COMPOSITE MATERIAL FIRE FIGHTING

Presented to: The Sixth Triennial International Fire & Cabin Safety Research Conference
Atlantic City, New Jersey

Presented by: John C. Hode
SRA International

Date: October 25-28, 2010

Creation of a Test Method

First objective:

- Determine if self-sustained combustion or smoldering will occur.
- Determine the time to naturally cool below 300°F (150°C)

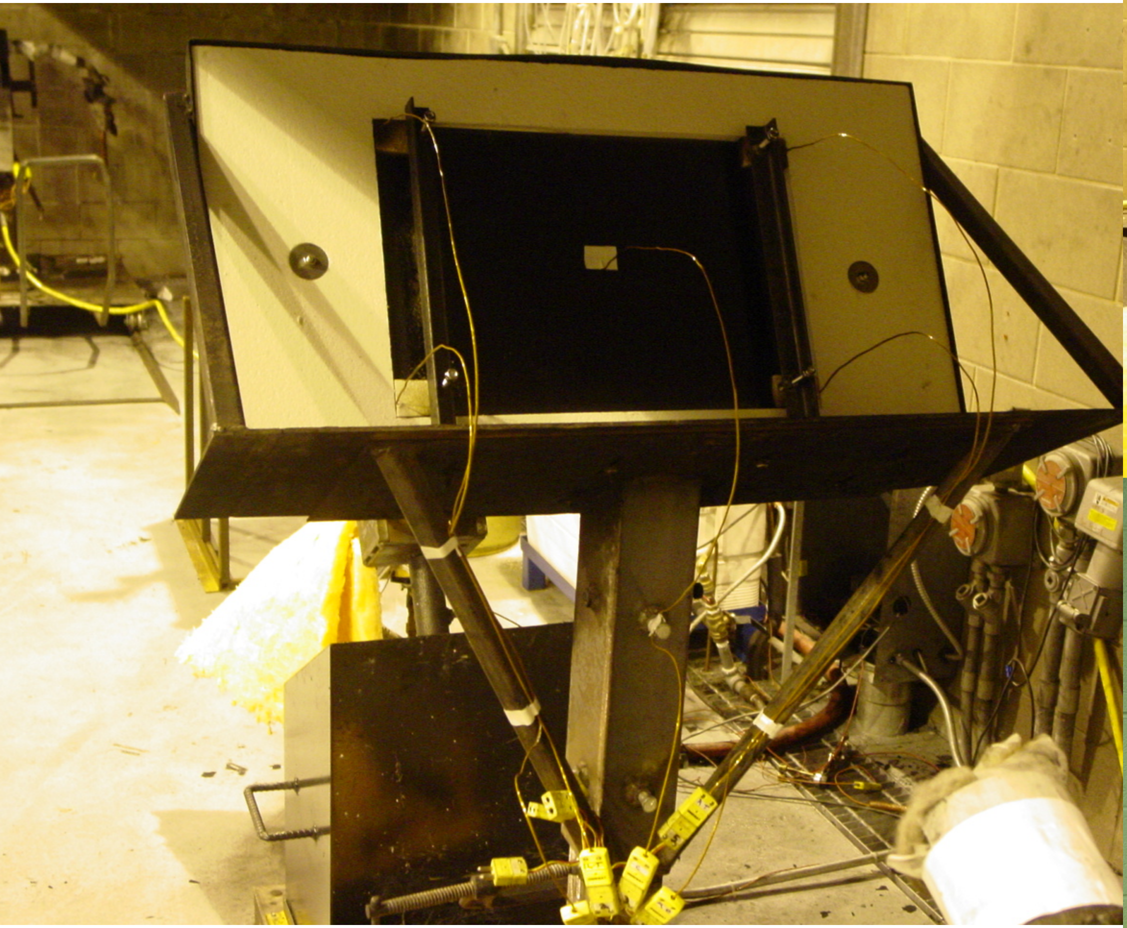
Second objective:

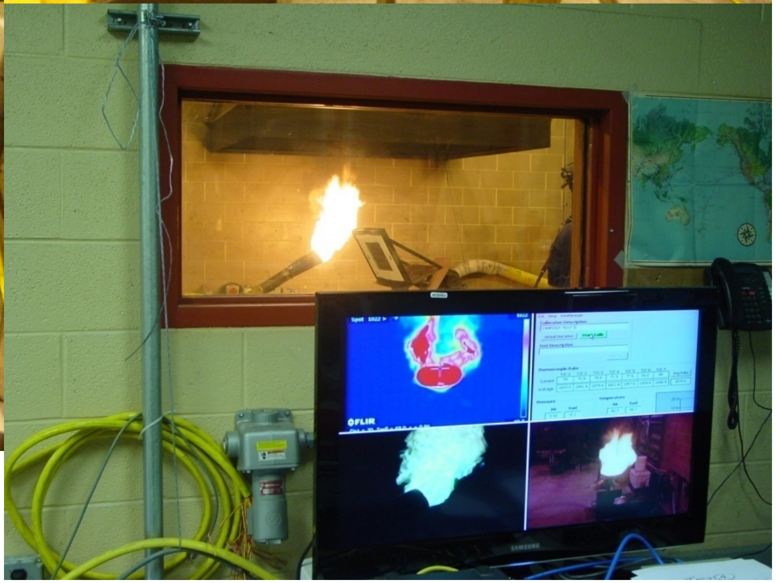
Determine how much fire agent is needed to extinguish visible fire and cool the material sufficiently to prevent re-ignition.

Exposure times of Initial tests:

- 10, 5, 3, 2, & 1 minutes
  - FAR Part 139 requires first due ARFF to arrive in 3 minutes.
  - Actual response times can be longer or shorter.

Initial Test Set-up





Initial Findings

1. Post-exposure flaming reduces quickly without heat source
2. Off-gassing causes pressurization inside the panel causing swelling
3. Internal off-gassing can suddenly and rapidly escape
4. Off-gas/smoke can be ignited
5. Longer exposures burn away more resin binder
6. Smoldering can occur
7. Smoldering areas can cause re-ignition
8. Smoldering temperatures can be near that of fuel fires
9. Fibers can be oxidized by high temperatures and sufficient oxygen
10. Insulated areas cooled much more slowly than uninsulated areas

Small & Intermediate Scale Testing

Small-scale and Intermediate-scale testing being conducted by Hughes Associates Inc. (HAI).

Small & Intermediate Scale Testing

- Baseline intermediate scale tests will be conducted to see if results from Phase I are repeatable with Phase II test design.
- **Small scale tests**
  - ASTM E1354 Cone Calorimeter
    - Data to support exterior fuselage flame propagation/spread modeling
  - ASTM E1321 Lateral Flame Spread Testing (Lateral flame spread)
- **Thermal Decomposition Modeling**
  - Thermal Decomposition Apparatus (TDA)
  - Thermal Gravimetric Analysis (TGA)
  - Differential Scanning Calorimetry (DSC)
  - Pyrolysis Gas Chromatograph/Mass Spectroscopy (PY-GC/MS)

Small & Intermediate Scale Testing cont

- **Intermediate scale tests (agent application to be tested at this scale)**
  - Three different heat sources evaluated
    - Propane fired area burner (2 sizes)
    - Propane torch
    - Radiant heater
  - Sample panels are 4 feet wide by 6 feet tall
    - Protection added to test rig to avoid edge effects.
  - A representative backside insulation was used in several tests.

Small & Intermediate Scale Materials

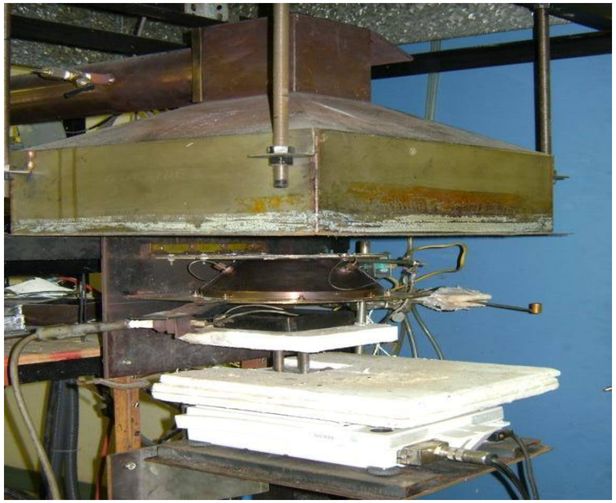
- **CFRP**
  - Unidirectional T-800/350ºF cure epoxy, 16 ply quasi-isotropic [0,-45,45,90]S2, nominal thickness of 3.2 mm (0.126 inch) Finished 60/40 fiber-resin
- **OSB**
  - Georgia Pacific Blue Ribbon®, nominal thickness of 14.7 mm (0.578 inches)
  - Flame spread rating of 150-200

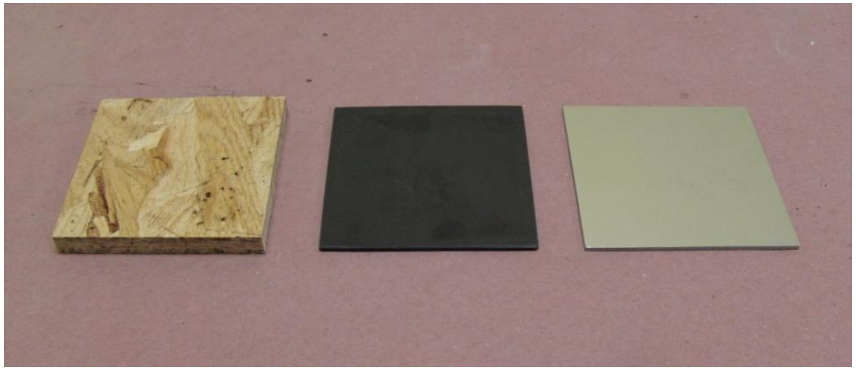
Composite Skin Fire Characteristics and Suppression

- **Approach**
  - Small scale materials testing

    ⇩

  - Results feed into fire model of combustion and propagation
  - Intermediate scale tests
    - Reduce reliance on large tests
  - Materials
    - Composite (CFRP -B787)
    - Aluminum/plastic (GLARE – A380)
    - Surrogate – (wood board)

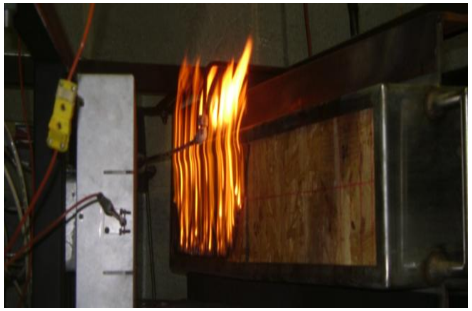




ASTM E1321 Lateral Ignition & Flame Spread

- **Wood was the only material in which lateral flame spread was observed**
- **CFRP and GLARE – some burning at seams**

OSB



CFRP

GLARE

Small Scale Tests - Combustibility

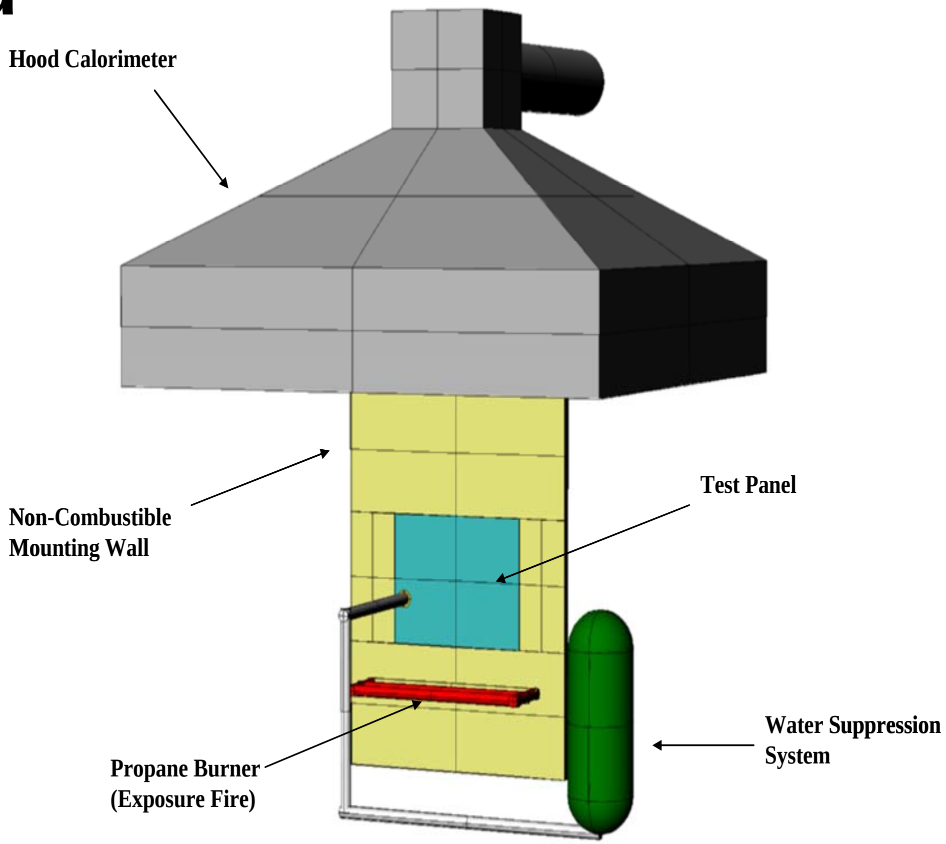
- **Composite Skin Materials Have Similar or Lower Combustible Properties compared to “Ordinary” Combustibles**
- **Compared to wood, composites:**
  - Require more imposed energy to ignite
  - Ignite slower
  - Have a shorter duration of burning(due to smaller thickness)

		For 100 kW/m² Exposure		
Sample	**Minimum Heat Flux for Ignition (kW/m²)**	**Tim to Ignition (sec)**	**Burning Duration (sec)**	**Avg. HRR (kW/m²)**
OSB	12	8	490	172
CFRP	16	29	113	153
GLARE	25	82.5	129	66.5

Intermediate Test Series

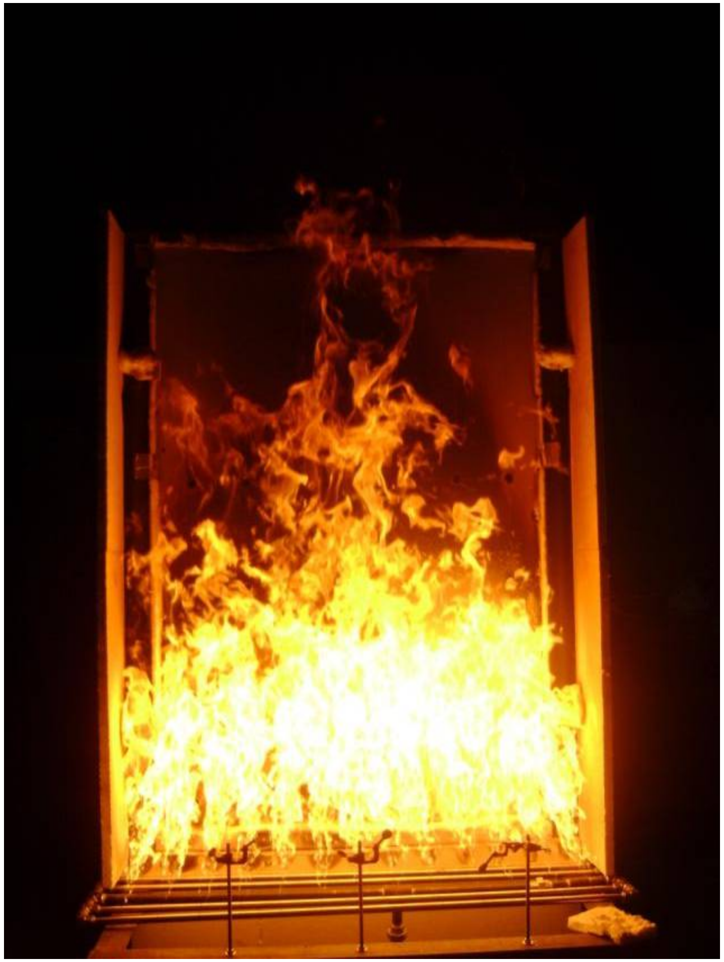
12 total tests conducted

- **9 with OSB**
  - 1 uninsulated
  - 8 insulated
- **3 with CFRP**
  - 1 uninsulated
  - 2 insulated



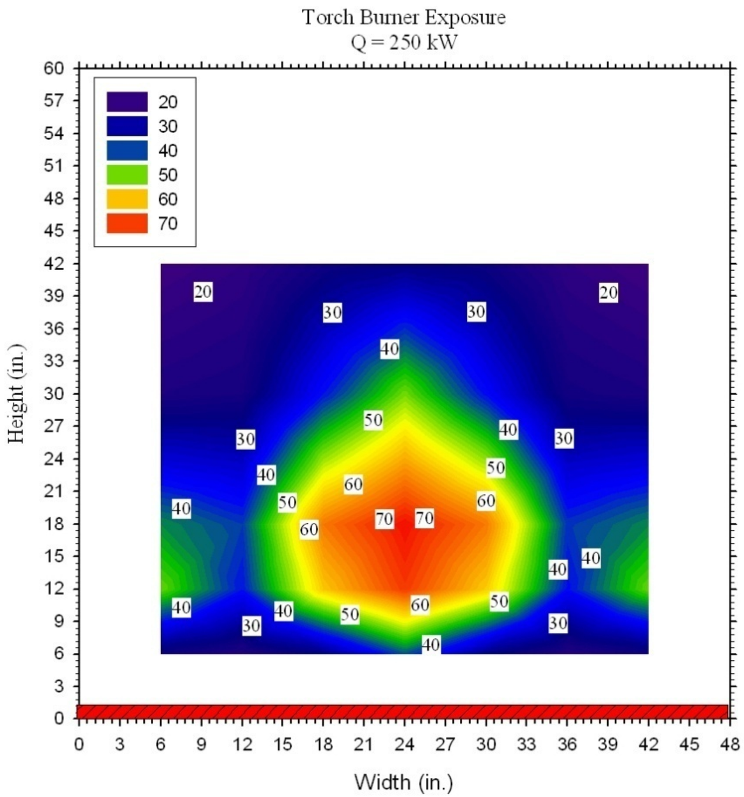
Intermediate-Scale Propane Area Burners

Low Heat Flux Uniform Exposure
$q''_e = 35 – 70\ kW/m^2$

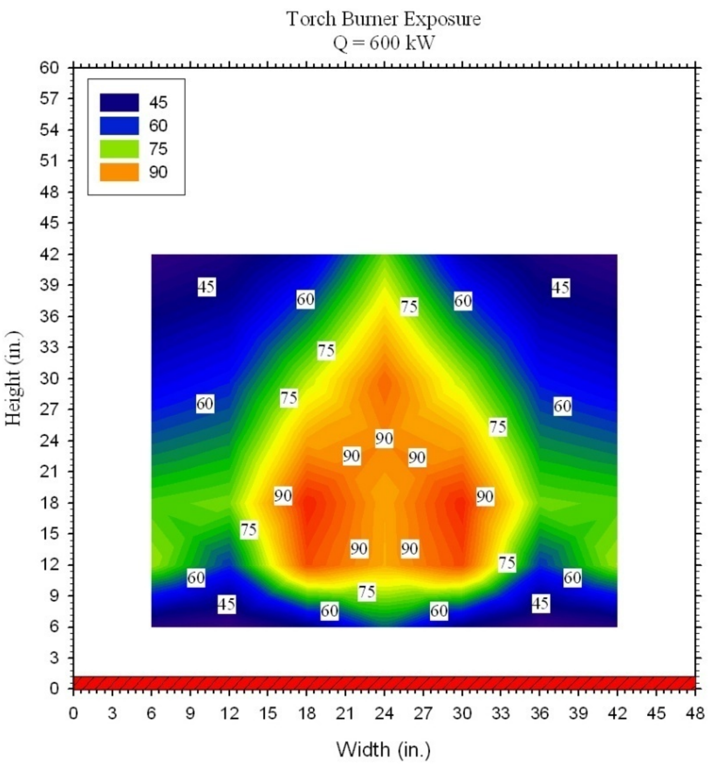


High Heat Flux Uniform Exposure
$q''_e = 70 – 100\ kW/m^2$

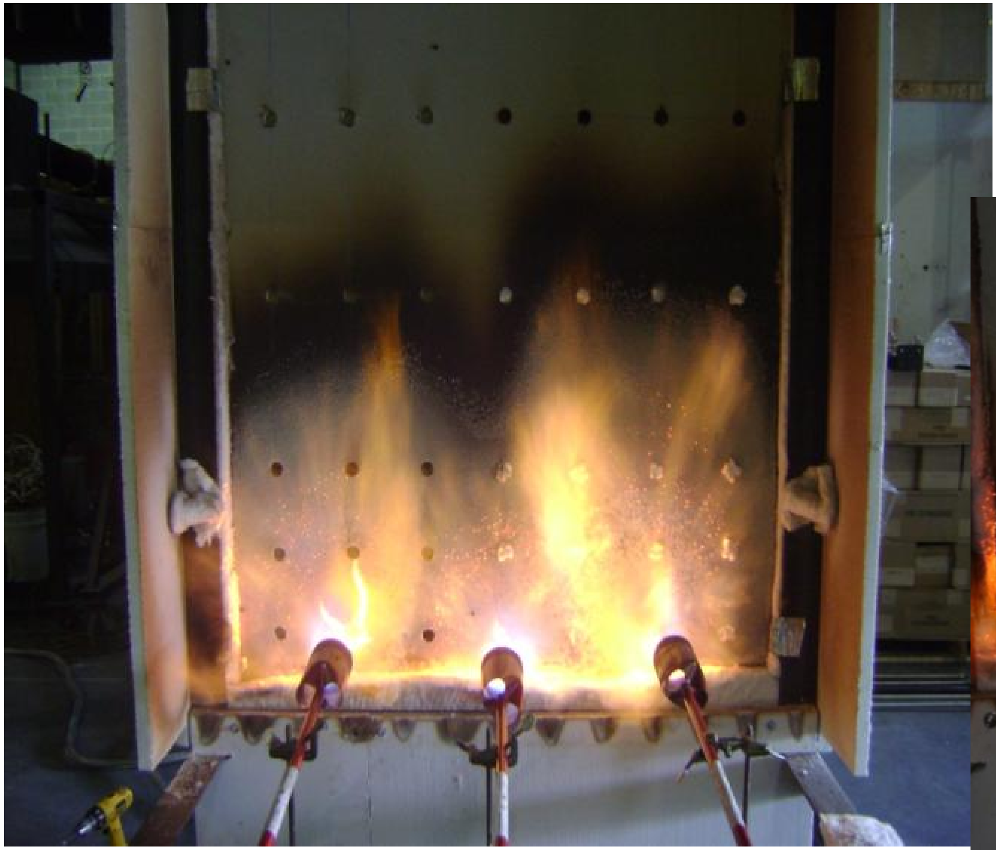
Small Area Exposure



Large Area Exposure

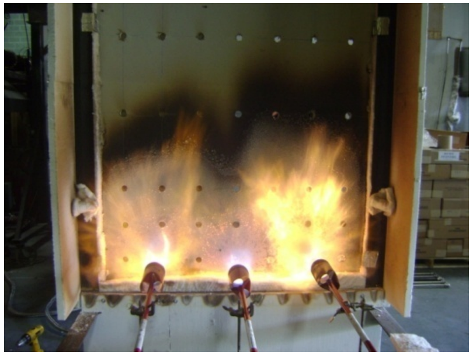


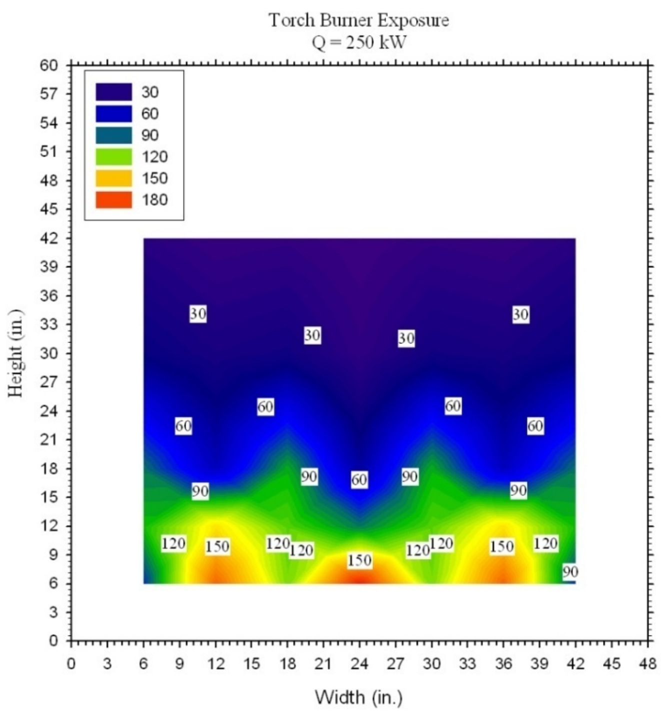
Intermediate-Scale Propane Torches



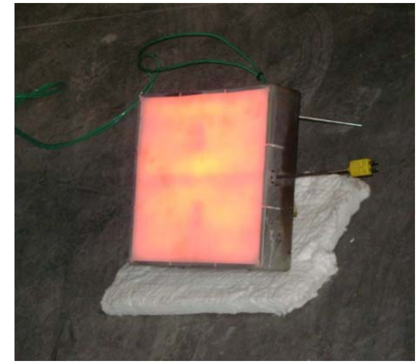
High Heat Flux Localized Exposure
$q''_e = 120 – 200\ kW/m^2$

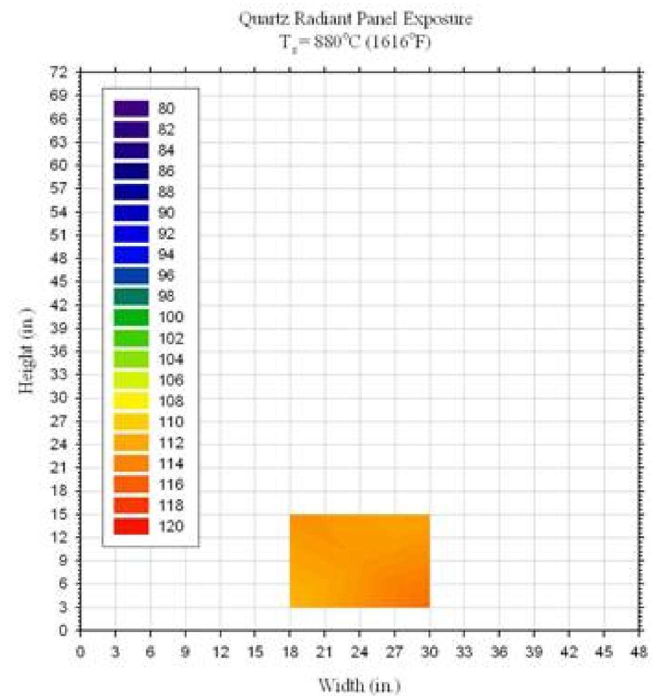
Torch (180kW/m²) Exposure





Radiant Panel (100kW/m²) Exposure





OSB Exposed to Large Area Burner with Insulation Backing

Large Area Burner On

Burner Off – 0 seconds

Burner Off – 30 seconds

Burner Off – 60 seconds

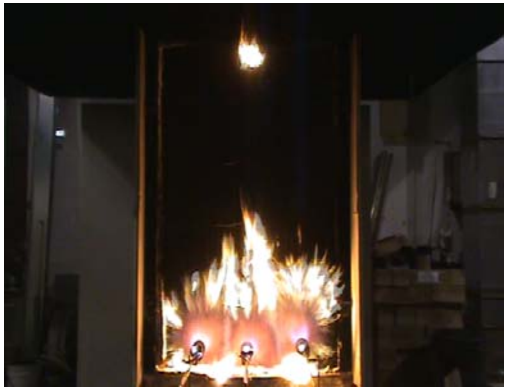
Burner Off – 100 seconds

CFRP Exposed to Torch Burner with Insulation Backing

Torch Ignition

1 minute after ignition

1.5 minutes after ignition

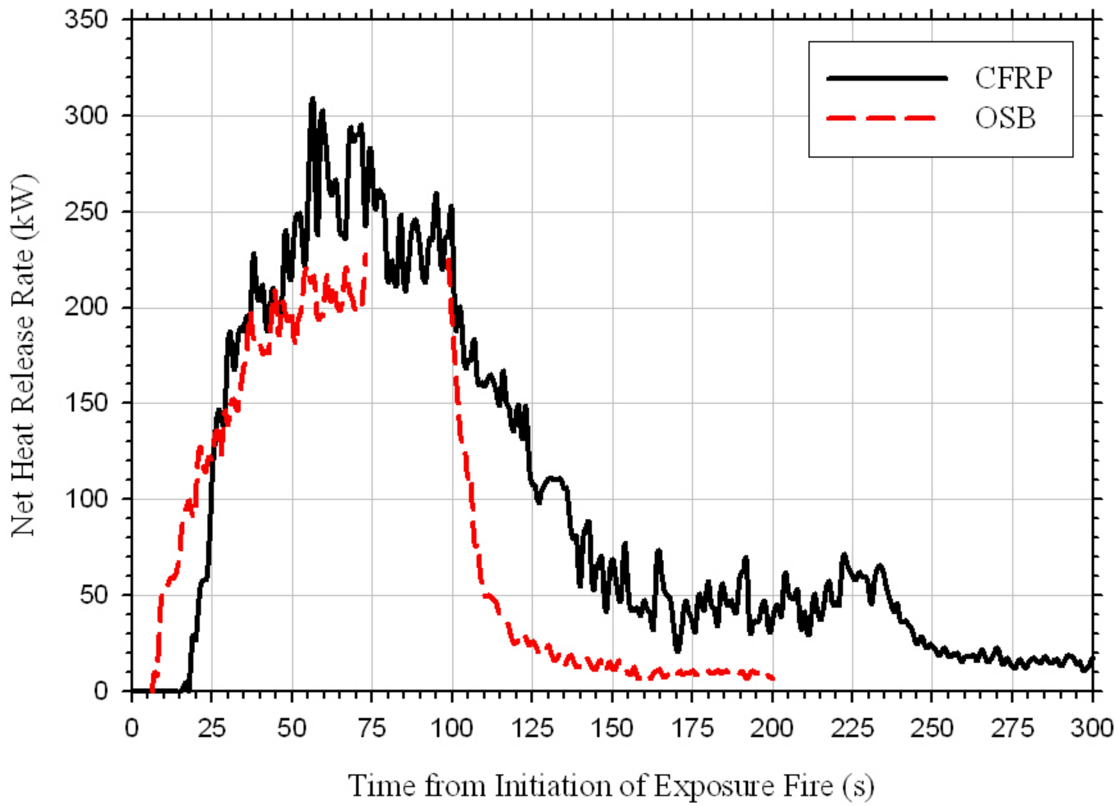


2.5 minutes after ignition

4 minutes after ignition
Torches Out

15 seconds after
torches out

Comparison of CFRP & OSB Heat Release



Intermediate Scale Findings

- Vertical/Lateral flame spread only occurred during exposure
- Post-exposure flaming reduced quickly without heat source
- Ignition occurred quickly into exposure
- Generally, time to ignition & HRR are consistent with cone calorimeter data

CFRP Torch Test

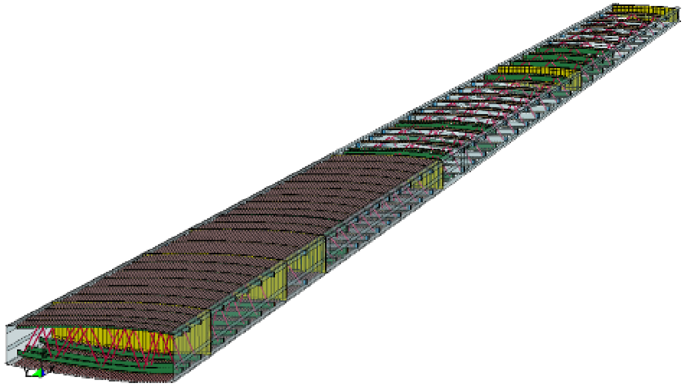
- Exposure 180 kW/m2
- Duration 250 seconds (4 min 10 sec)
- Panel Ignition at 16 seconds
- HRR increased after ignition to peak of 300 kW over 60 seconds
- HRR decayed after 90 seconds to steady-state value of 50 kW
- Post-exposure burning for 37 seconds

Intermediate Scale Test Conclusions

- **OSB vs. CFRP**
  - Both materials burn and spread flame when exposed to large fire
  - Heat release rates and ignition times similar
  - The thicker OSB contributed to longer burning

- **Large Scale Implications**
  - OSB can be used as a surrogate for CFRP
  - Flaming and combustion does not appear to continue after exposure is removed
    - Since there was no or very little post exposure combustion, no suppression tests performed as planned
    - Minimal agent for suppression of intact aircraft?

Qualifiers to Intermediate Scale Results



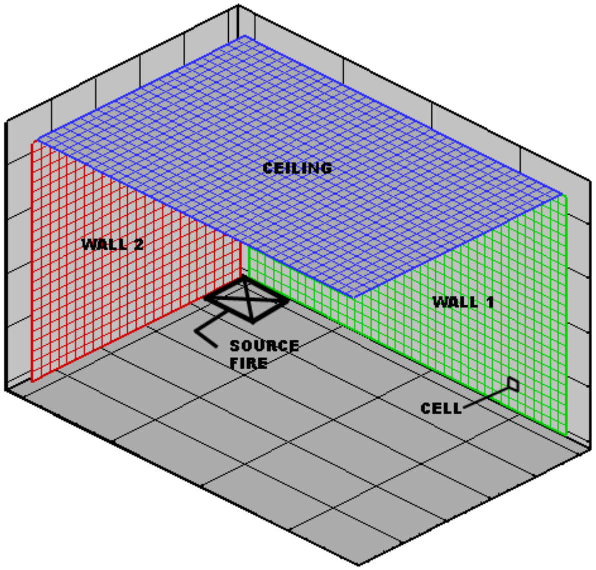
EXAMPLE COMPLEX GEOMETRY FIRE TEST SETUP FOR CFRP FLAMMABILITY EVALUATION.

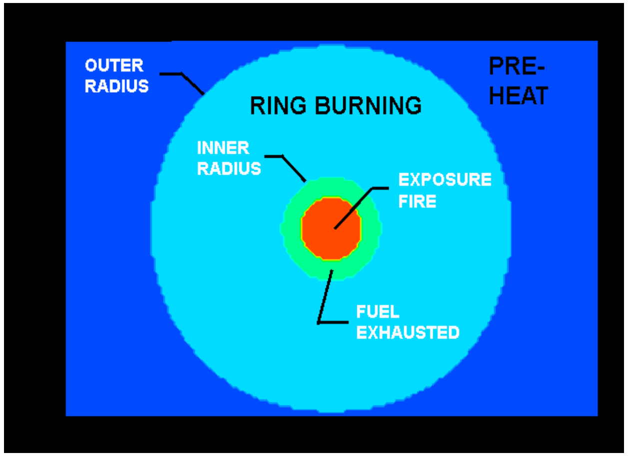
- **Need to check GLARE**
  - No significant surface burning differences anticipated (may be better than CFRP)
- **Verify /check CFRP for thicker areas (longer potential burning duration)**
- **Evaluate edges/separations**
  - Wing control surfaces
  - Engine nacelle
  - Stiffeners
  - Post –crash debris scenario

Can a well established fire develop in a post-crash environment?

Flame Spread Modeling Analysis

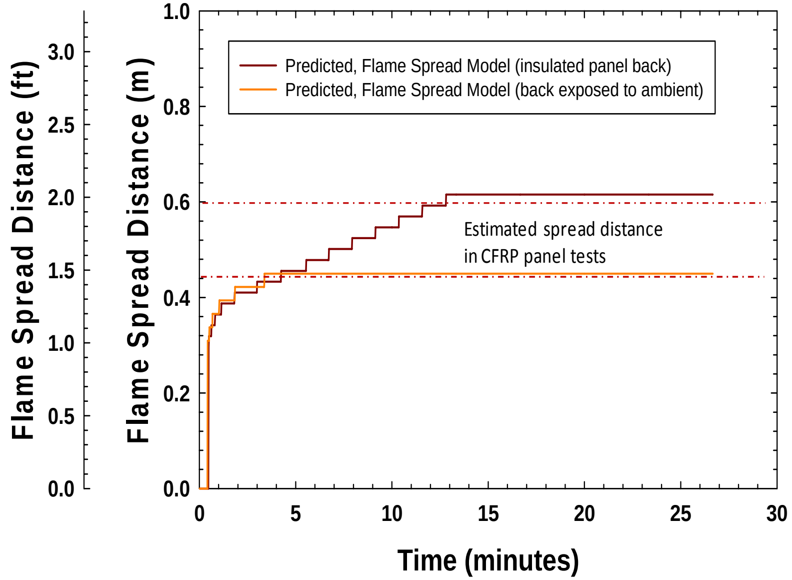
- **Analytical tool developed**
  - Calculates flame spread on vertical and horizontal surfaces
  - Multiple exposures
    - External flux/flame radiation
    - Hot gas layer
  - Predicts heat release rate and flame spread
  - Input data developed from small scale tests



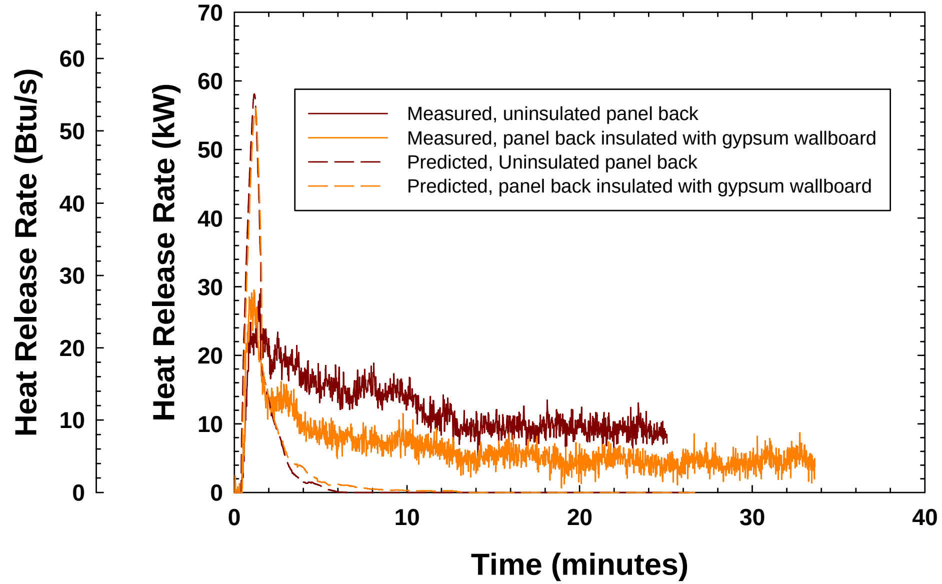


Model Validation

- **Intermediate scale tests with ORP and CFRP**
  - Radiant panel/line burner/torch exposures
- **Wood tests (literature) with accelerating and decelerating flame spread conditions**



Flame spread distance (CFRP radiant panel test)



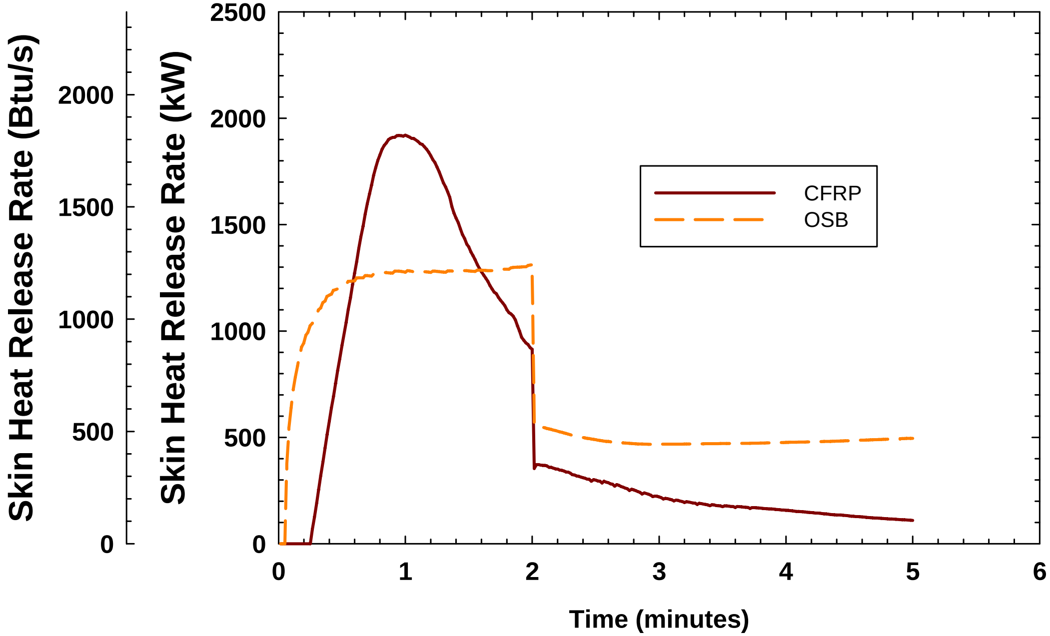
Heat release rate (CFRP radiant panel test)

Modeling Analysis of Aircraft Skin

- **Twenty configurations evaluated (parameter variation)**
  - Skin panel dimensions, exposure fires, exposure durations, exposure fire suppression rate
- **Hydrocarbon pool fire exposures (JP-5) – skin immersed, peak fluxes 135 – 180 kW/m²**
- **Vertical panel (no curvature)**
- **Flame spread not predicted beyond area initially ignited by pool**
    - Some vertical flame propagation after exposure fire suppressed
    - No significant lateral flame propagation after exposure fire suppressed
    - Heat release rate decreases rapidly after suppression
    - Results not significantly affected by scenario parameters

Flame Spread Model – Typical Result

- Heat Release Rate – 10 MW exposure fire/ 20 ft tall panel
- 2 minute exposure, rapid suppression
- Lateral propagation stops when fire suppressed
- Fire does not propagate to top of panels
- OSB and CFRP similar propagation behavior
- OSB has higher heat release rate after suppression
- OSB ignites faster and has a faster initial spread



Preliminary Modeling Conclusions

- Fire propagation is not predicted for large scale fires exposing vertical CFRP and OSB panels
- OSB and CFRP have similar flame propagation and peak heat release rates, but OSB has higher heat release rate after pool fire suppression and allows faster initial spread
- Modeling did not consider three-dimensional configurations (wing-fuselage connection)
- Fuselage treated as vertical flat surface – future flame spread model revisions could account for curvature
- Thermal penetration after ignition yet to be performed – decomposition model plus intermediate validation data will be used for this

Overall Findings

- Flame propagation and self-sustained flaming does not significantly occur in the absence of external fire source.
- Epoxy off-gas is combustible.
- CFRP can smolder.
- Epoxy off-gas causes composite to swell through internal pressurization.
- OSB is potential surrogate for large scale tests to assess extinguishment test methods to save composites for data collection.

Participation welcome

- **Soliciting comments and ideas on:**
  - Potential test configurations
  - Relevant previous testing results and data
  - Sources for aviation-type carbon fiber composites and FML
  - Other helpful ideas