Development of a Flame Propagation Test Method for Structural Composite Materials in Inaccessible Areas

International Aircraft Materials Fire Test Working Group Meeting

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Introduction

- **Carbon fiber composites are being used more frequently in aerospace applications**
  - Increased strength
  - Lower density
  - Better corrosion resistance

- **New designs of commercial transport airplanes include primary structure constructed from carbon fiber composites**

- **Current FAR's do not require flammability testing for fuselage skins or structures, as traditional designs are inherently non-flammable**

- **To continue with the FAA's efforts to enhance in-flight fire safety, materials in inaccessible areas of the cabin should meet a flammability test based on the "block of foam" fire source**

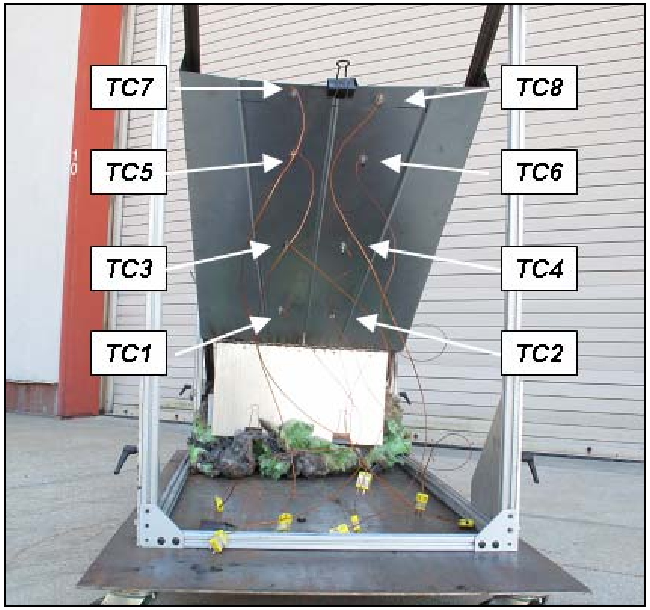
Objective

- **Develop a standardized laboratory-scale flammability test method to determine the flame propagation resistance of structural composite materials**

- **Test should correlate with an intermediate-scale test using the block of foam fire source**
  - Thermal/acoustic insulation
  - Ducting
  - Wire insulation

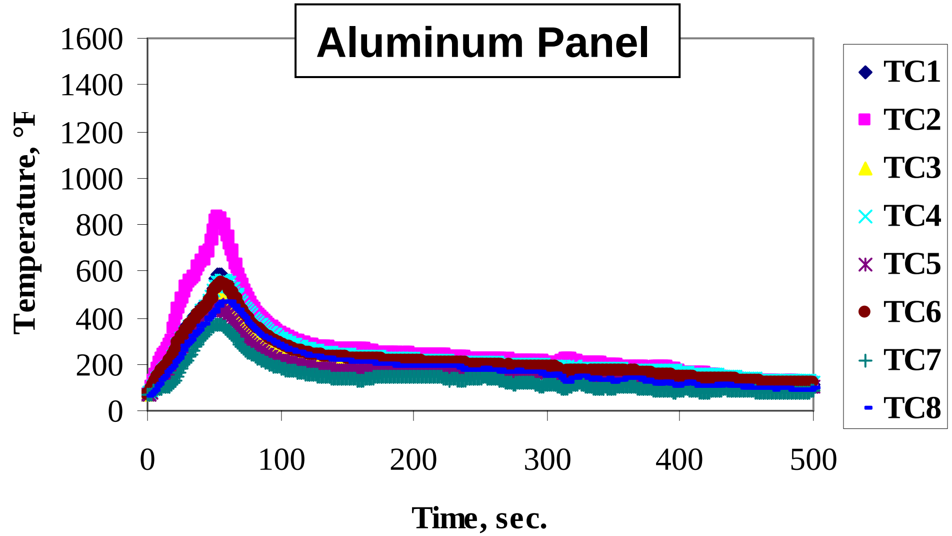
Intermediate Scale Test Rig

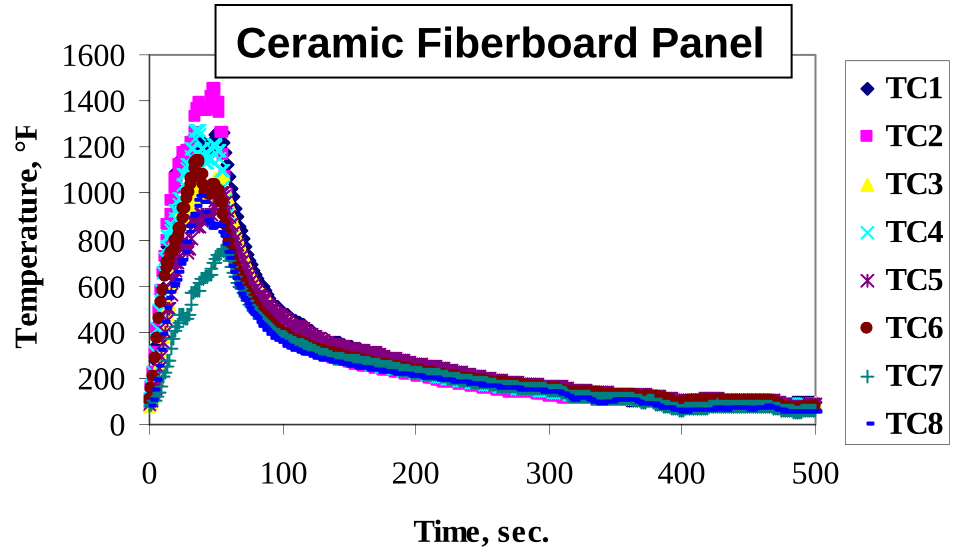
- **A sample holder was constructed to simulate an inaccessible area in an aircraft cabin**
- **Flat panels of composite material were tested due to the high cost of curved panels**
  - Panel dimensions 18”x48”x1/8”
- **The angle of incidence can be varied**
  - 30° chosen for strong flame impingement and buoyancy assisted propagation
- **4” x 4” x 9” untreated urethane foam block fire source**
  - 10 mL heptane soaked into bottom of foam block to promote uniform burning
- **Thermocouples measure inboard panel temperature to assess flame propagation**



Baseline Test

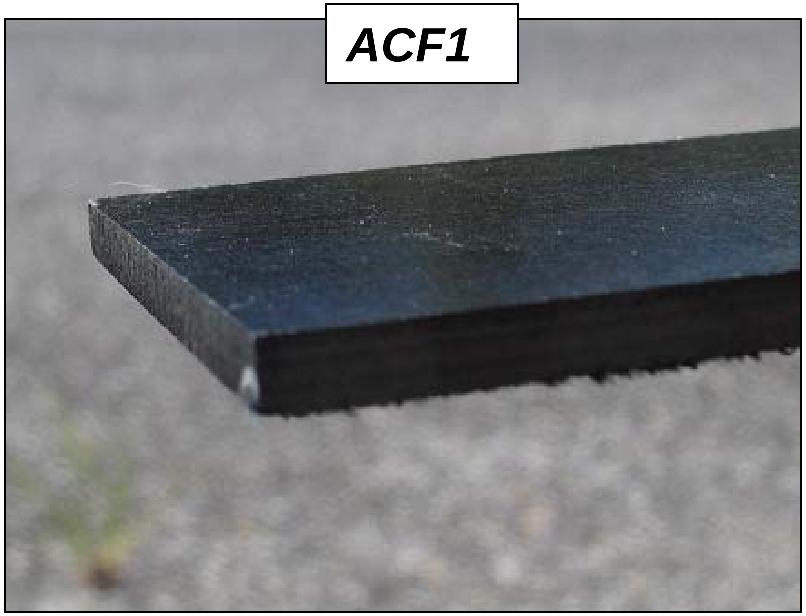
- Baseline tests were run with panels of aluminum and ceramic fiberboard
- Temperature profiles were measured for duration of foam block burning
- Peak temperature is indicative of conductivity of panel
- Peak width indicates duration of burning event

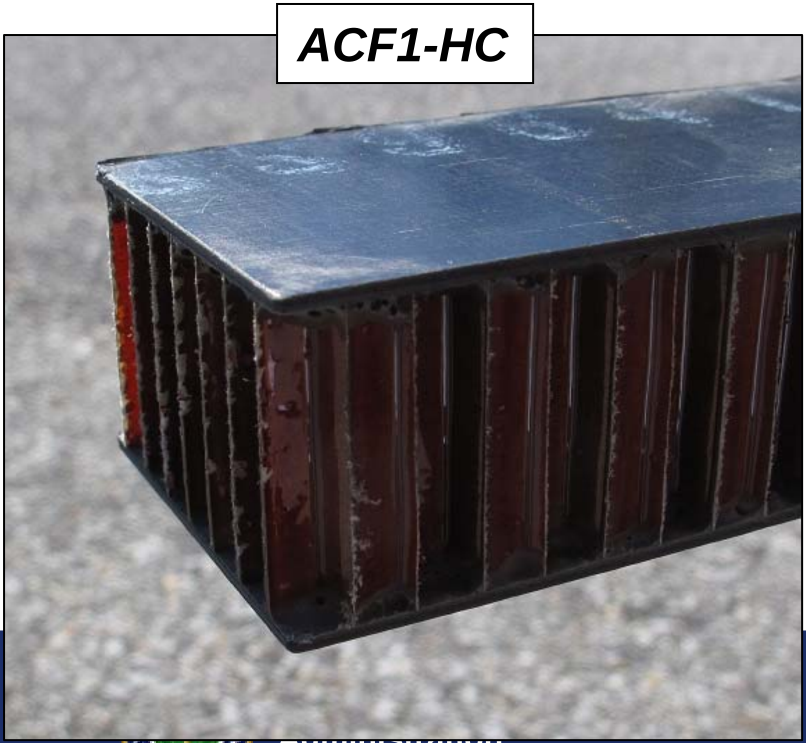




Composite Materials

- **Non-aerospace composites**
  - GAR10: glass-cloth laminate with epoxy resin binder
  - GRP: glass-reinforced polyester sheet
  - FLXCF: flexible fine weave carbon fiber sheet
  - RGDCF: rigid woven carbon fiber sheet
- **Aerospace grade composites**
  - ACF1: carbon/epoxy panel 16 plies unidirectional tape, 320 g/m^2 aerial weight, prepregged with amine cured, toughened 356°F epoxy resin system
  - ACF2: carbon/epoxy panel unidirectional carbon tape, 1.79 g/cm^3 density, prepregged with a toughened, 365°F cure epoxy system
  - ACF3: carbon/epoxy panel woven carbon fabric, 193 g/m^2 aerial weight prepregged with 250°F cure epoxy system
  - ACF1-HC: 4 plies of ACF1 prepreg bonded with film adhesive to both sides of a 1” thick, .25” cell size honeycomb core, total sample thickness 1 1/16”



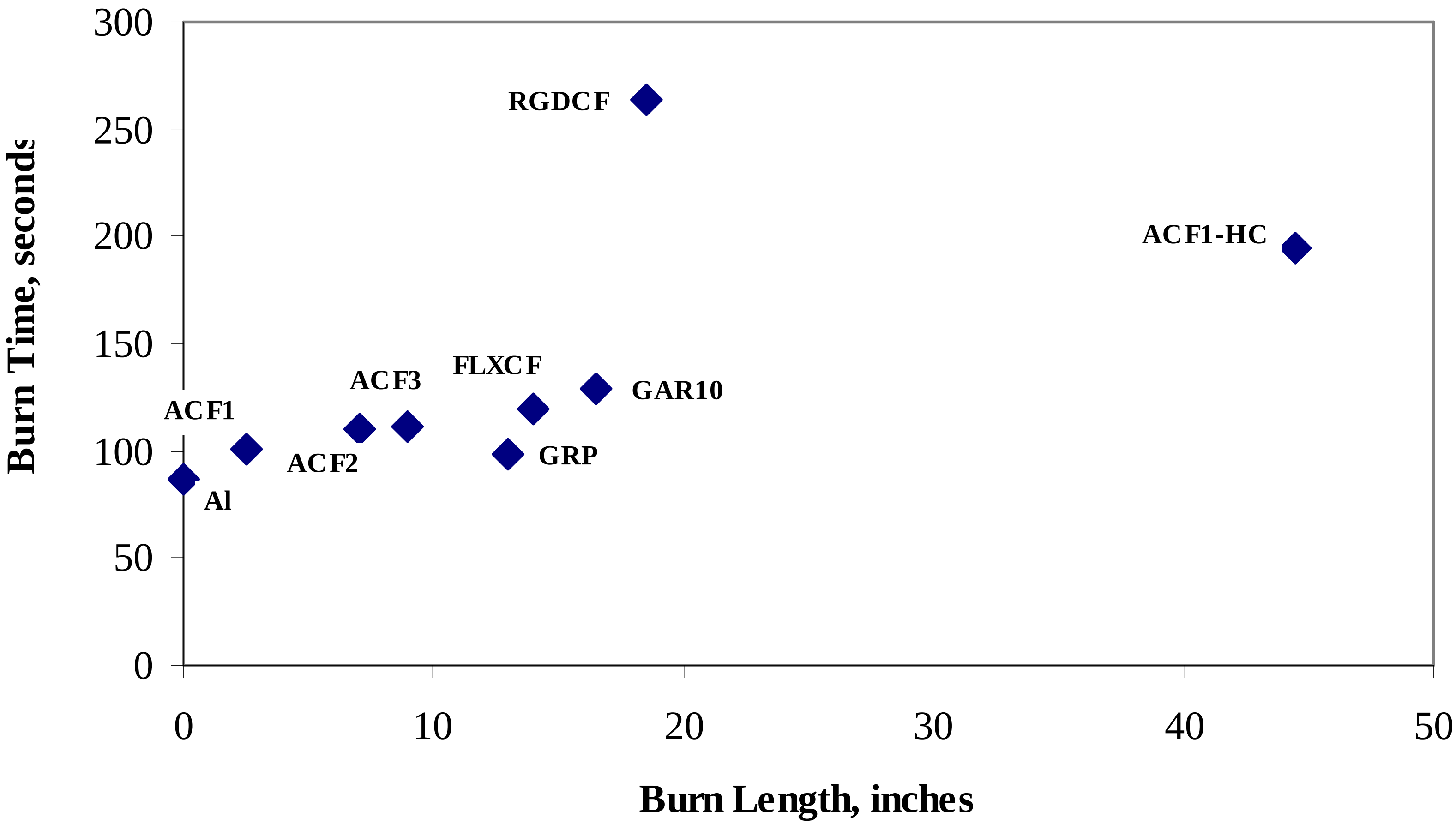


Intermediate Scale Tests

ACF1

ACF1-HC

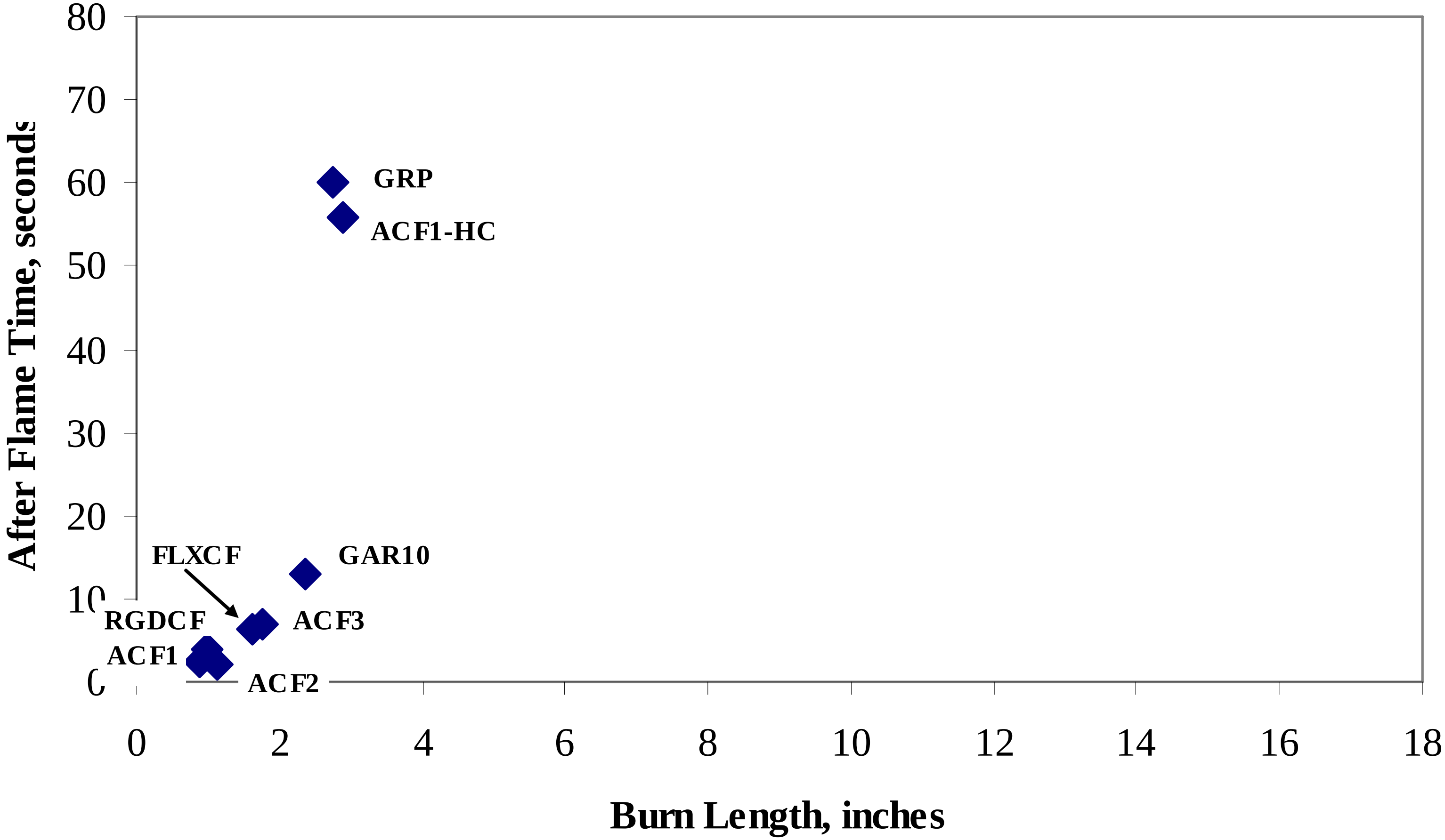
Intermediate Scale Test Results



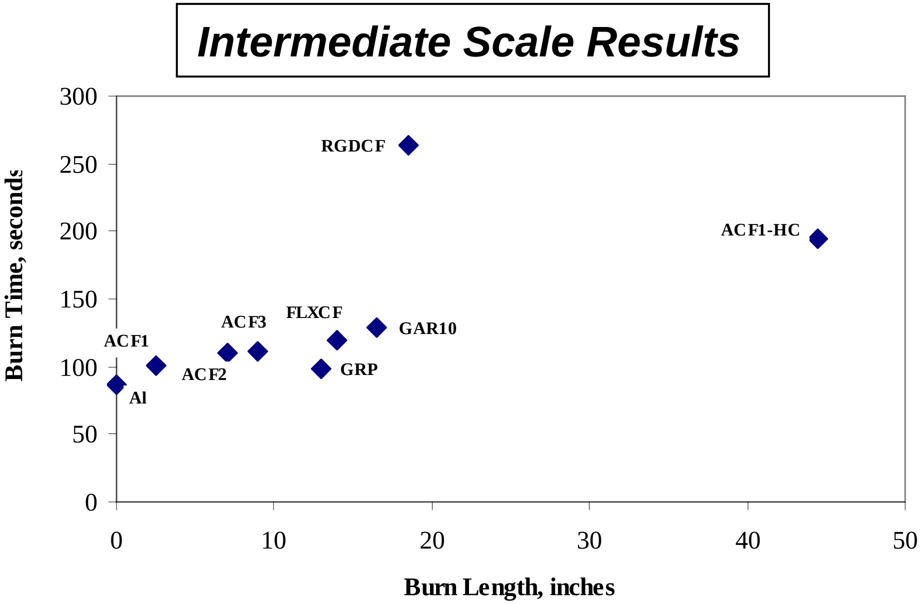
Radiant Panel Test Series #1

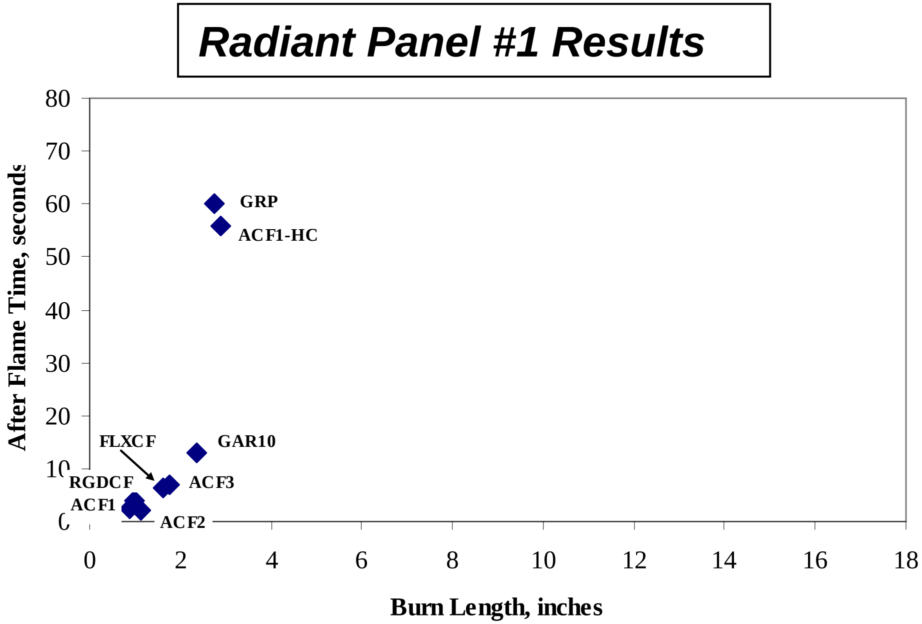
- **R&D Panel at FAATC Bldg 217**
- **Radiant heat panel set to 1.5 BTU/ft^{2}s at "zero position"**
- **Sample holder frame used to align samples with plane of "zero position"**
  - Sample size 11"W x 24"L
- **Test parameters**
  - 1 min pre-heat of sample
  - 15 sec. flame impingement

Radiant Panel Test Series #1 Results



Radiant Panel Test Series #1 Results





Radiant Panel Test Series #2

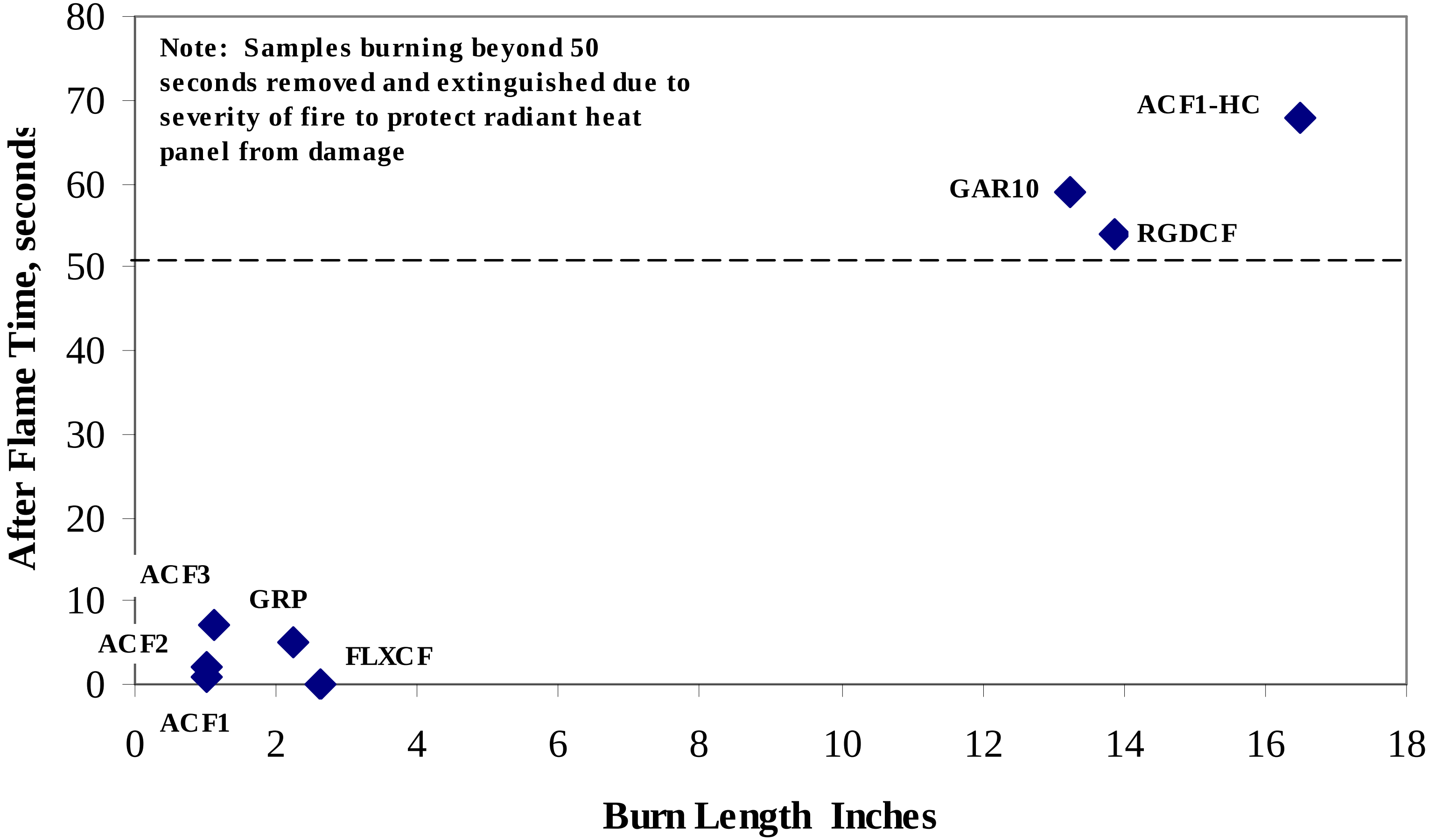
- **R&D Panel at FAATC Bldg 217**
- **Radiant heat panel set to 1.5 BTU/ft2s at “zero position”**
- **Sample holder frame used to align samples parallel to radiant panel**
  - 6 ¼” distance from panel
  - Sample intersects with “zero plane” at “zero position”
  - Sample size 11”W x 24”L
- **Test parameters**
  - 1 min pre-heat of sample
  - 15 sec. flame impingement

Configurations 1 vs 2, RGDCF

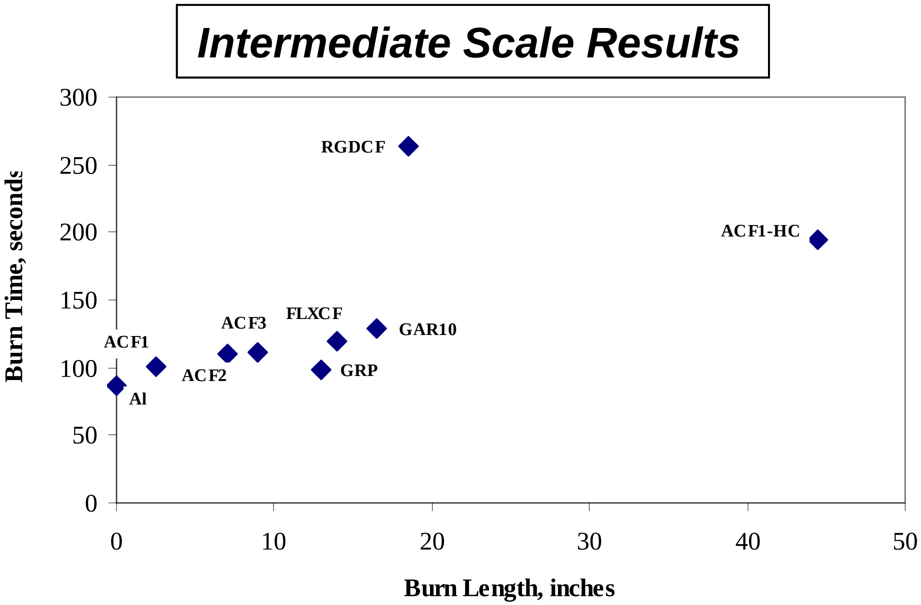
RGDCF Radiant Panel #1

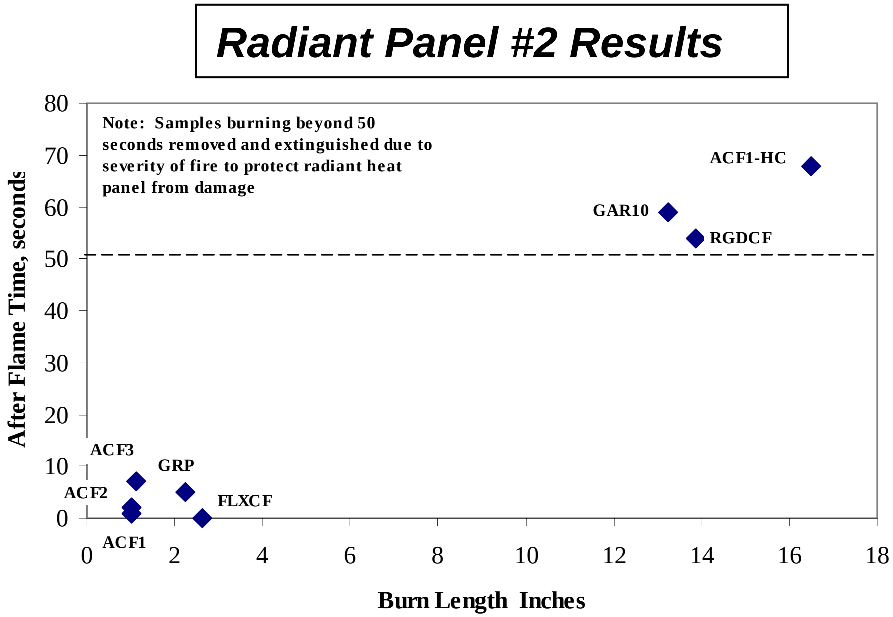
RGDCF Radiant Panel #2

Radiant Panel Test Series #2



Radiant Panel Test Series #2 Results





Summary

- An intermediate-scale test rig was developed and was successful in simulating the effects of a moderately severe hidden fire on the inboard side of a composite fuselage.

- A variety of composite materials, including aerospace grade and non-aerospace grade samples, were tested on the intermediate scale test rig and ranked according to their ability to propagate flames from the foam block hidden fire source.

- As expected, the solid laminate aerospace composite materials outperformed the non-aerospace composites. The aerospace composite sandwich panel, however, was the worst performer, due to the thin structural layers backed by an insulating honeycomb core.

Summary (cont.)

- The test results emphasized the importance of qualifying the material and the sample configuration.

- The radiant panel apparatus, when calibrated to 1.5 BTU/ft2s with a one minute pre-heat, 15 second flame impingement, and sample orientation parallel to and six and one quarter inches from the radiant heat panel, was successful in replicating the fire worthiness ranking from the intermediate scale test.

- An appropriate pass-fail criteria would be a burn length not to exceed two inches and an after flame not to exceed ten seconds.

Draft Technical Note

- **Submitted to FAA sponsor, management September 2010**
- **Submitted to FAA technical report editors with changes December 2010**
- **Will be posted on Fire Safety Website once complete**

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DRAFT

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DOT/FAA/AR-TN

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This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

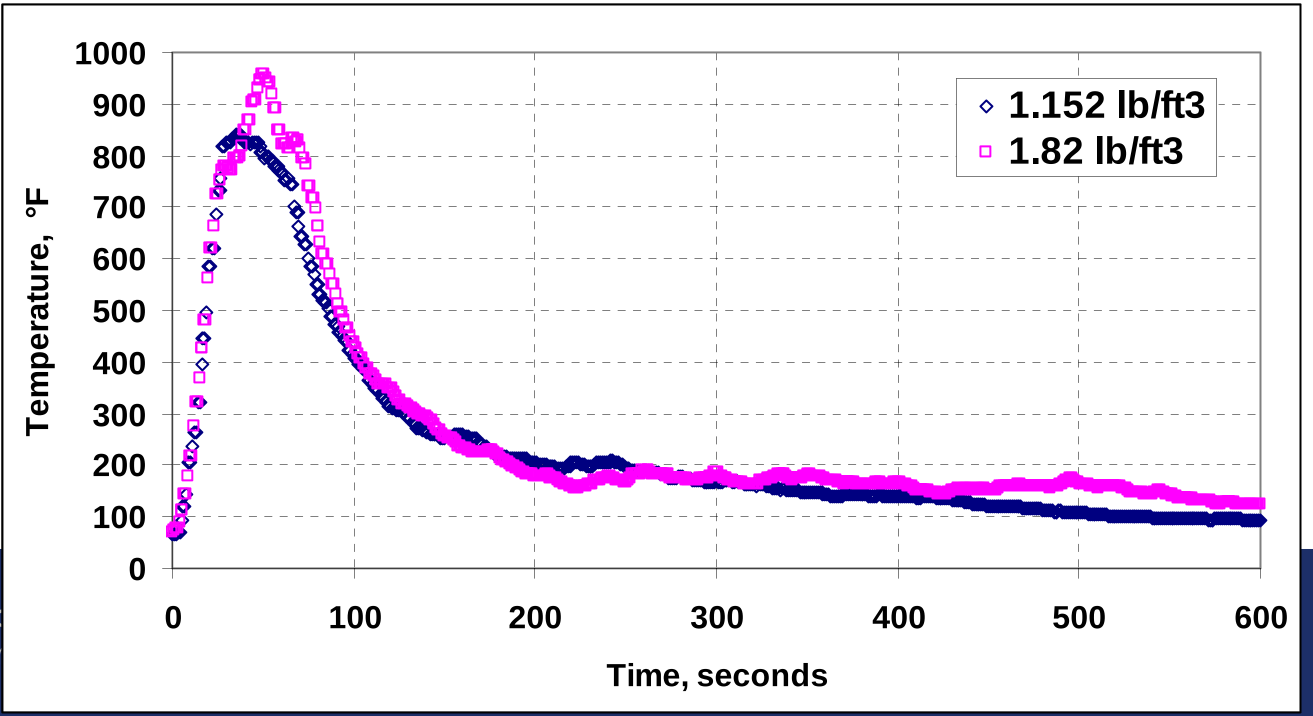
U.S. Department of Transportation
Federal Aviation Administration

Foam Block Details

- **Douglass Industries, Egg Harbor City NJ**
- **Polyurethane Foam, untreated, flammable**
- **Density: 1.1 lb/ft^3**
- **Dimensions: 4” x 4” x 9”**

1.82 lb/ft^3

1.152 lb/ft^3



Foam Block Density

- The 1.82 lb/ft^3 foam had a slightly higher peak temperature
- The 1.82 lb/ft^3 foam achieved peak temperature about 10 seconds after the 1.1 lb/ft^3 foam
- Both foams seem to burn for the same amount of time
- For consistency, testing should be performed with 1.1 lb/ft^3 untreated polyurethane foam blocks, 4” x 4” x 9”

Task Group Update

- A general test method description for the radiant panel tests was uploaded to the KSN site
- It includes general descriptions of the apparatus, definitions, basic calibration and test procedures
- This document will be used as a baseline for the radiant panel test apparatus chapter in the final report from this research activity

Radiant Panel Test Method (generel)

1 Scope

This test method is intended for the determination of the flammability and flame propagation of <...> materials, when exposed to radiant heat and a small open flame.

This test method is used for testing <...>, components or sub-component parts which have to meet the test criteria in accordance with <...> .

It is also intended to evaluate materials or constructions used for non metallic aircraft fuselage design and other related vehicles but it may also be used for other purposes, specified in applicable procurement and regulatory documents.

Results of this test may be used as elements of a fire risk assessment which takes into account all of the factors which are relevant for the assessment of the fire hazard of a particular end use. This is because the test method shall only be used to measure and describe the properties of materials, products or assemblies in response to heat and flame under controlled laboratory conditions but should not be used to describe or appraise the fire hazard or fire risk of materials, products or assemblies under actual fire conditions.

2 Normative References

This Airbus specification incorporates by dated or undated reference provisions from other publications. All normative references cited at the appropriate places in the text are listed hereafter. For dated references, subsequent amendments to or revisions of any these publications apply to this Airbus specification only when incorporated in it by amendment of revision. For undated references, the latest issue of the publication referred to shall be applied.

[1]	Code of Federal Regulations Title 14, Part 25	Airworthiness Standards: Transport Category Airplanes
[2]	DOT/FAA/AR-00/12	Aircraft Materials Fire Test Handbook (Last issue: http://www.fire.tc.faa.gov/handbook.stm)
[3]	ASTM – E648	Critical Radiant Flux of Floor Covering Systems using a Radiant Heat Energy Source
[4]	IEC 584-1	Thermocouples – Part 1: Reference tables
[5]	DIN51622	Liquefied Petroleum Gases: Propane, Propene, Butane, Butane and their Mixtures - Requirements

3 Definitions

Time of flame application	Time of flame application is the duration of time the burner flame is applied to the specimen.
After flame time	After flame time is the time in seconds that the specimen continues to flame after the burner flame is removed from the specimen.
Burn length	Burn length is the distance from the zero point to the farthest evidence of damage by flame propagation measured along the centerline. It includes areas of partial combustions, charring or embrittlement but not areas sooted, stained, warped or discolored nor areas where materials has shrunk or melted away from the heat
Flame propagation	Flame Propagation is the spreading of a flame during the test
Zero position	The zero position is the flame application point on the longitudinal centerline.

Questions?

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