COMPOSITE MATERIAL FIRE FIGHTING

Presented to: International Aircraft Materials Fire Test Working Group
Köln, Germany

Presented by: John C. Hode
SRA International

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Composite Aircraft Fire Fighting

THE BIG QUESTION:

Do composite skinned aircraft require more agent to control external fire and facilitate evacuation?

- **Extinguishment of the body of external fire.**
  - Our question: Will the composite skin continue to burn after the pool fire is extinguished, thereby requiring the fire service to need more extinguishing agent in the initial attack?
- **Cooling of the composite skin to below 300°F (150°C).**
  - Our question: How fast does the composite skin cool on its own and how much water and foam is needed to cool it faster?
    - 300°F (150°C) is recommended in the basic ARFF training.
    - Common aircraft fuels all have auto ignition temperatures above 410°F (210°C).

Representative Scenario
China Airlines at Japan Naha Airport, August 19, 2007

A leak in the wing fuel tank led to a major external fuel-fed pool fire

Testing in Two Phases

<u>First phase:</u>

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

<u>Second phase:</u>

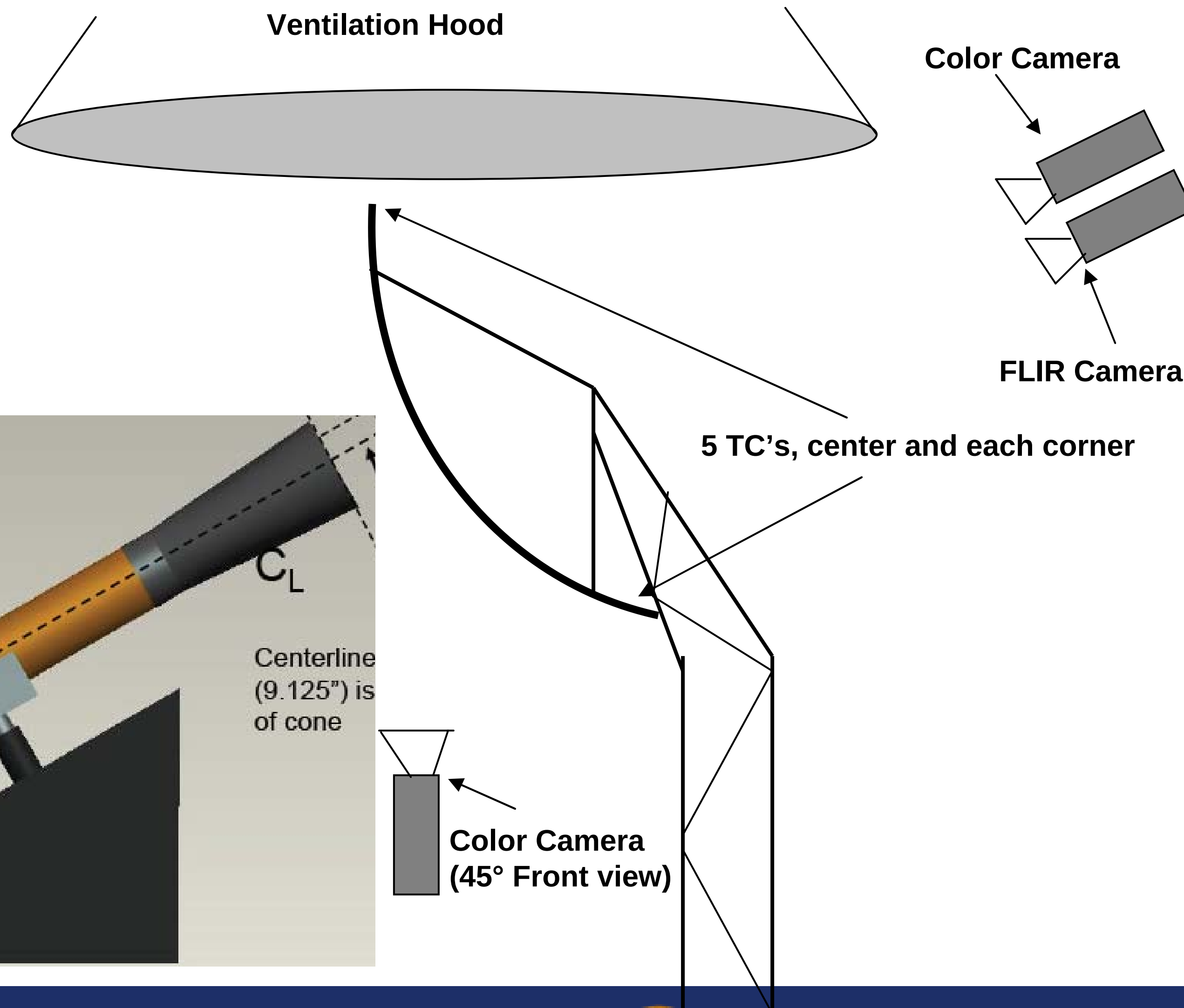
Determine how much fire agent is needed to extinguish visible fire and cool the material sufficiently to prevent re-ignition.

Exposure times of Phase I tests:

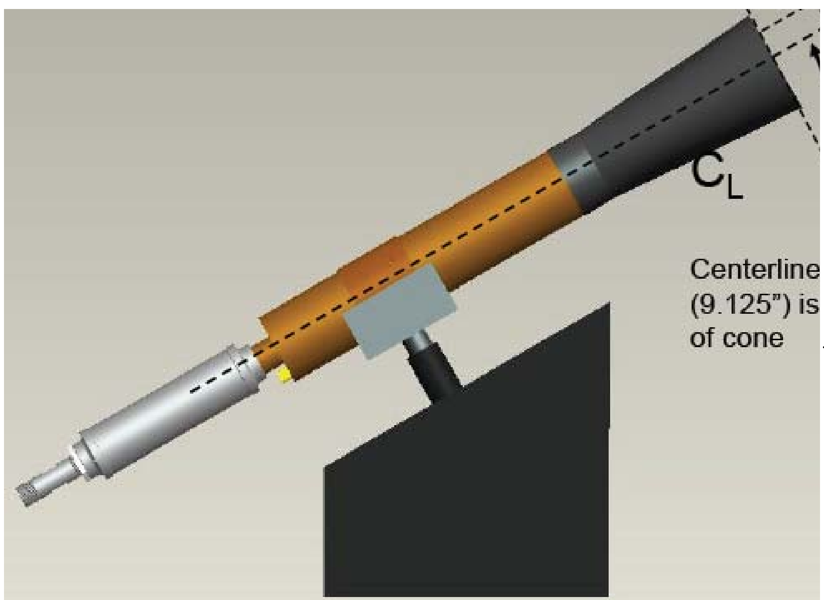
- 10, 5, 3, 2, & 1 minutes
  - FAR Part 139 requires first due ARFF to arrive in 3 minutes.
  - Actual response times can be longer or shorter.

Phase I testing of carbon fiber completed.

Test Set-up

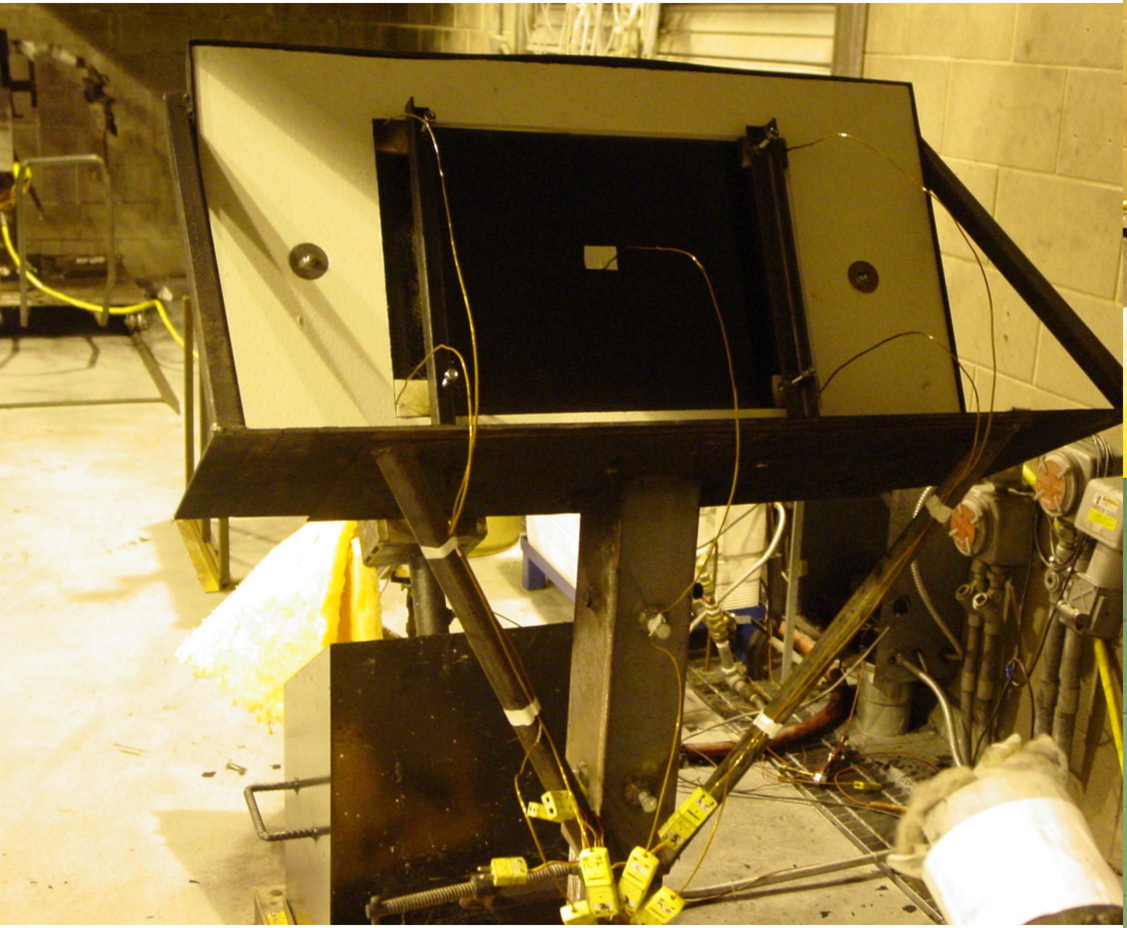


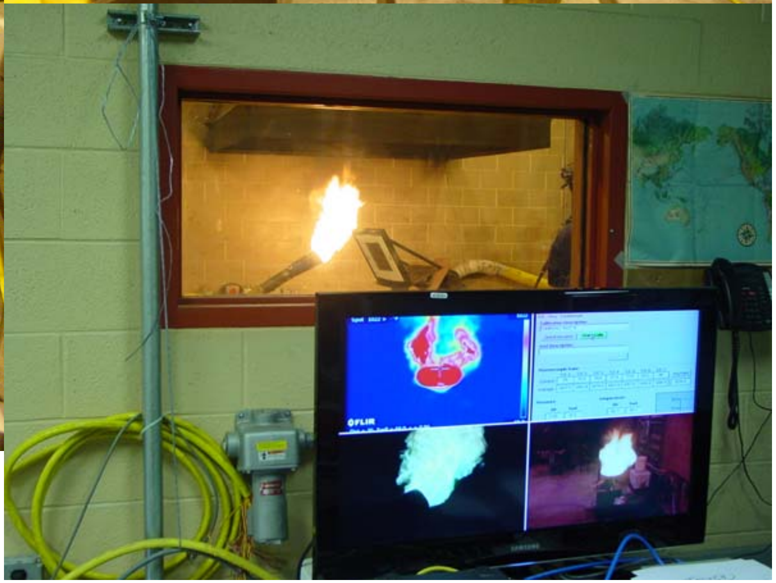
Ventilation Hood
Color Camera
FLIR Camera
5 TC’s, center and each corner
Color Camera
(45° Front view)



CL
Centerline
(9.125”) is
of cone

Actual Test Set-up





Phase I Findings

- **All tests showed some amount of post-exposure flaming. 1 minute exposures resulted in post-exposure flaming that were sustained well over 1 minute.**
- **Longer exposure burns of the epoxy allowed for glowing combustion of the fibers. Glowing combustion sometimes developed well after exposure**
- **Actual burnthrough never occurred but backside panel temperatures after 10 minute exposures were up to 822°F (442°C).**
- **Temperatures in insulated areas were always several hundred degrees Fahrenheit higher than the panel temperature. 10 minute exposures consistently reached at or above 1200°F (654°C). Average 1367.2°F (741.7°C)**
- **Fiber clusters were released during exposure. Oxidized fibers were noted around the damaged fiber edge where the burner was focused,**

Phase I Findings cont.

- Panel center, which was open to the air on both sides thereby allowing heat to readily dissipate, took a median of 133 seconds (2 minutes 13 seconds) to cool below 300°F (150°C).
- The time for insulated areas to naturally cool below 300°F (150°C) was not sufficiently recorded; however, those areas were above that level for many minutes, well beyond the end of data collection based on trend.
- Heavy amounts of combustible gas and smoke flowed from the edges of the panel and in a few cases was ignited by the front-side flame resulting in backside flashover or edge ignition.

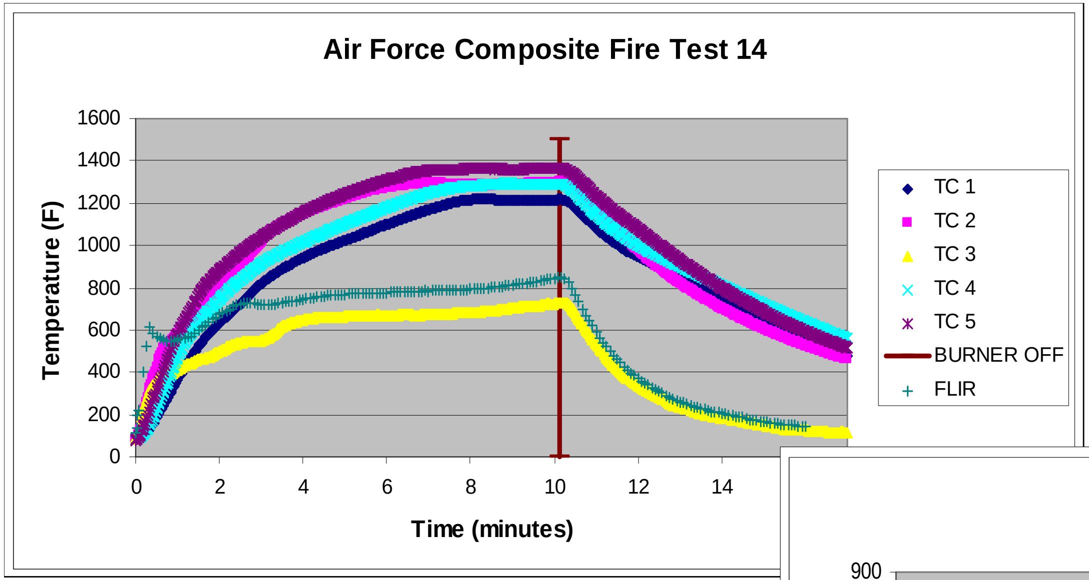
Phase I Findings cont.

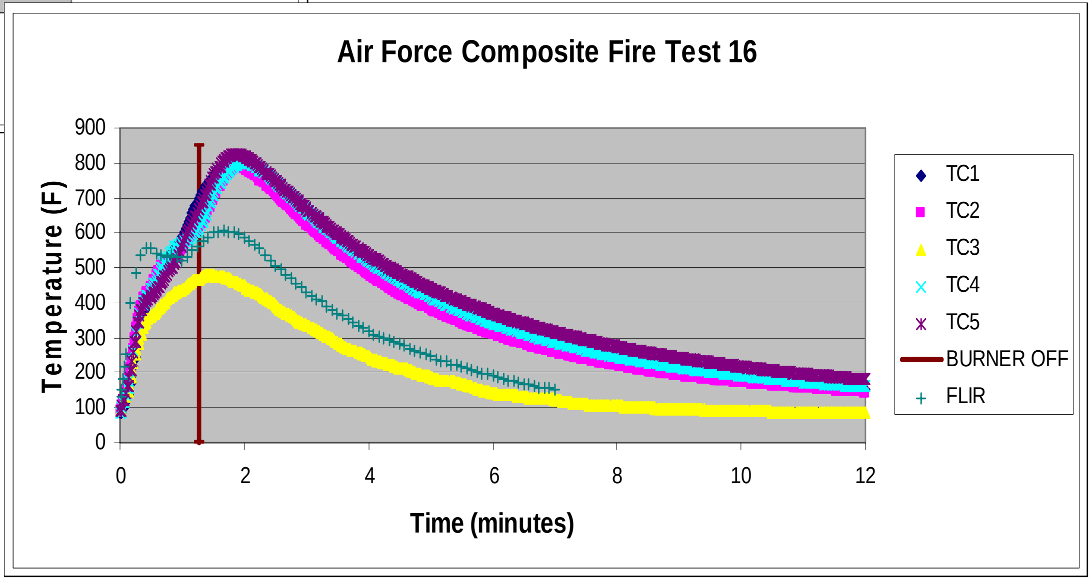
- **Wind enhanced glowing combustion and re-ignition.**
- **Radiation between carbon fiber panels can develop extremely high temperatures for sustained periods.**
- **Several tests experienced a mechanical failure of the panel edge. This may be due to the internal pressurization of the panel by epoxy vaporization.**

Phase I Findings cont.

- **Close up of gray oxidized and jagged fiber ends from Test 15**

Panel Temperatures cont.



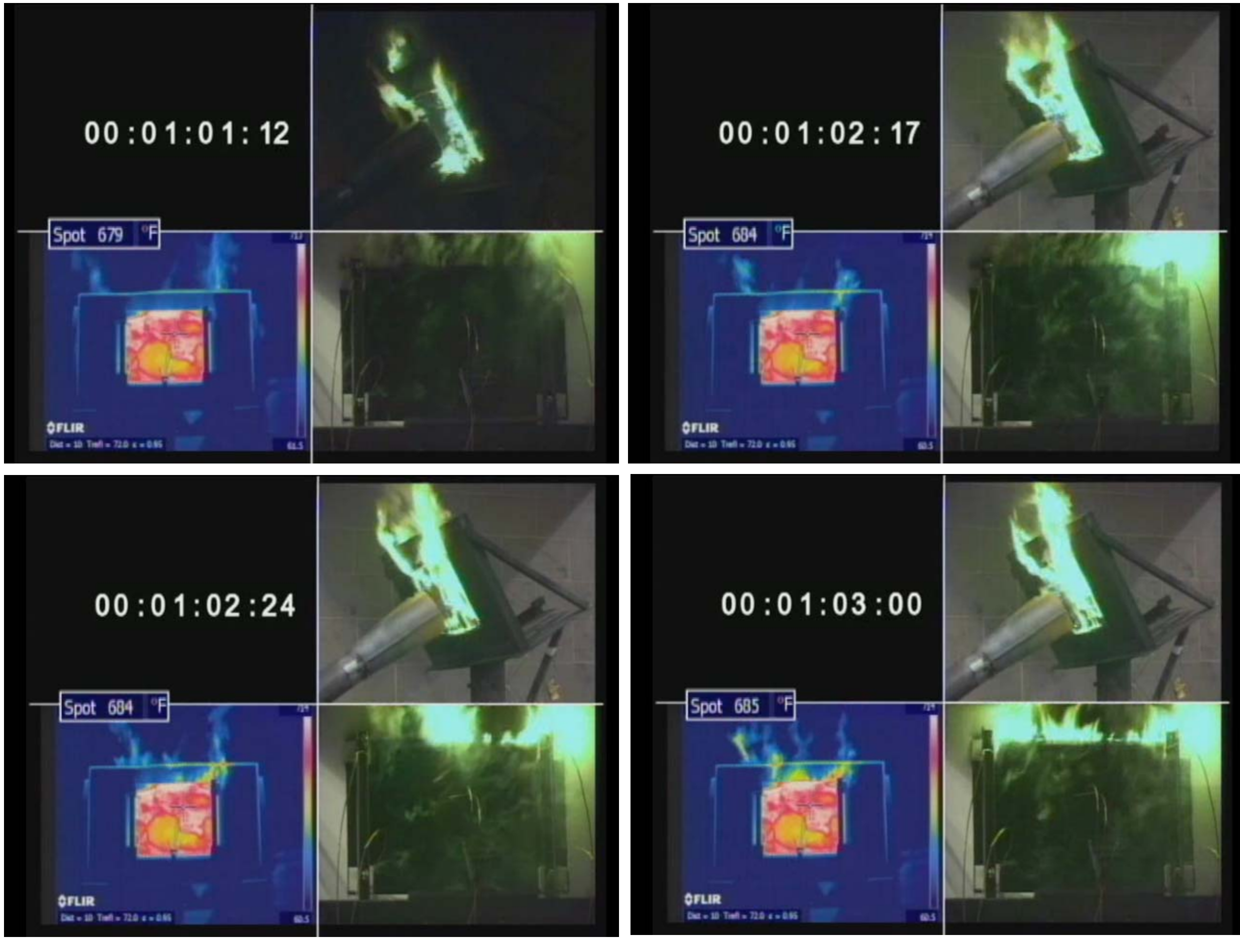


Mechanical Failures

- **Test 4 panel shown**
- **7 tests suffered sudden mechanical failures**
- **Failures occurred in 30 seconds on average**

Off-gas Ignition

From Test 18 video

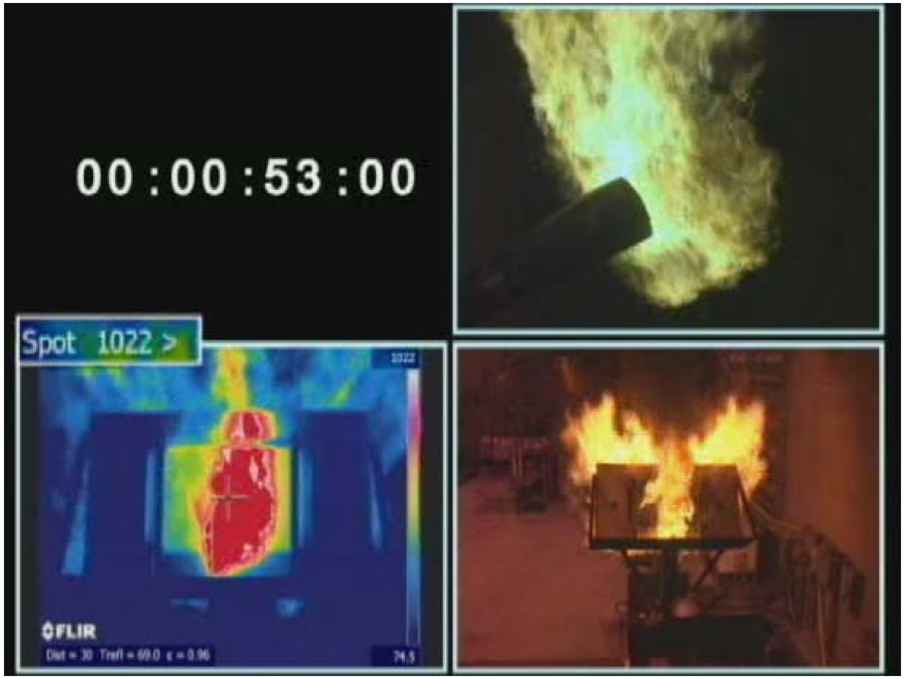


- **Heavy smoke from the backside was sometimes ignited by the front side flame. This was clearly observed during the video review.**
- **Here, the ignition of back-side off-gassing happened *after* the burner was turned off.**

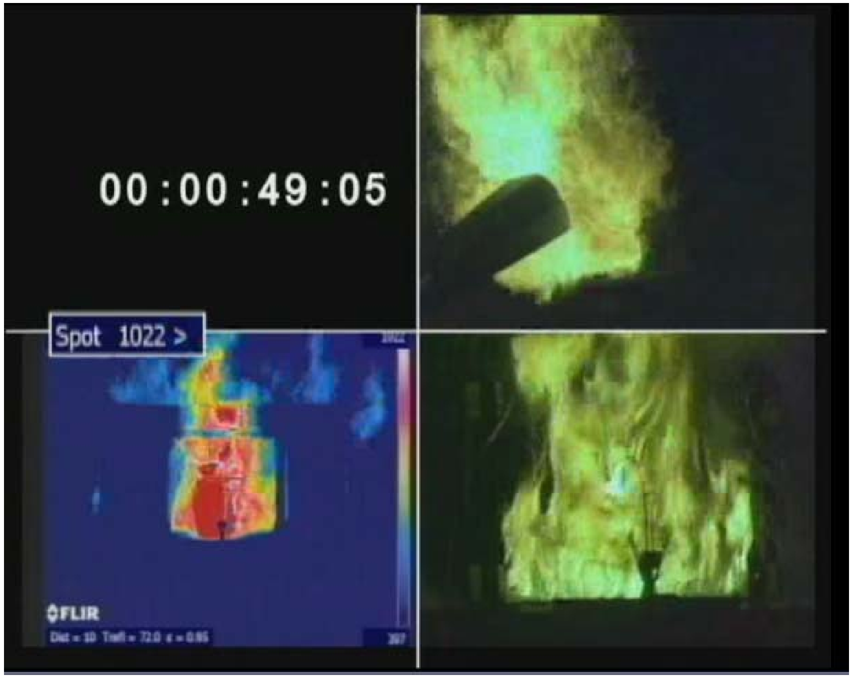
Rear Flashover

- **Two tests suffered mechanical failures at the bottom edge that allowed high heat to contact and ignite smoke emitting from the bottom edge.**
- **Ignition of bottom edge involved part of the panel face which evolved into flashover of the backside.**

Test 4 Flashover

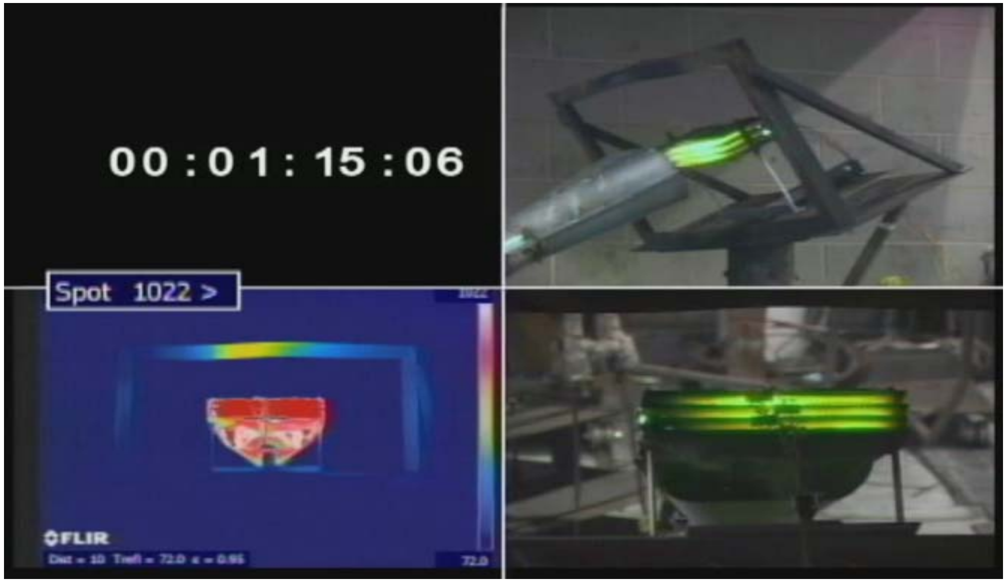


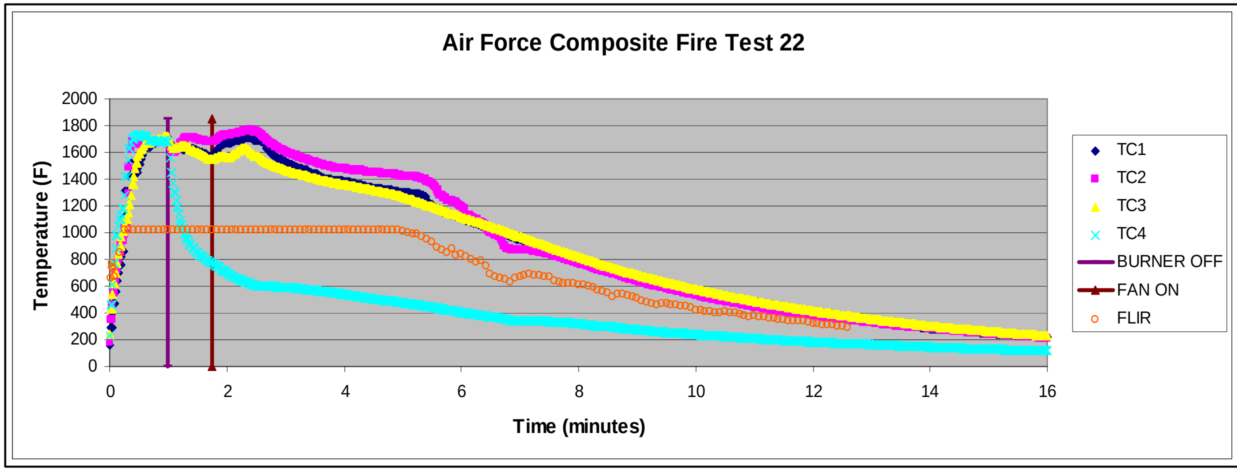
Test 21 Flashover



Alternate Test Configuration

- **Measured temperatures in the vicinity of 1750°F (962°C).**
- **Wind in second repetition caused glowing to last 52 seconds longer.**
  - 4:11 without fan
  - 5:03 with fan



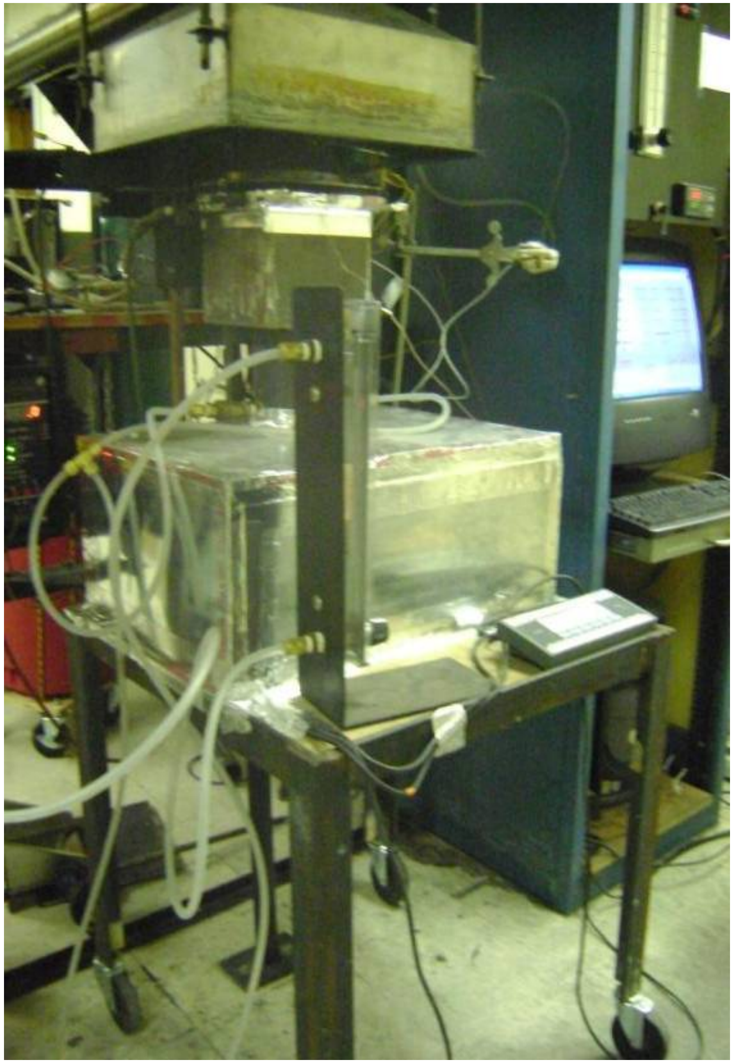


Phase II Testing

- **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 (Additional modeling data)
  - ASTM E1321 Lateral Flame Spread Testing (Lateral flame spread)
  - Thermal Decomposition Testing
- **Intermediate scale tests (agent application to be tested at this level)**
  - Propane fired line burner for fire source. 50 kW/m^2 and 200 kW/m^2 will be used.
  - Sample panels will be 4 ft wide by 6 ft tall with protection to avoid edge effects.
  - Standard aircraft insulation will be installed against backside in some baseline tests.

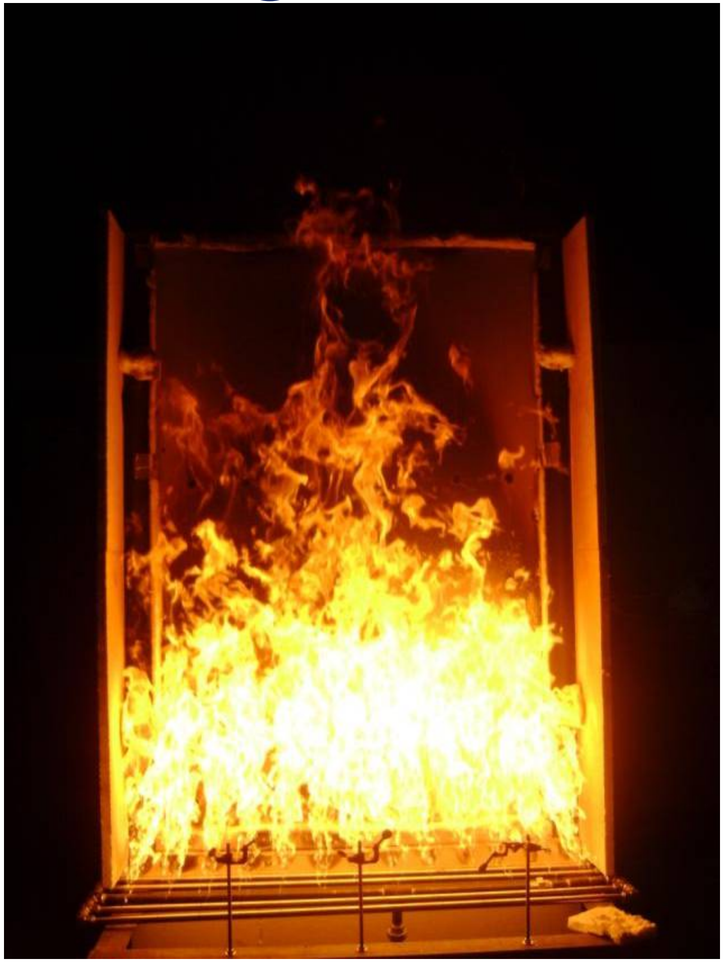
Thermal Decomposition Testing

- Thermal decomposition apparatus used to develop thermal properties for materials
- Properties are critical to thermal decomposition modeling
- Apparatus provides ability to thermally expose materials in an inert environment



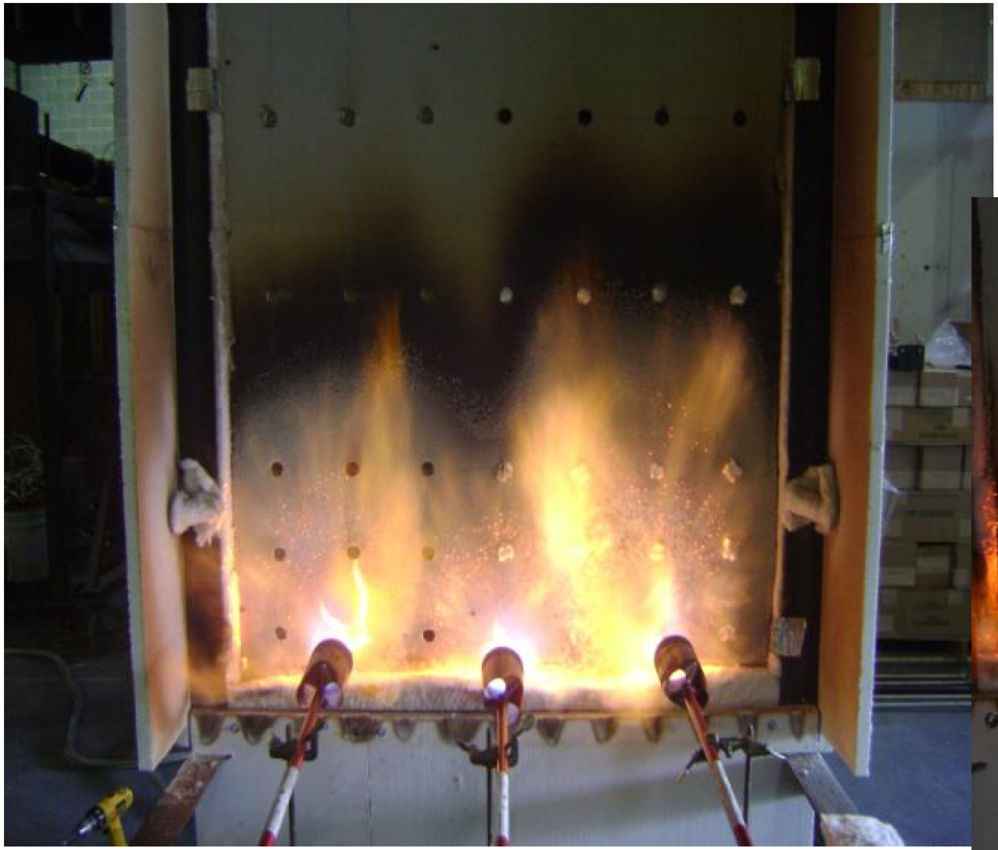
Intermediate-Scale Testing

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



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

Intermediate-Scale Fire Exposure Testing cont.



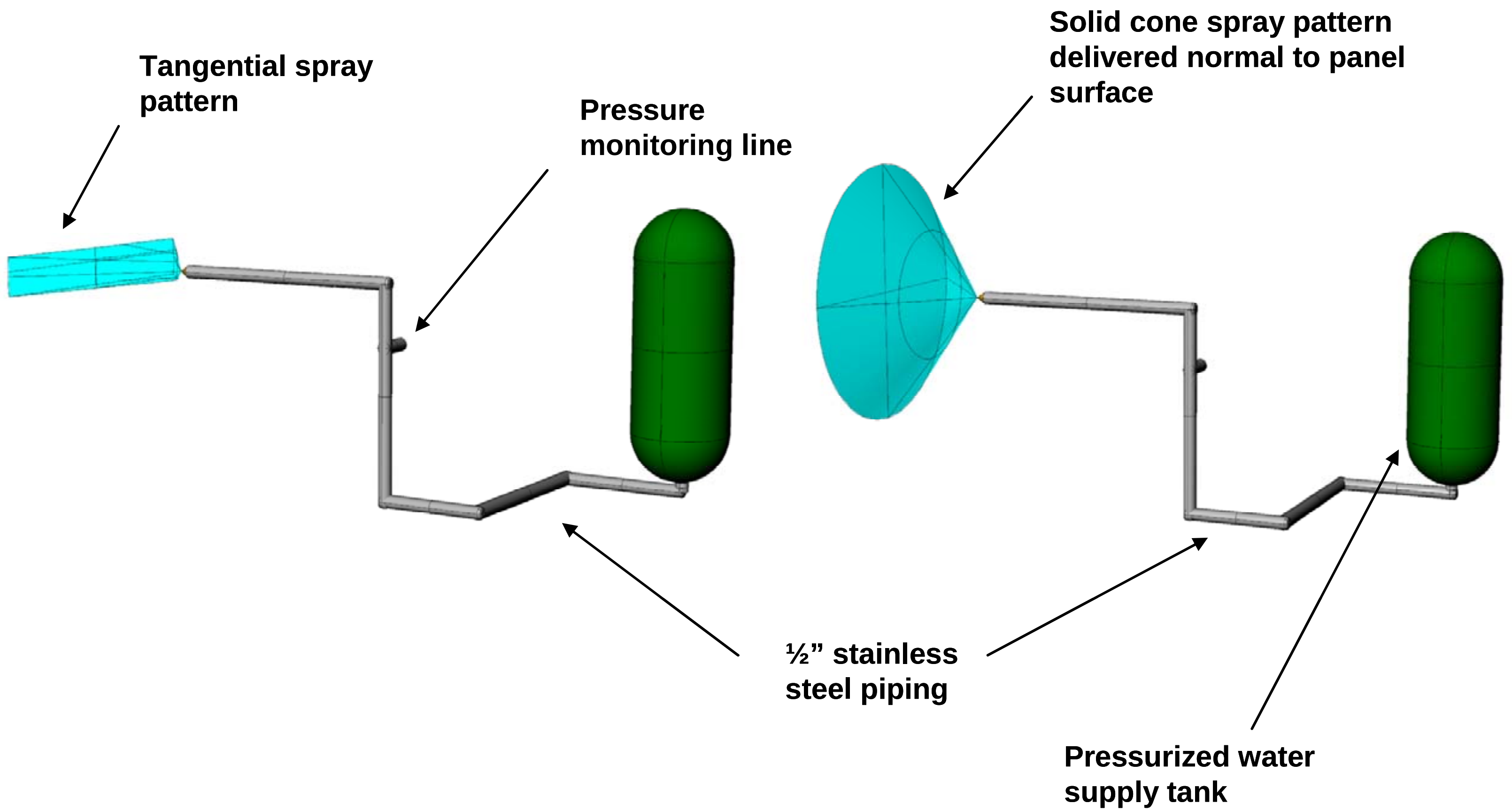
High Heat Flux Localized Exposure

q''_e = 120 – 200 kW/m^2

Agent Application

- For now, only water will be used as the extinguishing agent.
- Preliminary tests conducted on Oriented Strand Board (OSB) to evaluate burners and agent application method.
- Baseline tests will determine the worst case scenario. (insulated vs. un-insulated & heat flux)
- Agent applied to worst case combination in data collection tests.

Agent Application Patterns



Agent Application Patterns cont.

- Tangential spray pattern will be focused to the top of the panel to allow the agent to cascade down the panel.
- Conical spray pattern will be focused at the center to cover nearly all of the panel.

Test data will contribute to flame spread modeling.

Participation welcome

- **Soliciting comments and ideas on:**
  - Test configurations and potential ways to improve
  - Relevant previous testing results and data
  - Sources for aviation-type carbon fiber composites and FML
  - Other helpful ideas