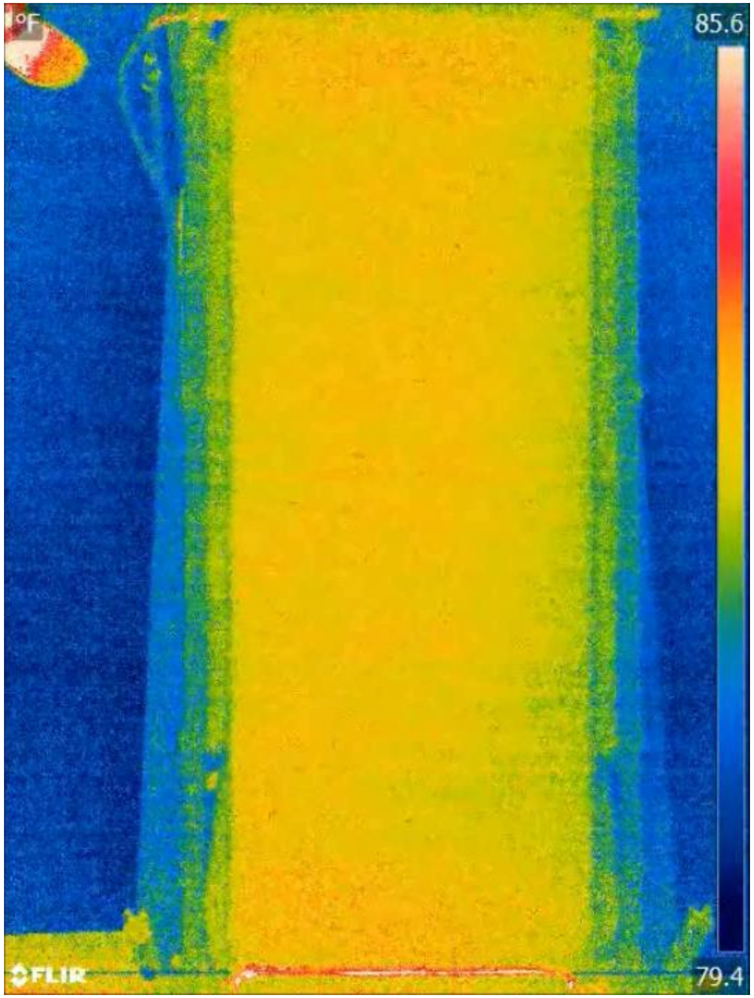
Simulated Shear Ties and Stringers



Insulation 16 Post-Test

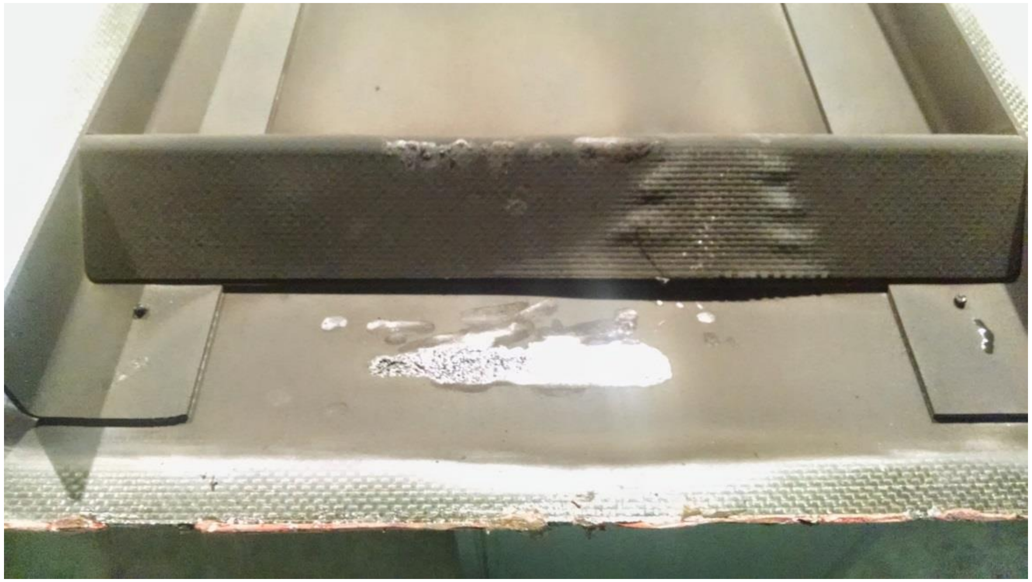


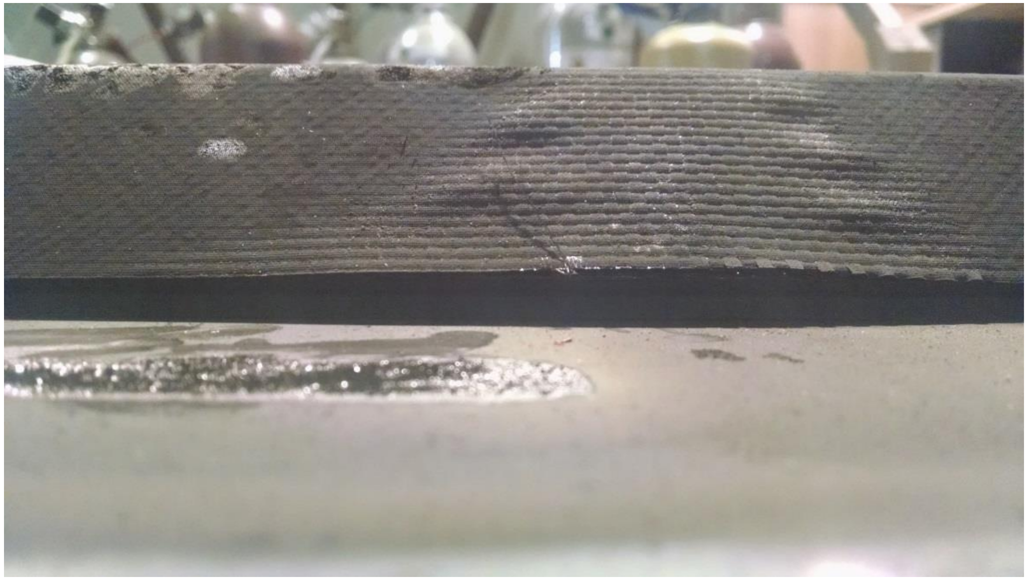
Structure no cooling

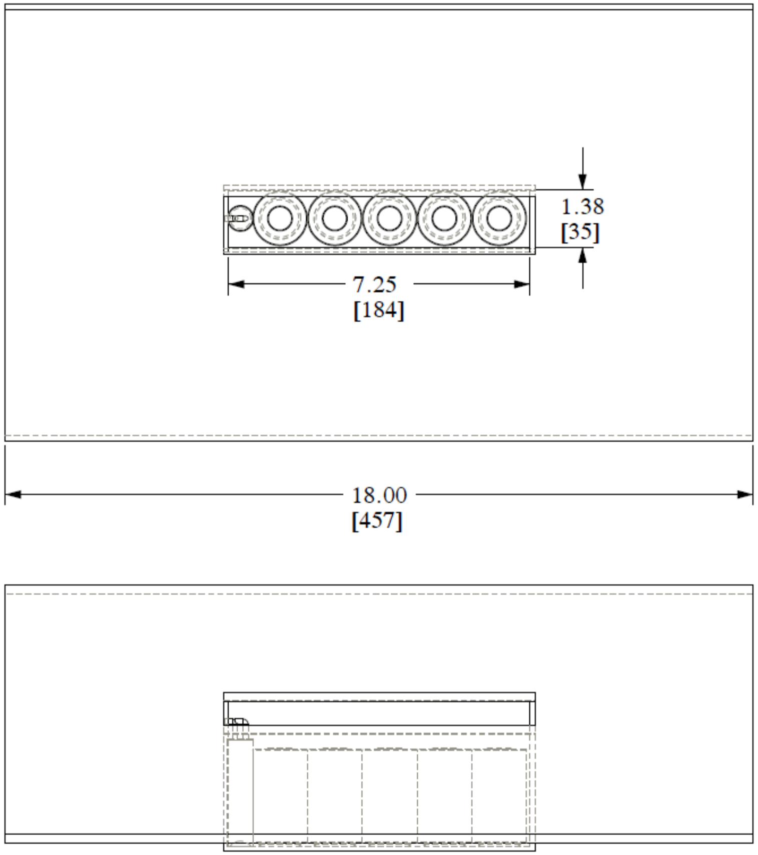


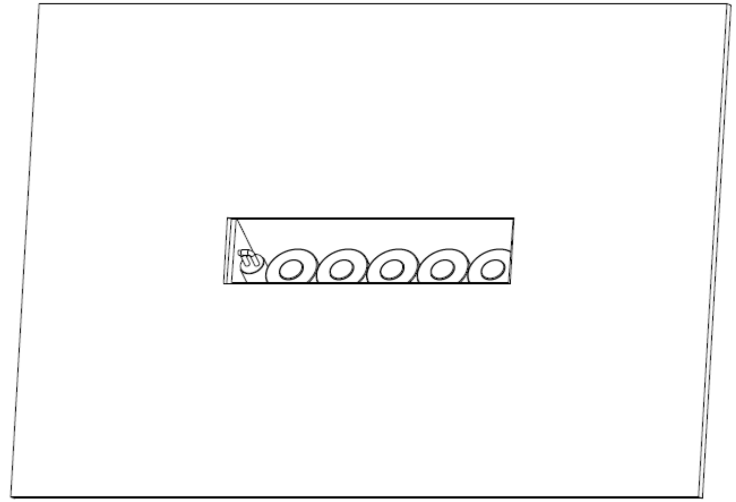
Structure w/cooling

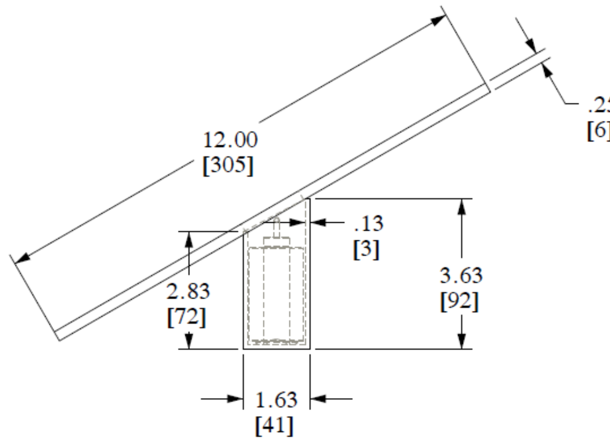
Insulation 17 Post-Test

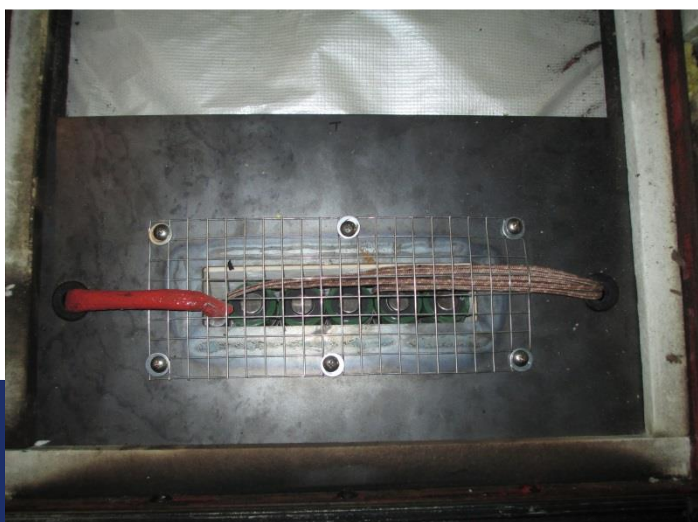






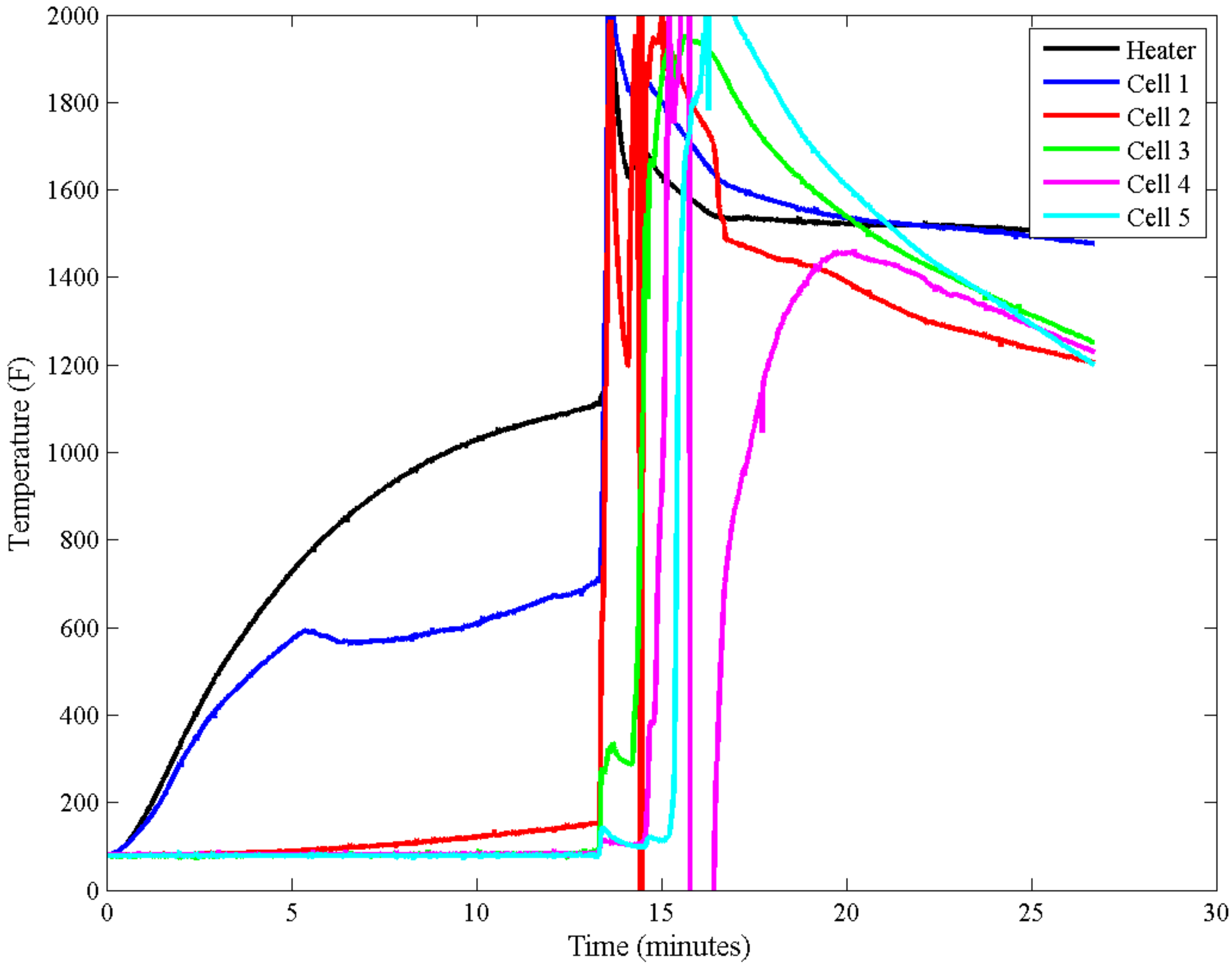






Battery Configuration

Battery Cell Temperatures

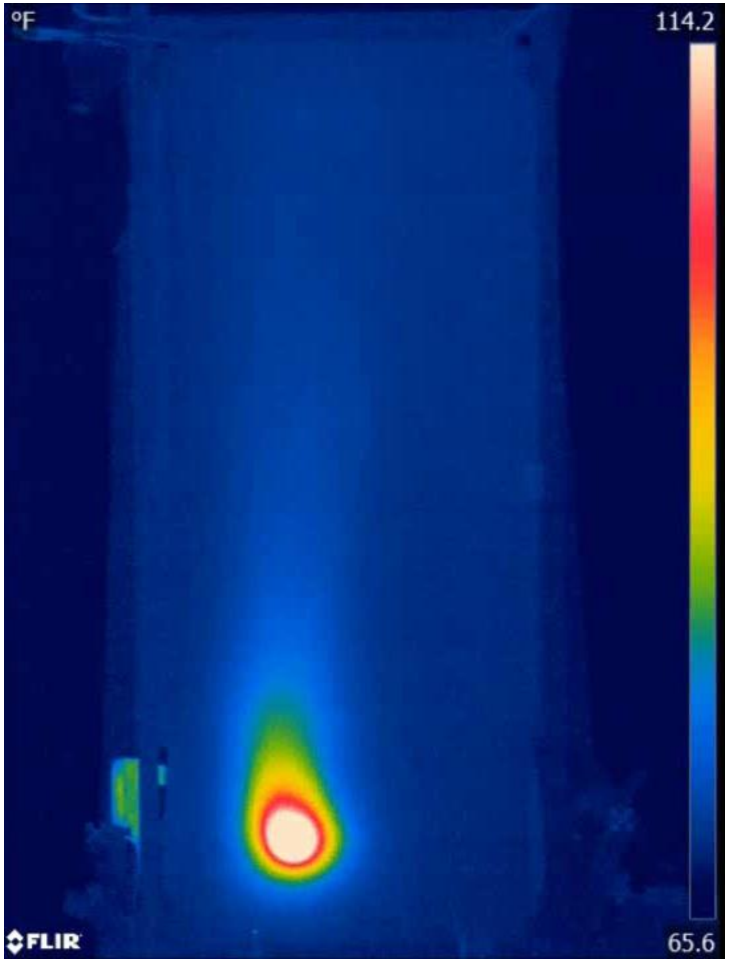


Gas Analyzers

Gas Measurement Location

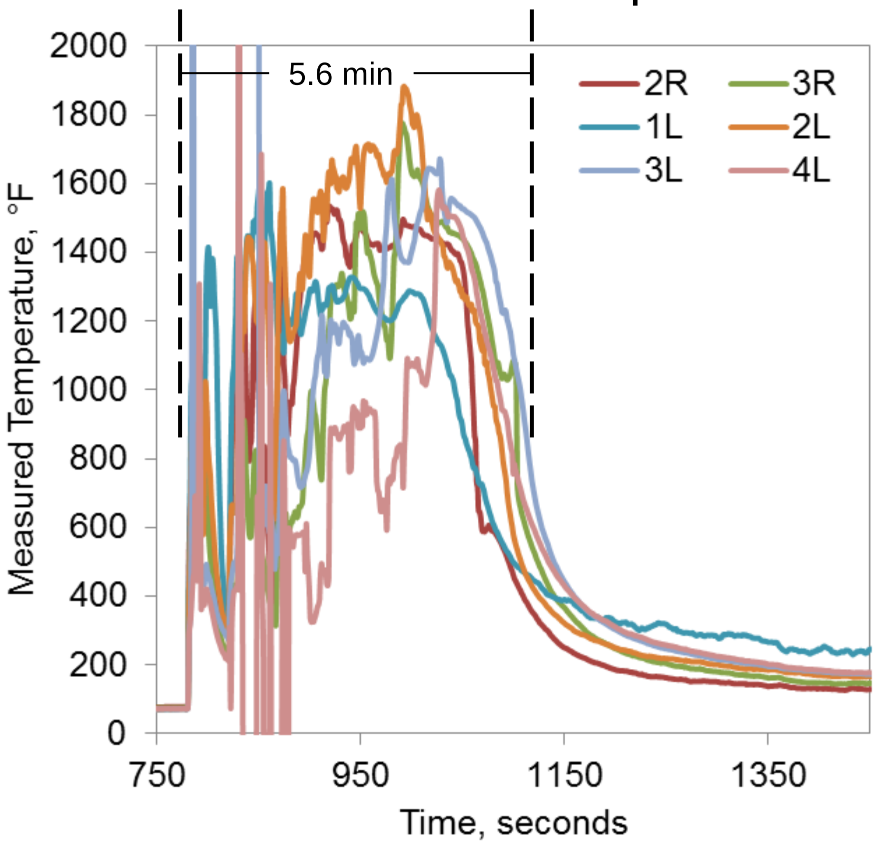
- **Non-dispersive IR Measurement of CO and CO_2**
- **Paramagnetic Measurement of O_2**
- **Single stream sample plumbed in series**
- **Filtered and dried to 1 micron & 5°C dew point**
- **6 Lpm flowrate**
- **Approx 20’ of ¼” sample line**

ELT Fire Source – 4x Play Speed

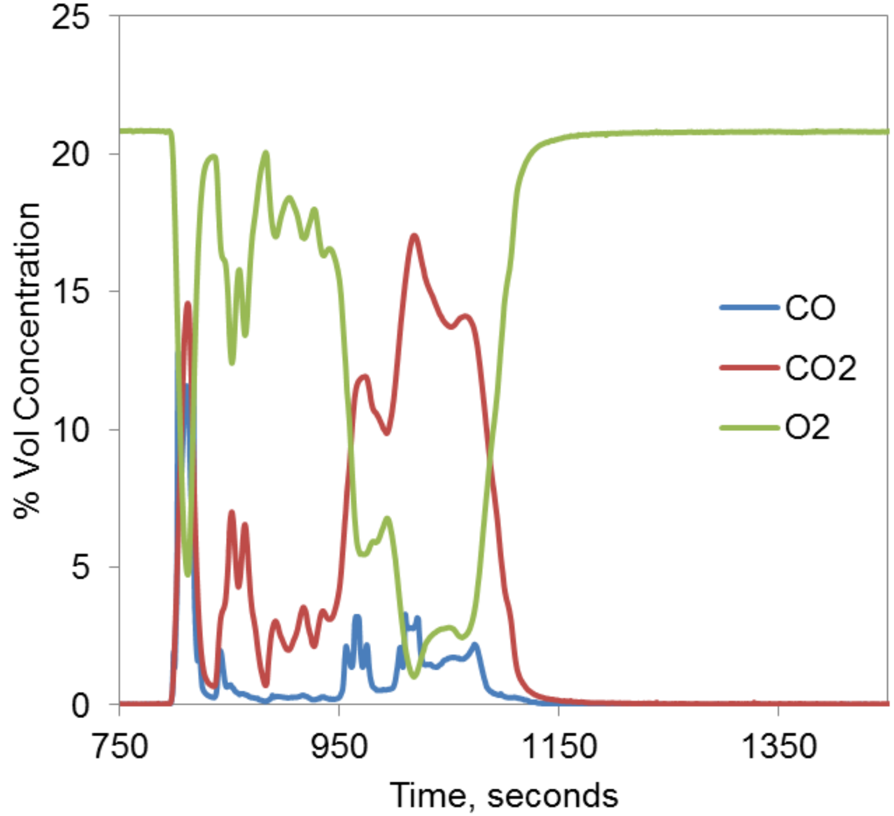


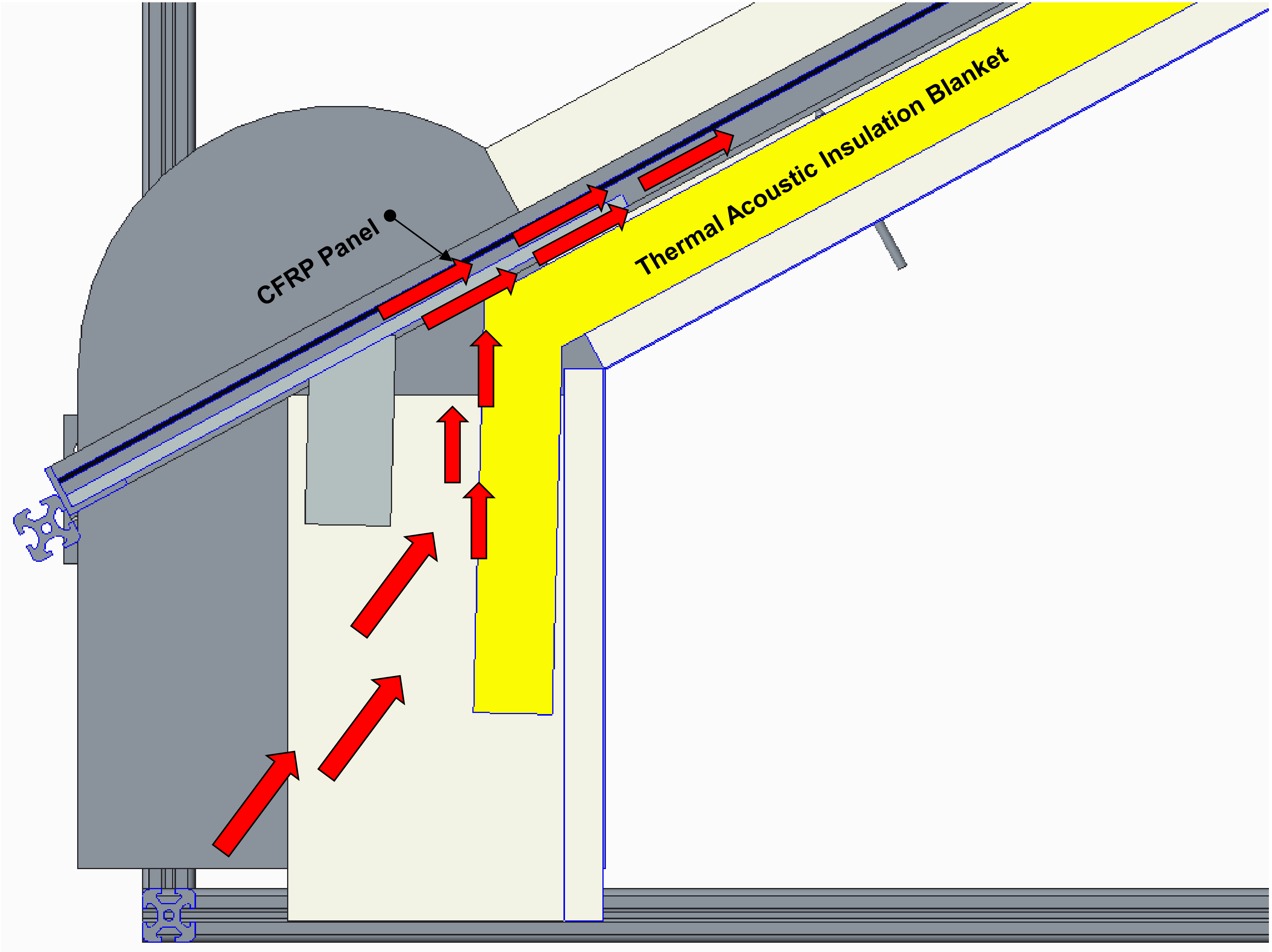
ELT Fire Source Measured Results

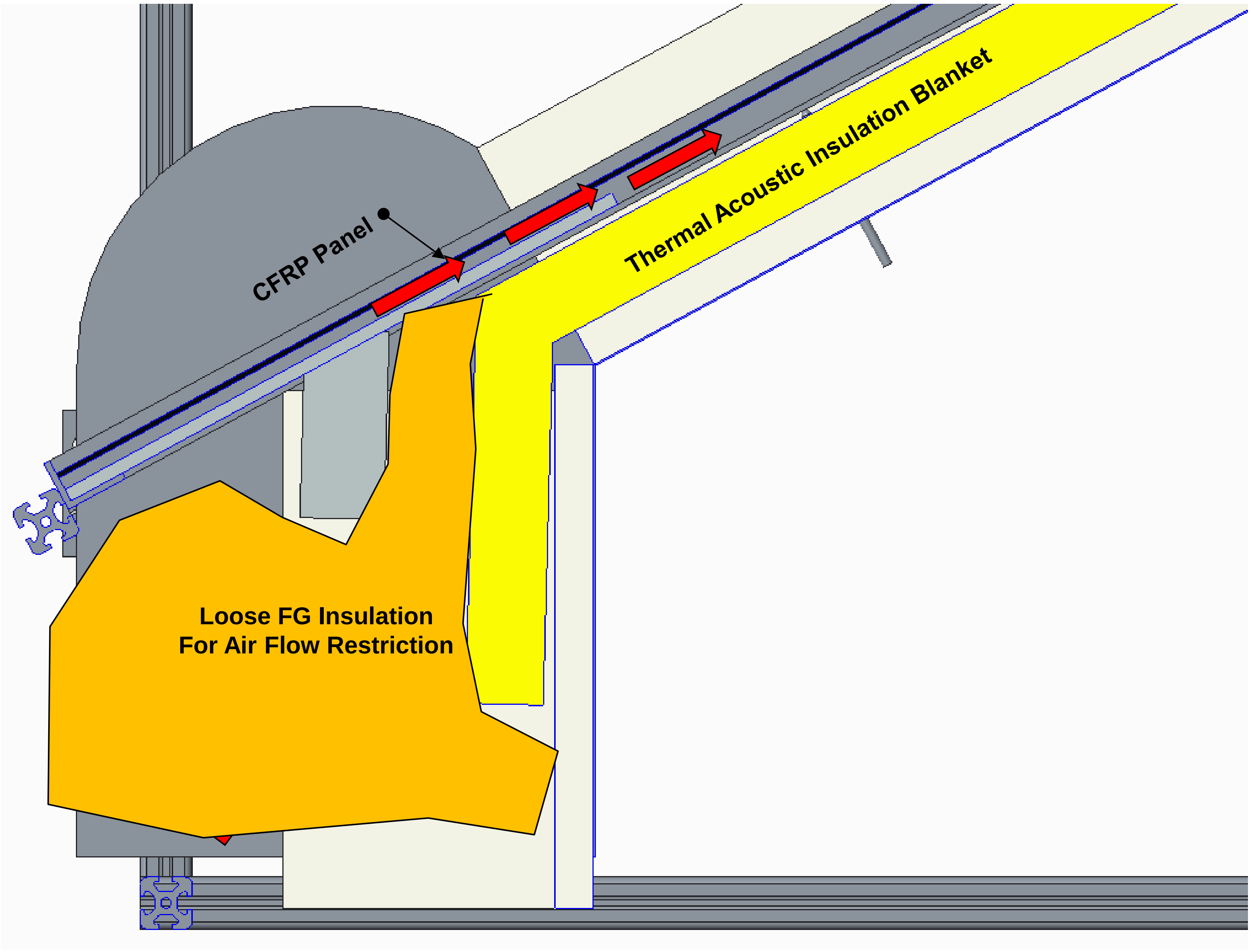
Measured Inboard Flame Temperatures



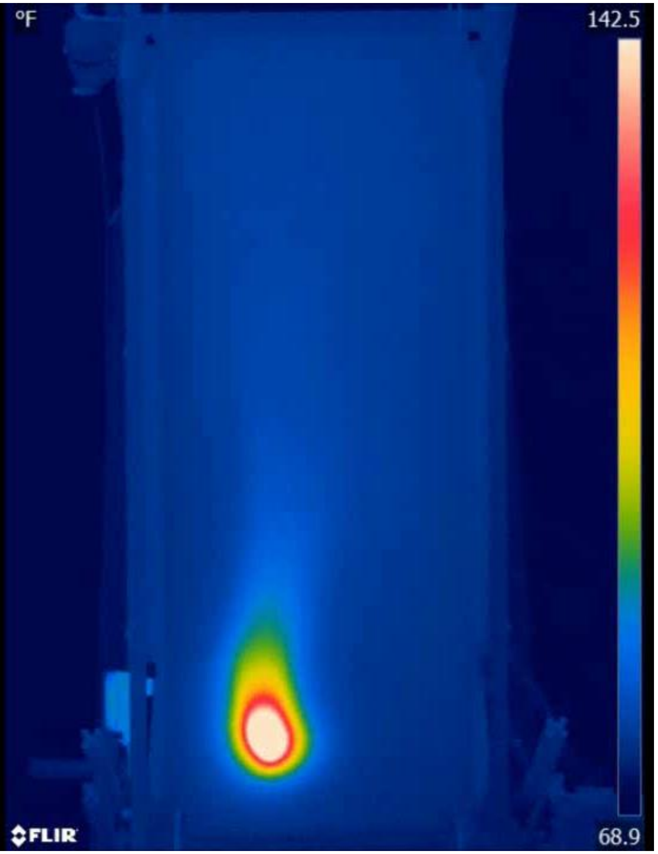
Measured Inboard Gas Concentrations

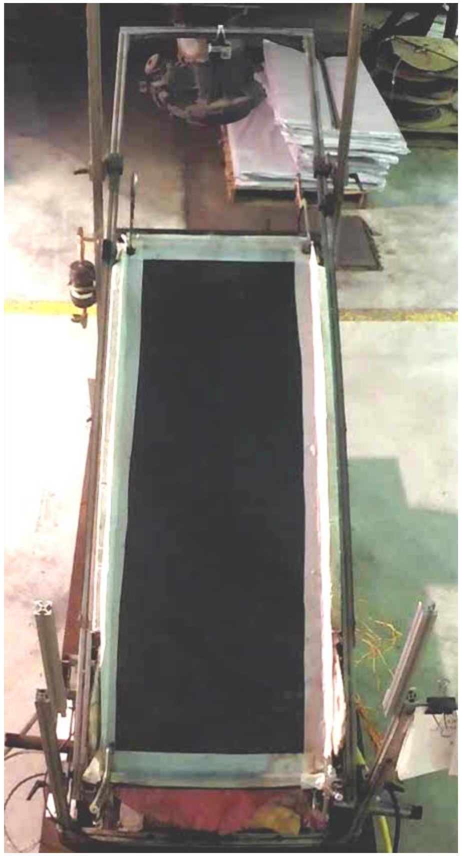


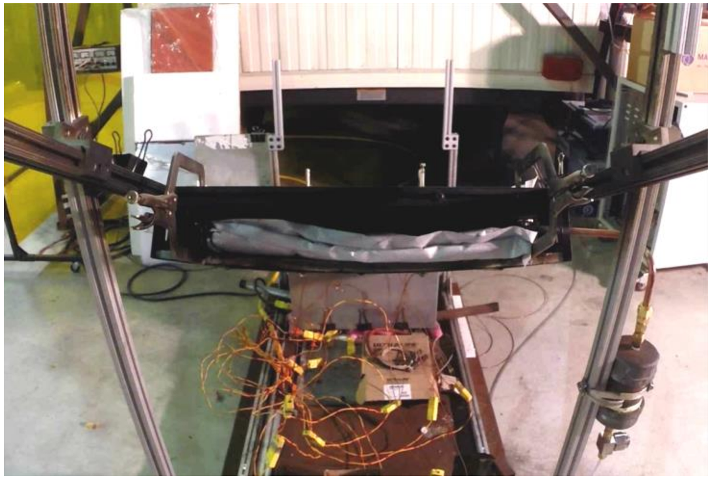

CFRP Panel
Thermal Acoustic Insulation Blanket


CFRP Panel
Thermal Acoustic Insulation Blanket
Loose FG Insulation
For Air Flow Restriction

ELT Fire Source w/Restricted Air Flow
4x Play Speed

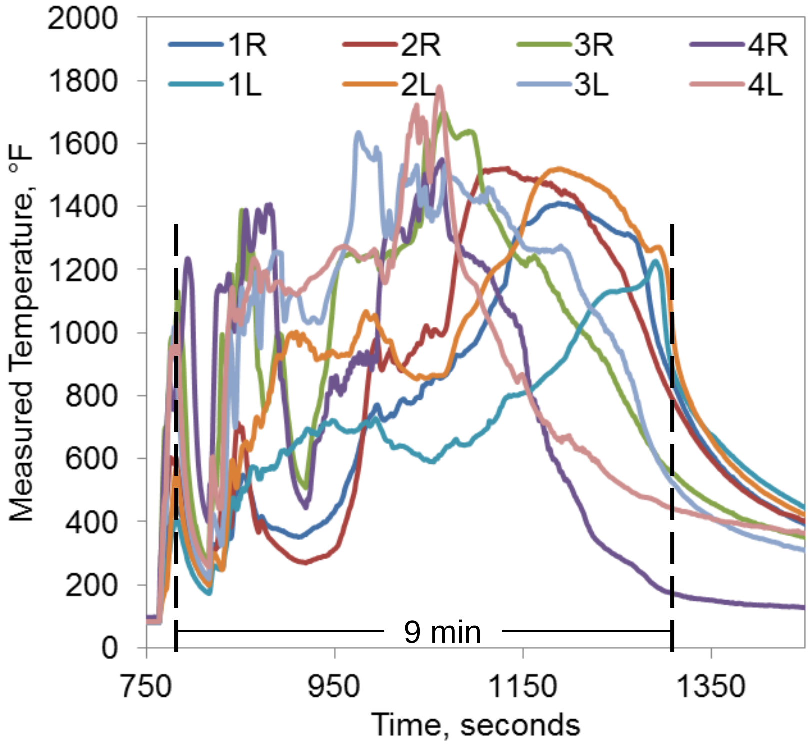




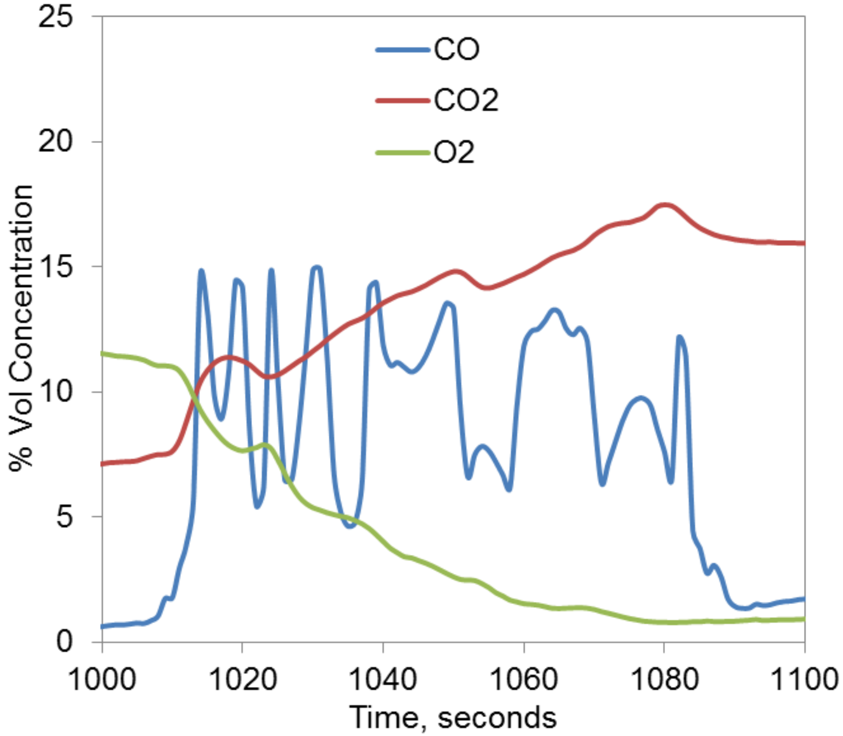


ELT Fire Source w/Restricted Air Flow Measured Results

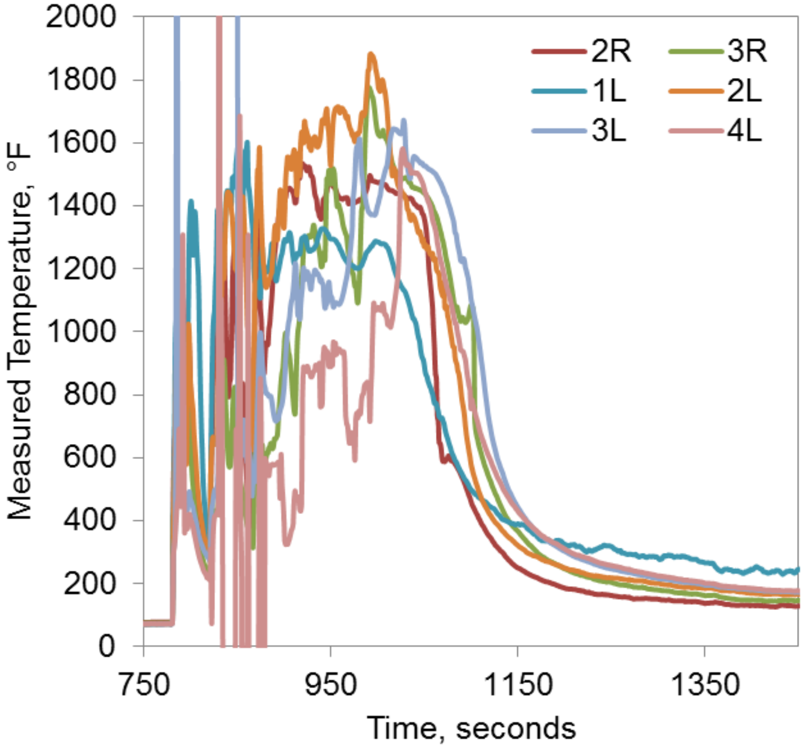
Measured Inboard Flame Temperatures



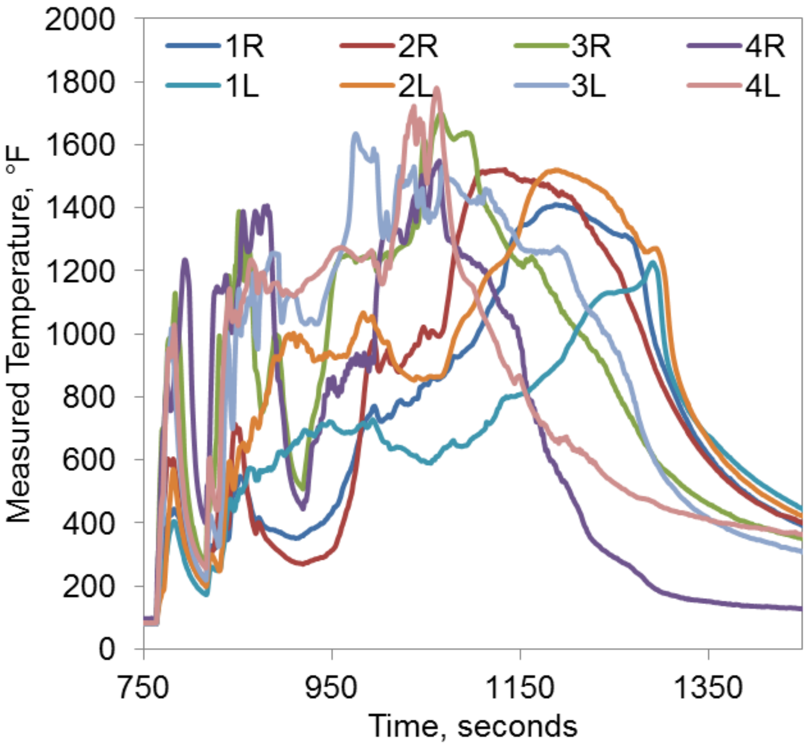
Measured Inboard Gas Concentrations

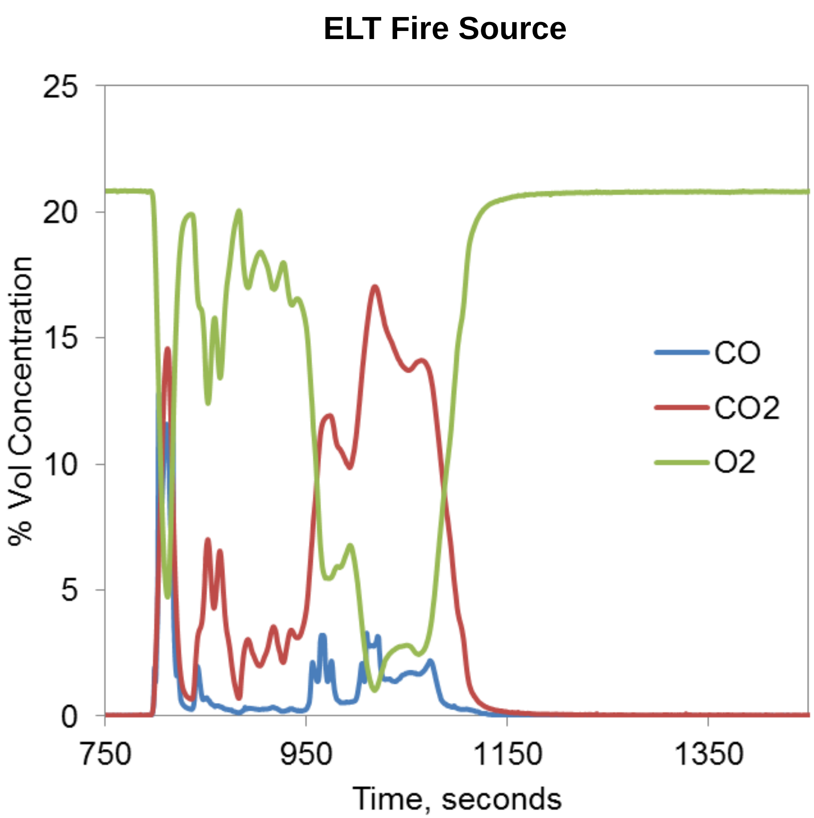


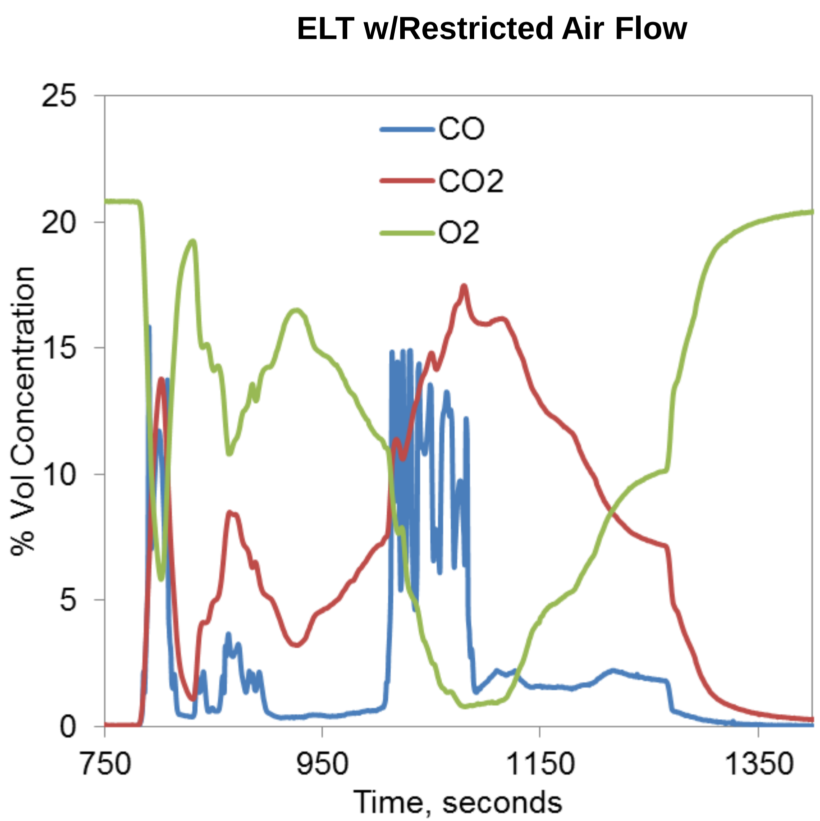
ELT Fire Source



ELT w/Restricted Air Flow




ELT Fire Source
% Vol Concentration
Time, seconds
CO
CO2
O2
0
5
10
15
20
25
750
950
1150
1350


ELT w/Restricted Air Flow
% Vol Concentration
Time, seconds
CO
CO2
O2
0
5
10
15
20
25
750
950
1150
1350

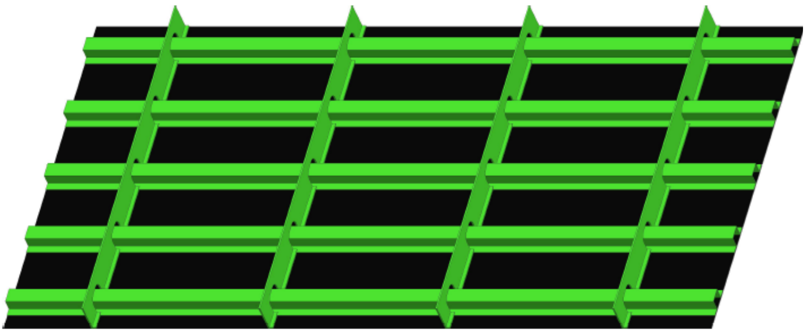
ELT Fire Source Test Observations

- The initial ELT fire source test resulted in a full-length flame propagation along the CFRP panel
- CO measurements were lower than expected
- The location where air flow is inducted during ELT tests was restricted with loose fiberglass batting
- Less available air resulted in higher CO measurements and a longer CFRP burning duration

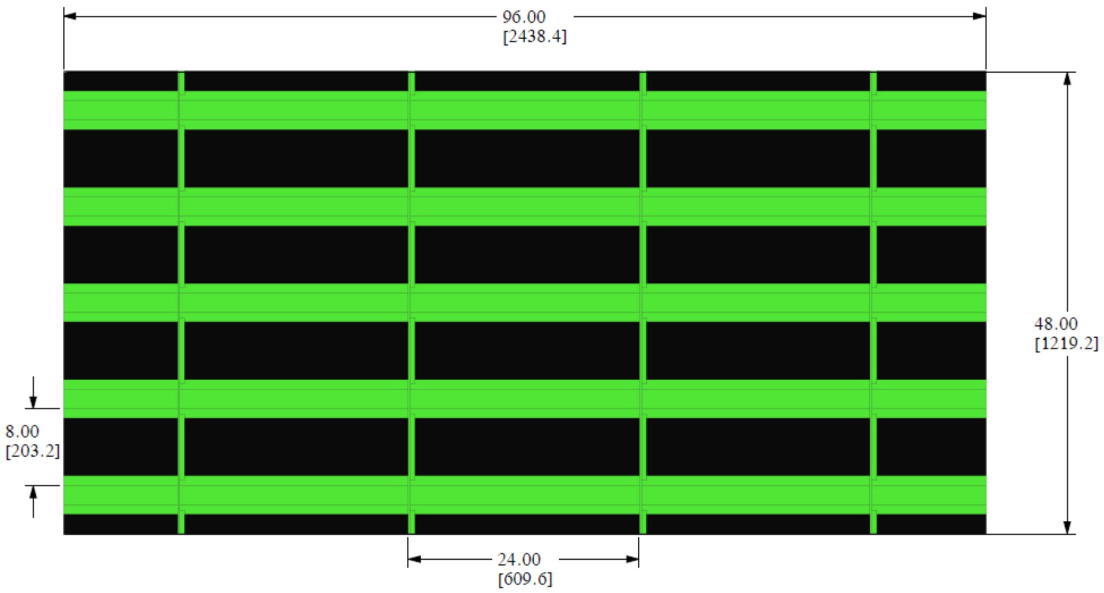
Main Takeaways

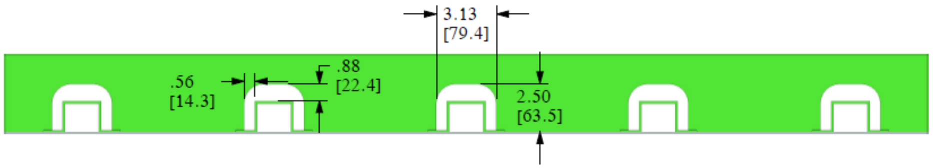
- **Foam block fire source and ELT fire source are fundamentally different**
  - Foam block requires sufficient air flow from the surrounding areas to fully develop, however
  - Foam block also requires a well-insulated enclosure in order to direct most of it's heat towards the test sample
  - ELT does not require sufficient air flow to fully develop
  - Once CFRP is burning from ELT source, very little airflow is required to maintain CFRP burning
- **All inaccessible aircraft areas are different**
  - Some may be so tight as to restrict air flow and inhibit flame propagation
  - Others may be just large enough to allow even a small fire to propagate
- **These tests represent only a handful of configurations**
- **Ultimate goal is to ensure that, for the most severe configurations where full length flame propagation is found, the propagation will be inhibited or eliminated when the exterior surface is cooled during in-flight conditions**

Large Scale CFRP Skin & Structure Tests

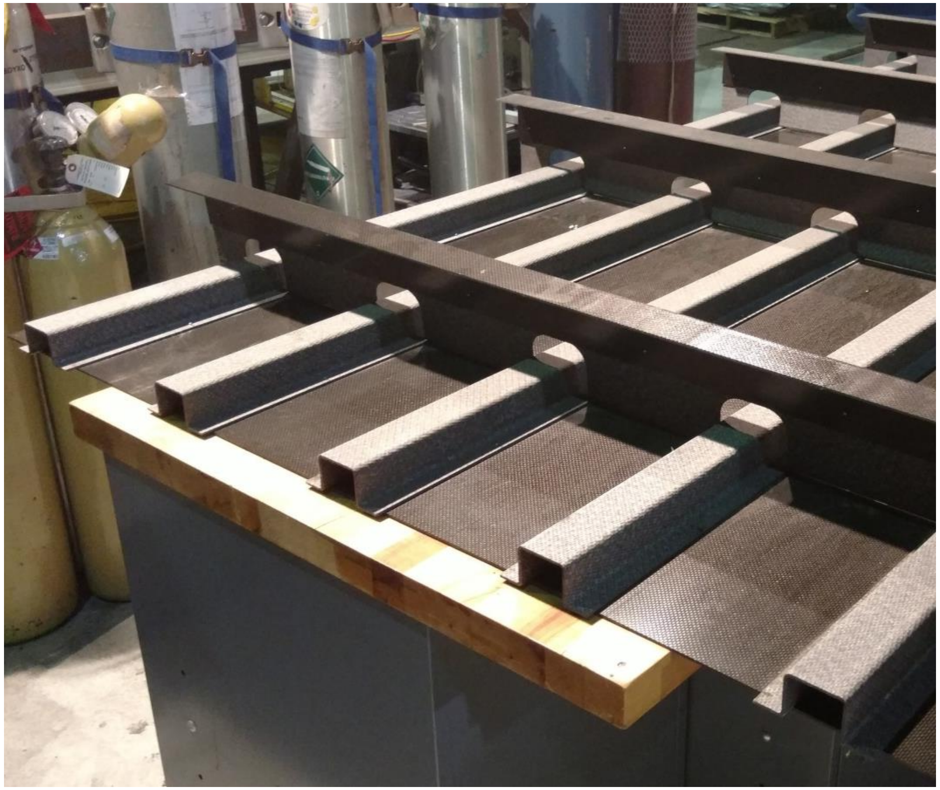


- Large scale CFRP skin and structure test fixture
- Study propagation of fire from bay-to-bay with and without cooling

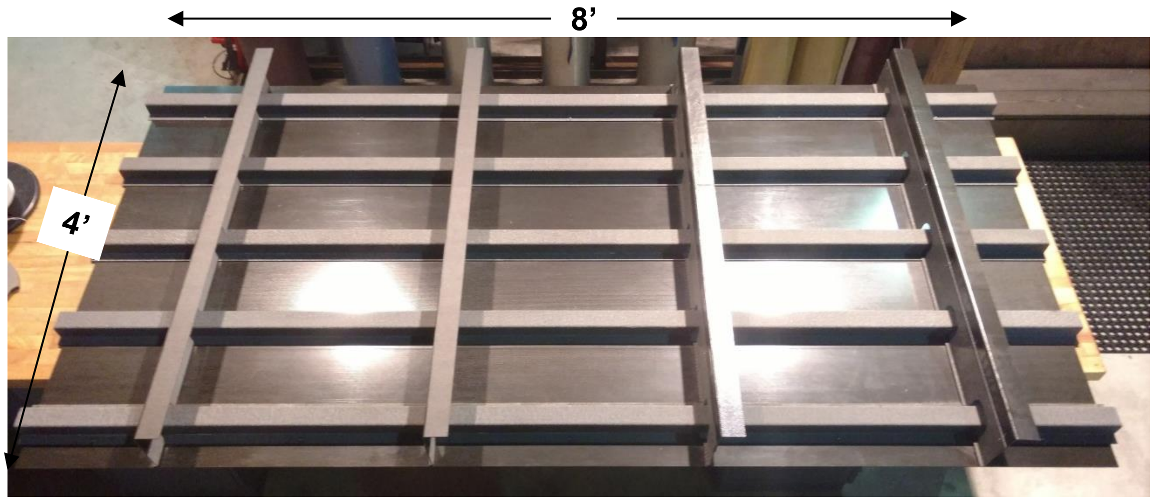


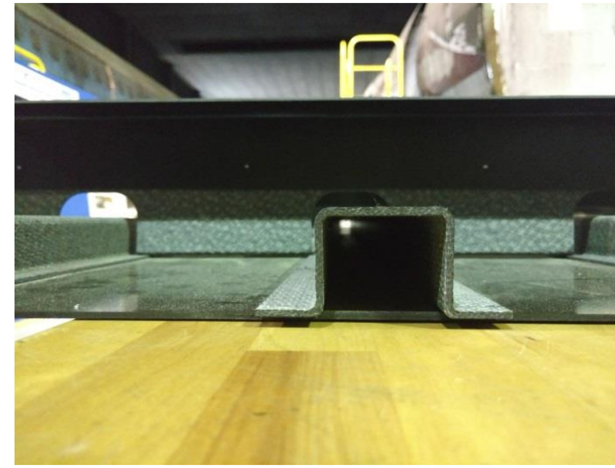


CFRP Structure Tests



Simulated CFRP Aircraft Structure

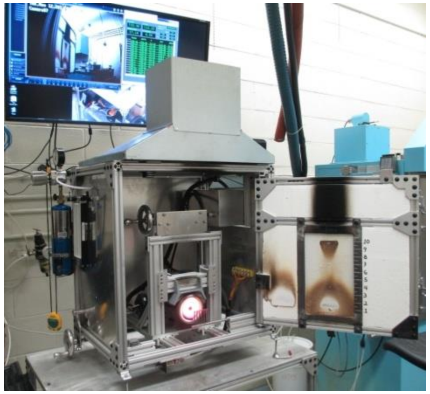




Large Scale Test Plan

- **Continue evaluating backside heat transfer methods to accurately represent in-flight cooling**
- **Begin planning baseline tests**
  - Construct rig to hold test panel at variable angles
  - Static ambient conditions on backside
    - Foam block
    - Simulated ELT
- **Test configuration guidance or suggestions welcome and encouraged**





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