Expanding Composites Use

• Increased use of composites in commercial aviation has been well established
  – 12% in the B-777 (First flight 1994)
  – 25% in the A380 (Maiden flight 2005)
  – 50% in both B-787 & A350 (Scheduled)

• A380, B-787 & A350 are the first to use composites in pressurized fuselage skin
Airport Fire Fighting Agent

• Aqueous-film-forming-foam (AFFF) is commonly used at U.S. airports. (MIL SPEC required by FAA)
• Agent quantities are the amount of water needed to make foam solution
• In the United States, the required quantities of agent are provided by Airport Index in CFR 139.317

THE BIG QUESTION:
Do composite skinned aircraft require more agent to control external fire and facilitate evacuation?
Extinguishing Burning Composite

OBJECTIVE
• Determine the best method and agents to quickly and efficiently extinguish a variety of aircraft composites

APPROACH
• Evaluate existing agents (Class A foam, AFFF, Heat absorbing gels) and application techniques (such as UHP) to identify the most effective method to extinguish fires involving large amounts of composites
• Use standardized composite samples of carbon/epoxy and GLARE
• Use standard sized fire
• Orient the composites in both horizontal and vertical configurations
• Evaluate the effects of wicking fuel into delaminated composite layers
FedEx DC10-10F, Memphis, Tennessee, USA
18 December 2003
Aluminum skinned cargo flight

Traditionally, the initial focus is on extinguishing the external fuel fire to stop fuselage penetration.
### Airport Firefighting
**What we know…**

<table>
<thead>
<tr>
<th>ALUMINUM</th>
<th>CARBON/EPOXY</th>
<th>GLARE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norm for ARFF</td>
<td>Unfamiliar to ARFF</td>
<td>Unfamiliar to ARFF</td>
</tr>
<tr>
<td>Melts at 660°C (1220°F)</td>
<td>Resin ignites at 400°C (752°F)</td>
<td>Outer AL melts, glass layers char</td>
</tr>
<tr>
<td>Burn-through in 60 seconds</td>
<td>Resists burn-through more than 5 minutes</td>
<td>Resists burn-through over 15 minutes</td>
</tr>
<tr>
<td>Readily dissipates heat</td>
<td>May hold heat</td>
<td>May hold heat</td>
</tr>
<tr>
<td>Current Aircraft</td>
<td>B787 &amp; A350</td>
<td>2 Sections of A380 skin</td>
</tr>
</tbody>
</table>
Airport Firefighting Equipment

• Thermal Imaging Cameras (TIC)
  – Provide color or black & white images

• Multi Gas Detectors
  – Detects 4 gasses,
    • Lower Explosive Limit (LEL) of combustible gas
    • Oxygen (O2)
    • Carbon Monoxide (CO)
    • Hydrogen Sulfide (H2S)

Both help to assess fire conditions
Carbon/Epoxy Mishaps

Fire Extinguishment

Navy F/A-18, San Diego, California, USA
8 December 2008

Fixing Composite Fibers for Recovery

Photo credit: Don Bartletti/Los Angeles Times, retrieved from LATimes.com

Photo credit: Allen J. Schaben/Los Angeles Times, retrieved from LATimes.com
Carbon/Epoxy Mishaps

Six hours to extinguish fire

Air Force B-2, Guam, USA
8 December 2008

83,000 gallons of water and 2,500 gallons of AFFF to achieve total extinguishment
Test Fire Requirements

• **Key Features**
  – Reproducible
  – Cost Effective
  – Realistic

• **Material**
  – Must achieve self-sustained combustion or smoldering
  – Test of agents and application technologies
Cone Calorimeter


“Data from this instrument can be used in research to predict the full-scale fire behavior of certain furnishings and wall lining materials. [6]” p. 3

“Babrauskas and Parker [7] deduced that the spectral distribution of this source approximates the irradiance in compartment fires, where radiation is the primary process for energy transfer.” p. 4
FAA Burn-through Test Method

• **NextGen Burner**
  – Simulates open pooled fuel fire
  – Flame temperature approximately 1900 deg F (16 Btu/ft² sec)

• **This test method is currently the only one that presents a repeatable simulation of an external fuel pool fire**

• **The burner can be used without any modification for these tests**
Proposed test set-up

- Sample oriented to the burner in the same manner as insulation blanket samples.
- Thermocouples fixed to each of the four edges and front and back faces of the sample.
- Forward Looking Infrared (FLIR) video cameras placed in front and rear of sample to correlate with TC data and give understanding of what TICs might see.
- Color video cameras positioned adjacent to FLIR cameras to capture the same view. Images will be compared to FLIR to determine any visual cues of temperature reduction.
- If feasible, air samples will be collected to assess products of combustion. Data may be helpful to determine if off-gassing from combustion can be a measure of extinguishment.
Proposed test set-up

TC’s on front and back faces

Instrumented hood to collect air samples

TC’s, all 4 edges

Color Camera (side view)

Centerline (9.125”) is 1/4 of cone
Testing in two stages

• **First stage:** Determine if self-sustained combustion or smoldering will occur after 5 minute pre-burn. If no result with 5 minute pre-burn, increases of 5 minute increments will be applied to assess what duration will.

• **Second stage:** If first condition is met, determine how much fire agent is needed to cool the material sufficiently to extinguish and prevent re-ignition.
Agent Application

• Propose to use nozzle and delivery defined in MIL-SPEC, MIL-F-24385F
  – 2 gallons/minute
  – Made by National Foam Systems (or equal)
  – Modified for test
    • Shortened length from 2 1/2 inches to 1 1/4 inches
    • “wing-tip” spreader added to outlet, 1/8 inch wide circular orifice, 1 7/8 inches long
  – Nozzle pressure maintained at 100 lb/in²
  – Solution temperature 23 deg C +/- 5 deg C

Nozzle could be mounted or hand-held for application
MIL-SPEC Nozzle
For your consideration…

• Use of existing test methods allows greater confidence in results
• FAA oil burner is the best representation of an external, impinging pooled fuel fire
• MIL-SPEC nozzle provides a repeatable application method for small scale
Relevant Literature

- Sorathia, U et.al., July/August 1997, *Review of Fire Test Methods and Criteria for Composites*
  - Discussion of composites fire test methods
- FAA Advisory Circular 20-107A, *Composite Aircraft Structure*
  - Requires fire penetration resistance to be at least 5 minutes
- Webster, H., DOT/FAA/CT-90-10, *Fuselage Burnthrough From Large Exterior Fuel Fires*
  - Documents burn-through times for aluminum
  - Documents aluminum burn-through times
  - GLARE burn-through resistance of over 15 minutes during cargo liner tests
  - Documents resin ignition temperature for carbon/epoxy composite used in aircraft
- Lyon, R.E., DOT/FAA/AR-TN95/22, *Fire Response of Geopolymer Structural Composites*
  - Documents a 94 second ignition time for carbon/epoxy resin
- Navy NAVAIR 00-80R-14, 15 October 2003, NATOPS U.S. Navy Aircraft Firefighting And Rescue Manual, Section 2.7.1 *Composite Materials*
  - Documents ignition temperature for carbon/epoxy
- Miller, A., 2007, *Engineering the best: Boomers, a bridge and the Boeing 787 at University of Washington, College of Engineering*
  - Discussed burn-through resistance of over 20 minutes during tests on 787 carbon/epoxy
Relevant Literature, continued

  - Documents resin ignition temperature for carbon/epoxy composite used in aircraft
  - Cone calorimeter is an interior materials test
  - Small-scale nozzle design and discharge parameters
- NFPA 412 2009 ed. *Standard for Evaluating Aircraft Rescue and Fire-Fighting Foam Equipment*
  - Hand line test
- FAA Fuselage Burn-through Test Method
  - Discusses oil burner test method and equipment
  - Describes in detail the oil burner test method and equipment
- FAA DOT/FAA/AR-00/12, *Aircraft Materials Fire Test Handbook*
  - Describes FAA required fire test methods
Participation welcome