COMPOSITE MATERIAL FIRE FIGHTING

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

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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…

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

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

Navy F/A-18, San Diego, California, USA

8 December 2008

Fire Extinguishment

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

Fixing Composite Fibers for Recovery

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 Calorimiter

Reference to Brown, J.E. et.al., NBSIR 88-3733, *"Cone Calorimeter Evaluation of the Flammability of Composite Materials"*, March 1988

"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

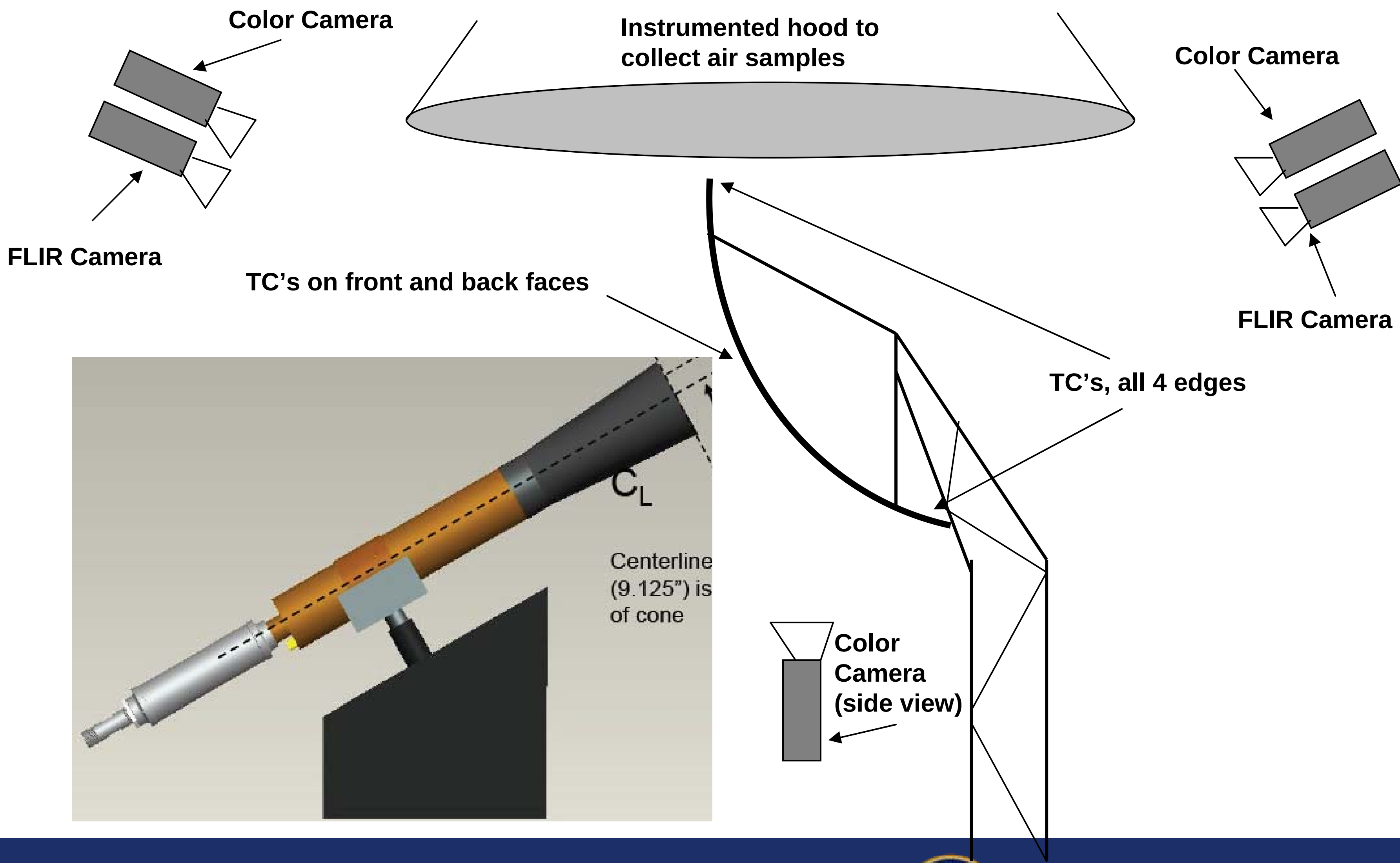
FAA Burn-through Test Method

- **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



Testing in two stages

- **<u>First stage:</u> 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.**

- **<u>Second stage:</u> 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/in^2
  - 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
- **Marker, T., DOT/FAA/AR-98/52, *Full-Scale Test Evaluation of Aircraft Fuel Fire Burnthrough Resistance Improvements***
  - Documents aluminum burn-through times
- **Hooijmeijer, P.A., Fiber Metal Laminates; An Introduction, Kluwer academic Publishers, Dordrecht, 2001, Chapter 26, "Burn-through and lightning strike".**
  - GLARE burn-through resistance of over 15 minutes during cargo liner tests
- **Quintiere, J.G. et.al., DOT/FAA/AR-07/57, *Flammability Properties of Aircraft Carbon-Fiber Structural Composite***
  - 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

- **Air Force Technical Order 00-105E-9, 31 December 2008, Revision 14, *Aerospace Emergency Rescue and Mishap Response Information (Emergency Services),* Chapter 3 Composite Material Hazards**
  - Documents resin ignition temperature for carbon/epoxy composite used in aircraft
- **Brown, J.E. et.al., March 1988, US Navy, NBSIR 88-3733, *Cone Calorimeter Evaluation of the Flammability of Composite Materials***
  - Cone calorimeter is an interior materials test
- **MIL-F-24385F 7 January 1992, *Military Specification Fire Extinguishing Agent, AFFF***
  - 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
- **CFR 14 Part 25.856, *Thermal/Acoustic insulation materials,* Appendix F, Part VII, Test Method To Determine the Burnthrough Resistance of Thermal/Acoustic Insulation Materials**
  - 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