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).
A leak in the wing fuel tank led to a major external fuel-fed pool fire
Testing in Two Phases

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

Second phase:
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

Knowledge Points:
- Ventilation Hood
- Color Camera
- FLIR Camera
- 5 TC’s, center and each corner

Diagram Details:
- Centerline (9.125”) is the edge of cone
- Color Camera (45° Front view)
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

• 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/m² and 200 kW/m² 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
$q_e^" = 35 – 70 \text{ kW/m}^2$

High Heat Flux Uniform Exposure
$q_e^" = 70 – 100 \text{ kW/m}^2$
Intermediate-Scale Fire Exposure Testing cont.

High Heat Flux Localized Exposure

$q''_e = 120 – 200 \text{ kW/m}^2$
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

- Tangential spray pattern
- Pressure monitoring line
- Solid cone spray pattern delivered normal to panel surface
- ½” stainless steel piping
- Pressurized water supply tank
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