Development of a Lab-Scale Flame Propagation Test Method for Composite Fuselage Materials

Federal Aviation Administration

Presented to: IAMFTWG, Renton, WA

By: Robert Ochs

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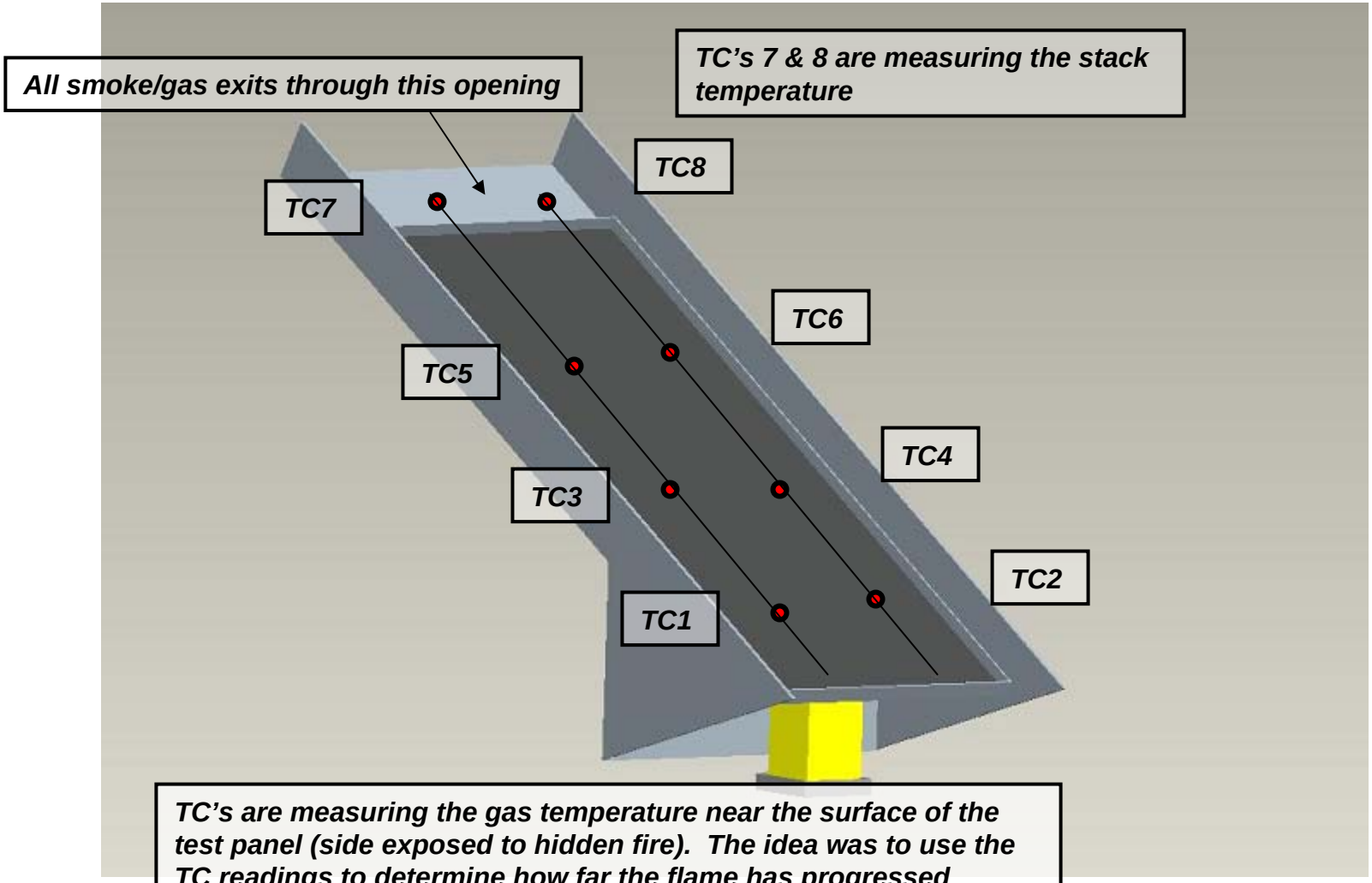
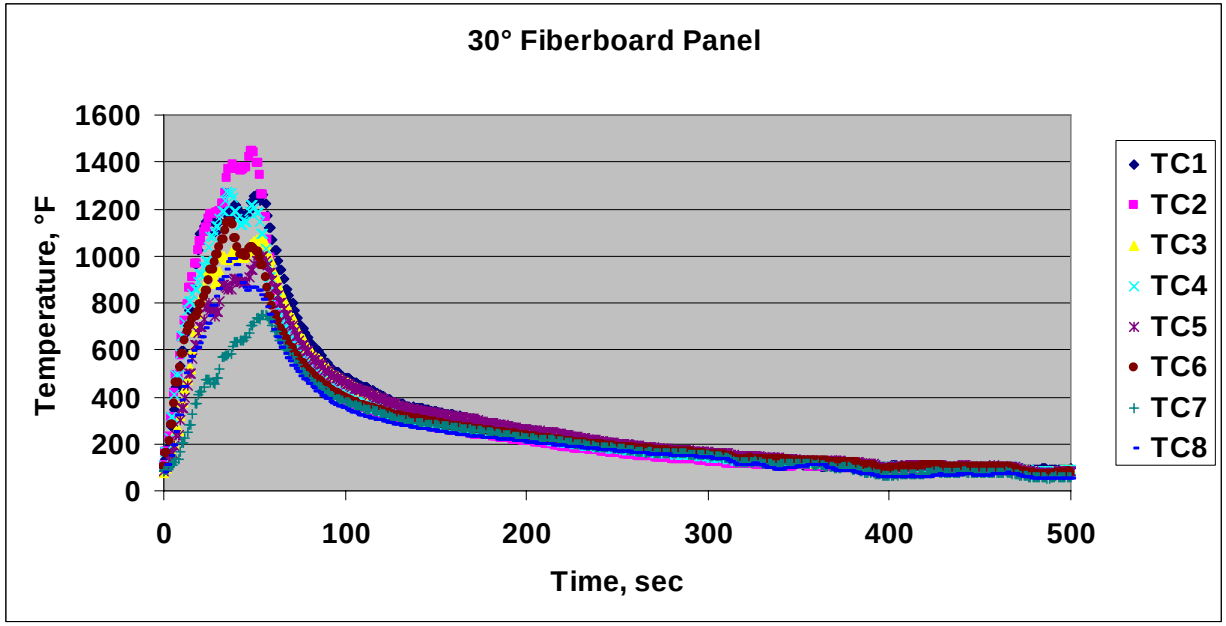
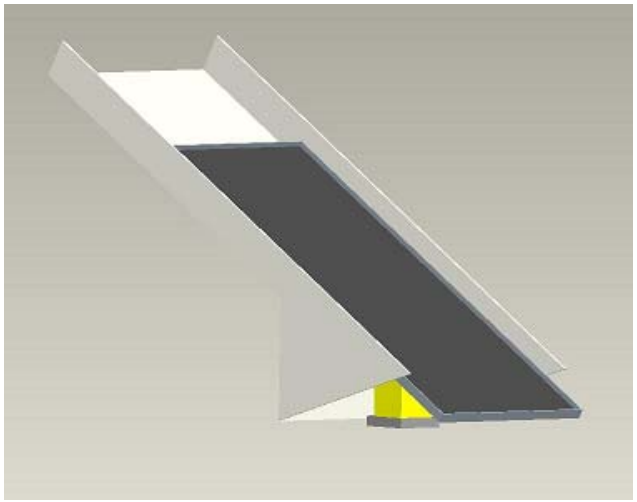
Objective

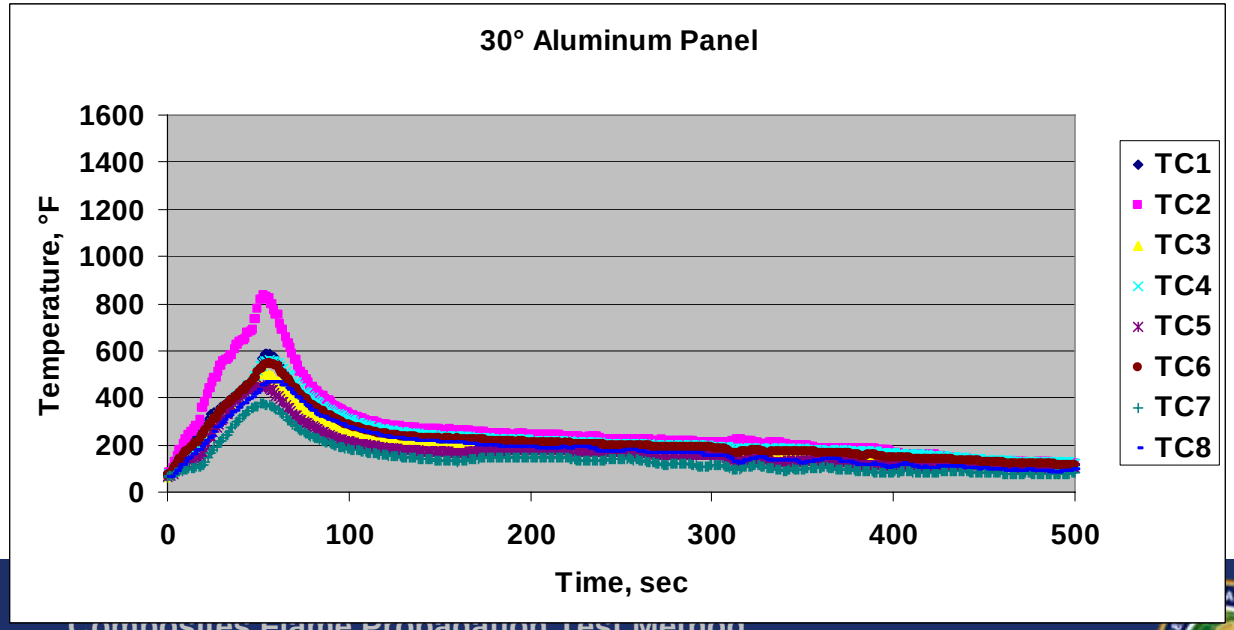
- **Develop a lab-scale test to determine the propensity of a non-traditional fuselage material to propagate a flame or to sustain flaming combustion when subjected to a standardized hidden fire threat**
- **Lab-scale test criteria is to be based upon intermediate scale testing**
  - Standard fire source used to simulate a hidden fire
    - 4” x 4” x 9” untreated urethane foam block
    - 10cc of heptane soaked into foam to provide more uniform burning
  - Various materials of similar mass and rigidity will be tested, both aircraft grade and non-aircraft



TC's are measuring the gas temperature near the surface of the test panel (side exposed to hidden fire). The idea was to use the TC readings to determine how far the flame has progressed during the test.

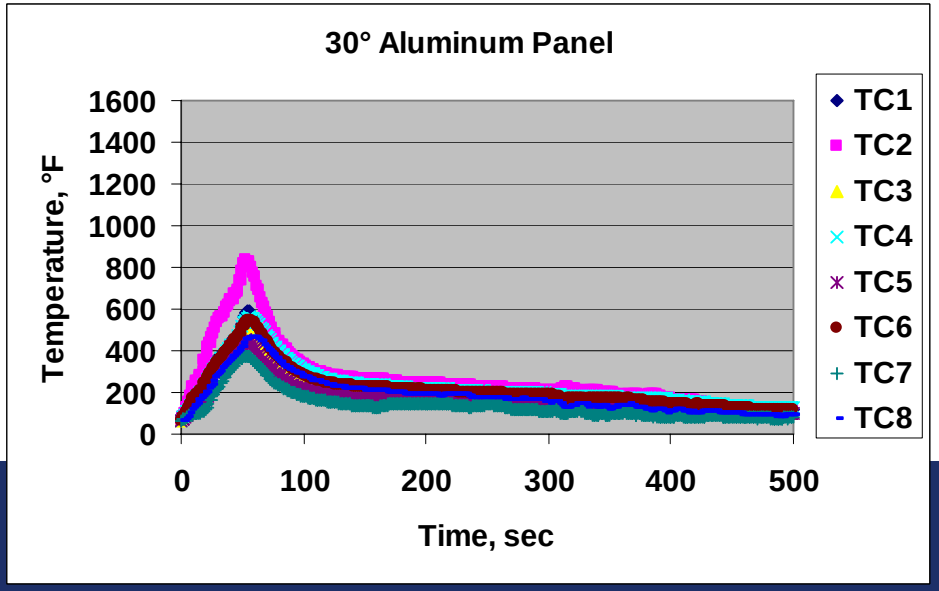

30° Fiberboard Panel
Temperature, °F
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Time, sec
TC1
TC2
TC3
TC4
TC5
TC6
TC7
TC8

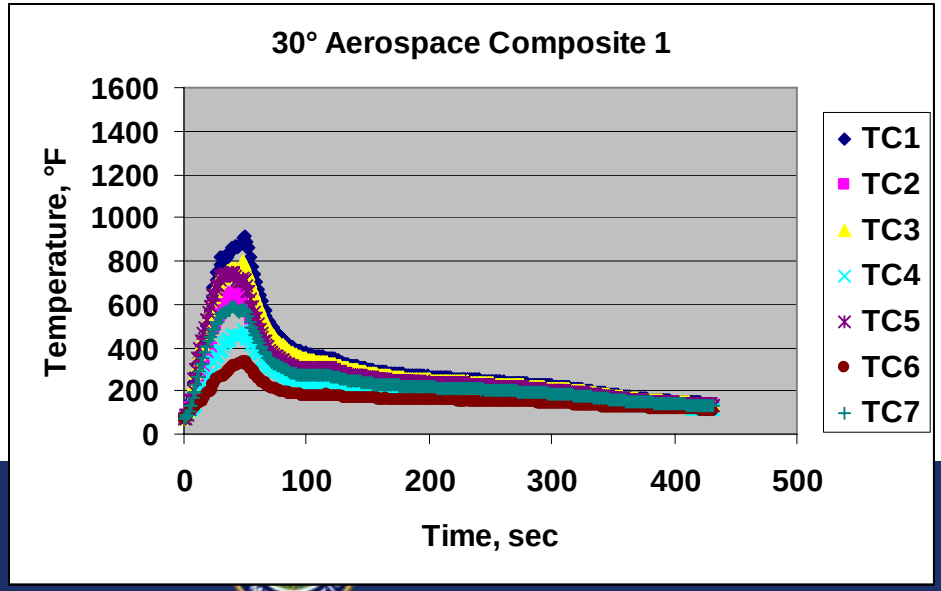


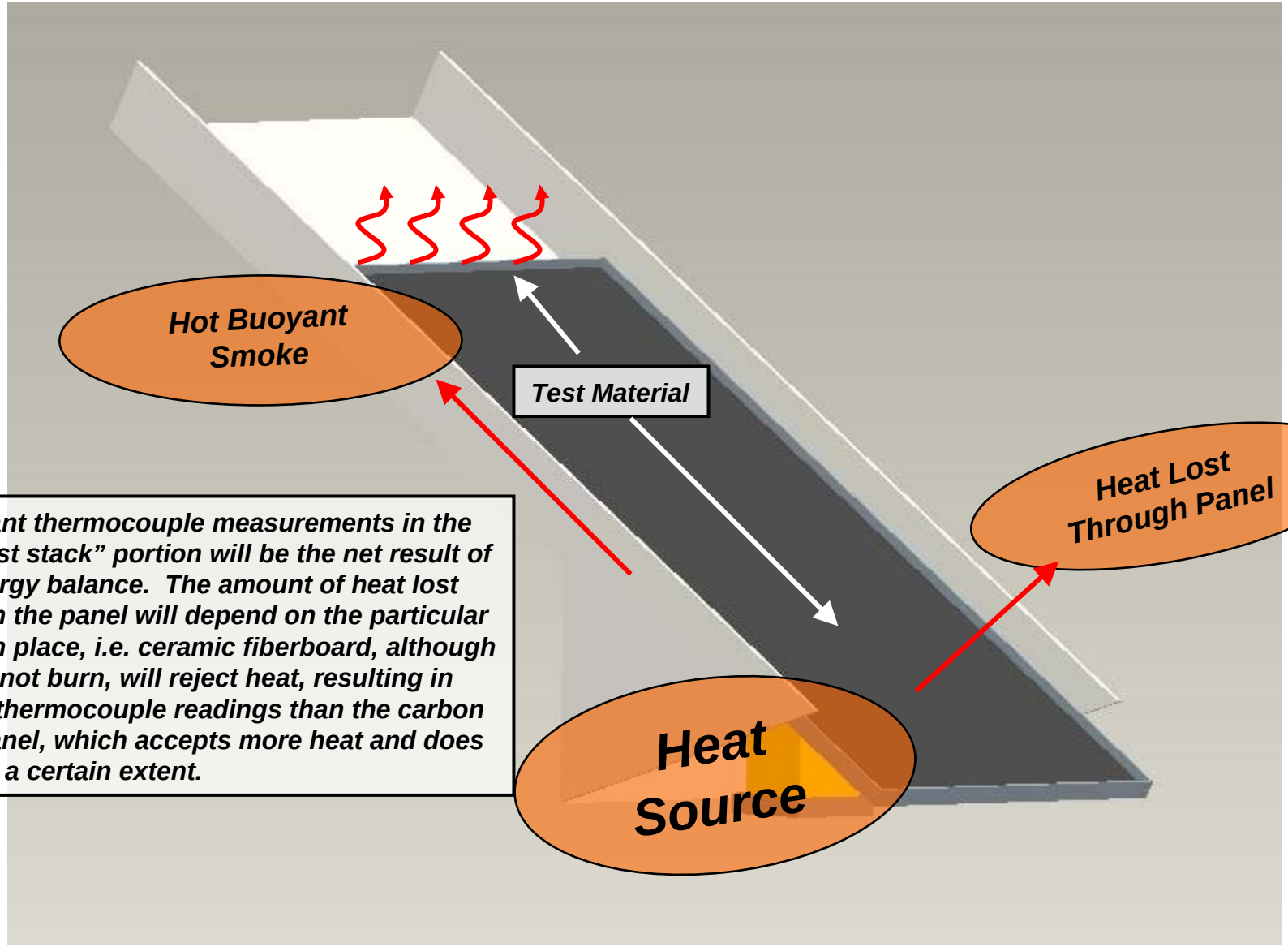

30° Aluminum Panel
Temperature, °F
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Time, sec
TC1
TC2
TC3
TC4
TC5
TC6
TC7
TC8

Materials in this Test Series

- **Aerospace Composites**
  - Unidirectional carbon fiber prepreg (ACF1)
  - Unidirectional carbon fiber prepreg (ACF2)
  - Woven carbon fabric/epoxy (ACF3)
  - Woven carbon fabric/epoxy (ACF4)
- **Non-aerospace Composites**
  - Garolite (phenolic laminate materials)
    - Grade CE cotton-cloth reinforced phenolic resin (GARCE)
    - Grade LE fine weave cotton reinforced phenolic resin (GARLE)
  - Fiber reinforced polymer fiberglass
    - Glass-reinforced polyester (GRP)
    - Glass-reinforced vinylester (GRV)
  - Rigid woven carbon fiber (RGDCF)
  - Flexible woven carbon fiber (FLXCF)
- **All samples 1/8” thickness**

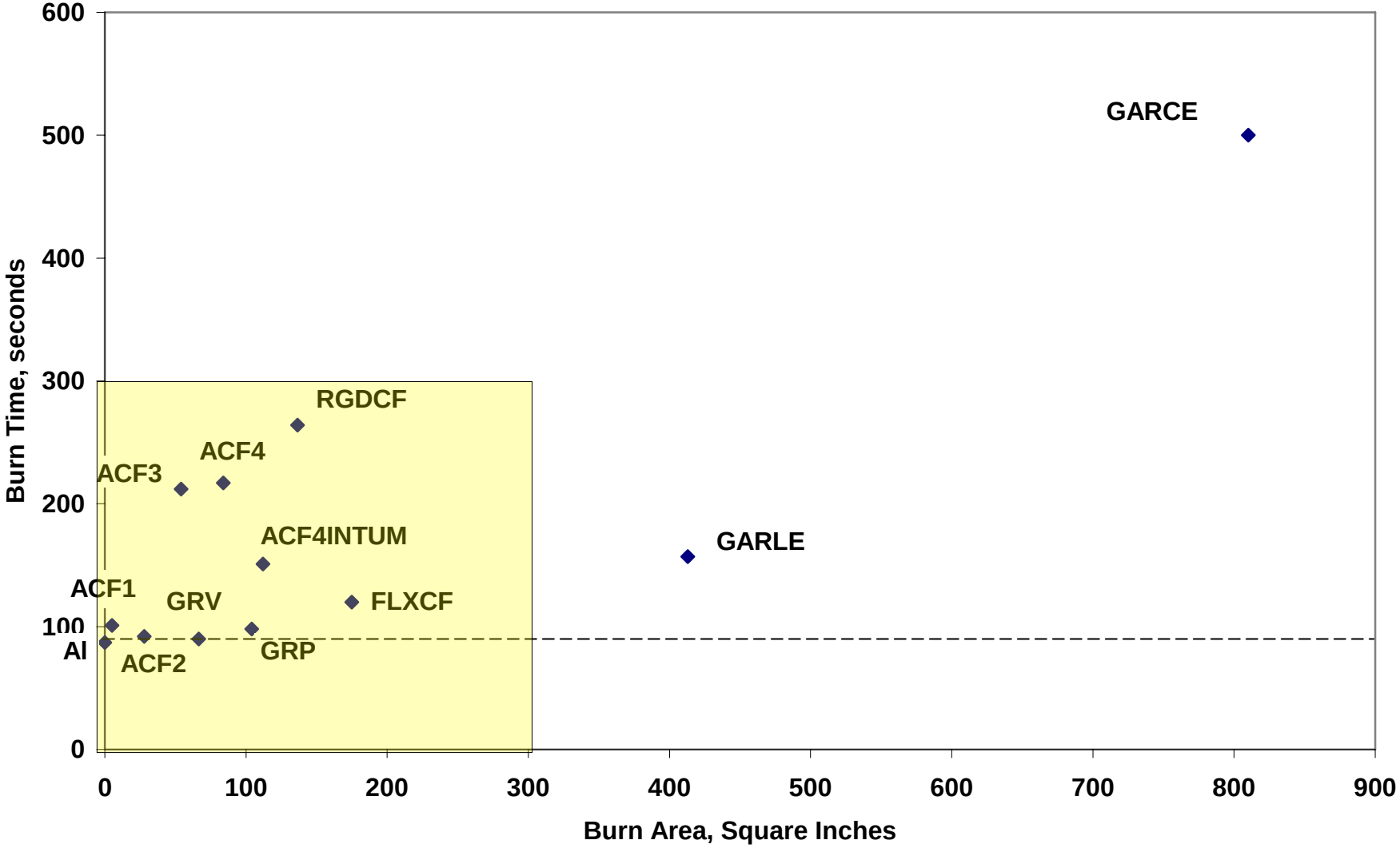

30° Aluminum Panel
Temperature, °F
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Time, sec
TC1
TC2
TC3
TC4
TC5
TC6
TC7
TC8


30° Aerospace Composite 1
Temperature, °F
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
Time, sec
TC1
TC2
TC3
TC4
TC5
TC6
TC7

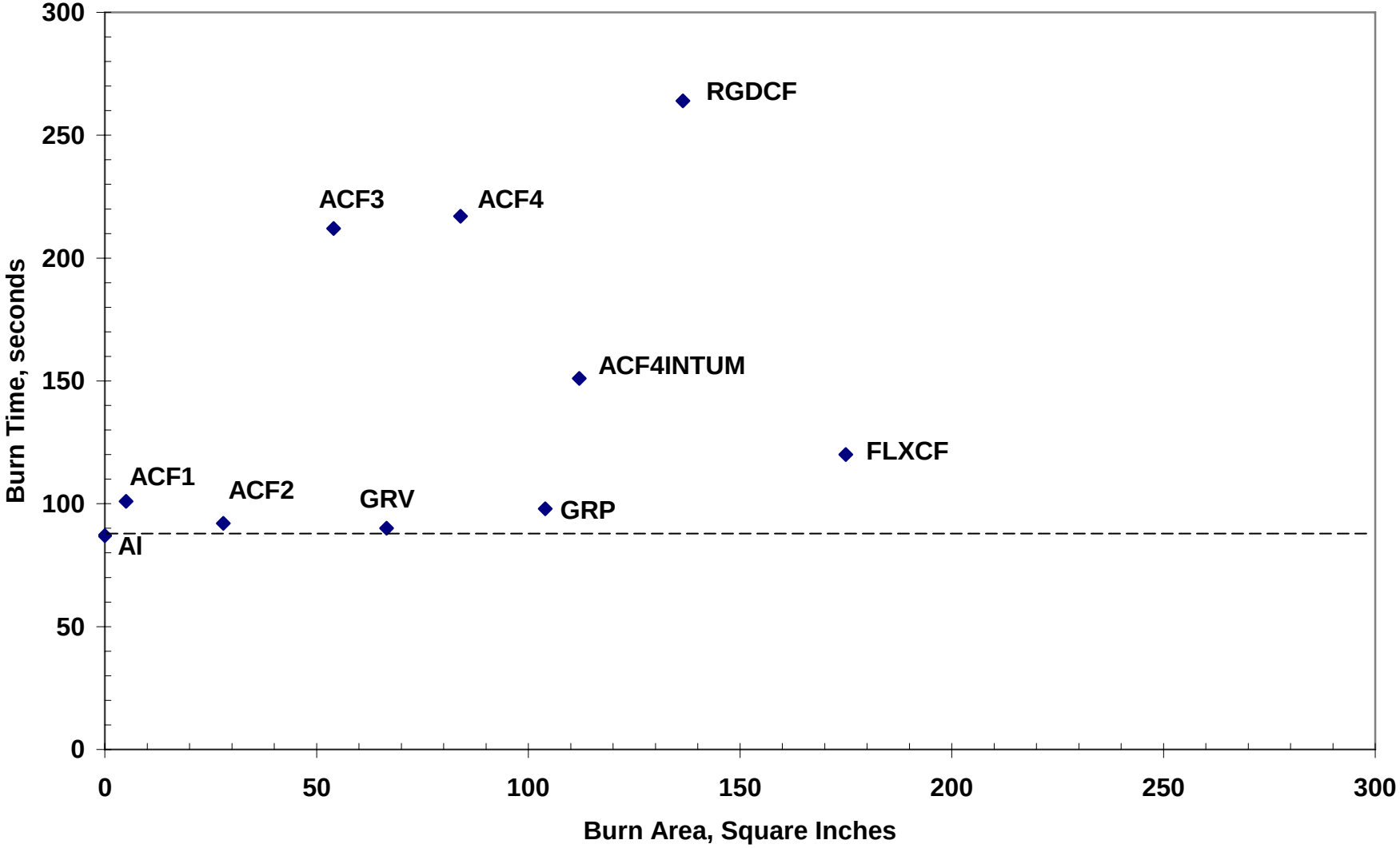


Resultant thermocouple measurements in the "exhaust stack" portion will be the net result of the energy balance. The amount of heat lost through the panel will depend on the particular panel in place, i.e. ceramic fiberboard, although it does not burn, will reject heat, resulting in higher thermocouple readings than the carbon fiber panel, which accepts more heat and does burn to a certain extent.

Intermediate Scale Test Results



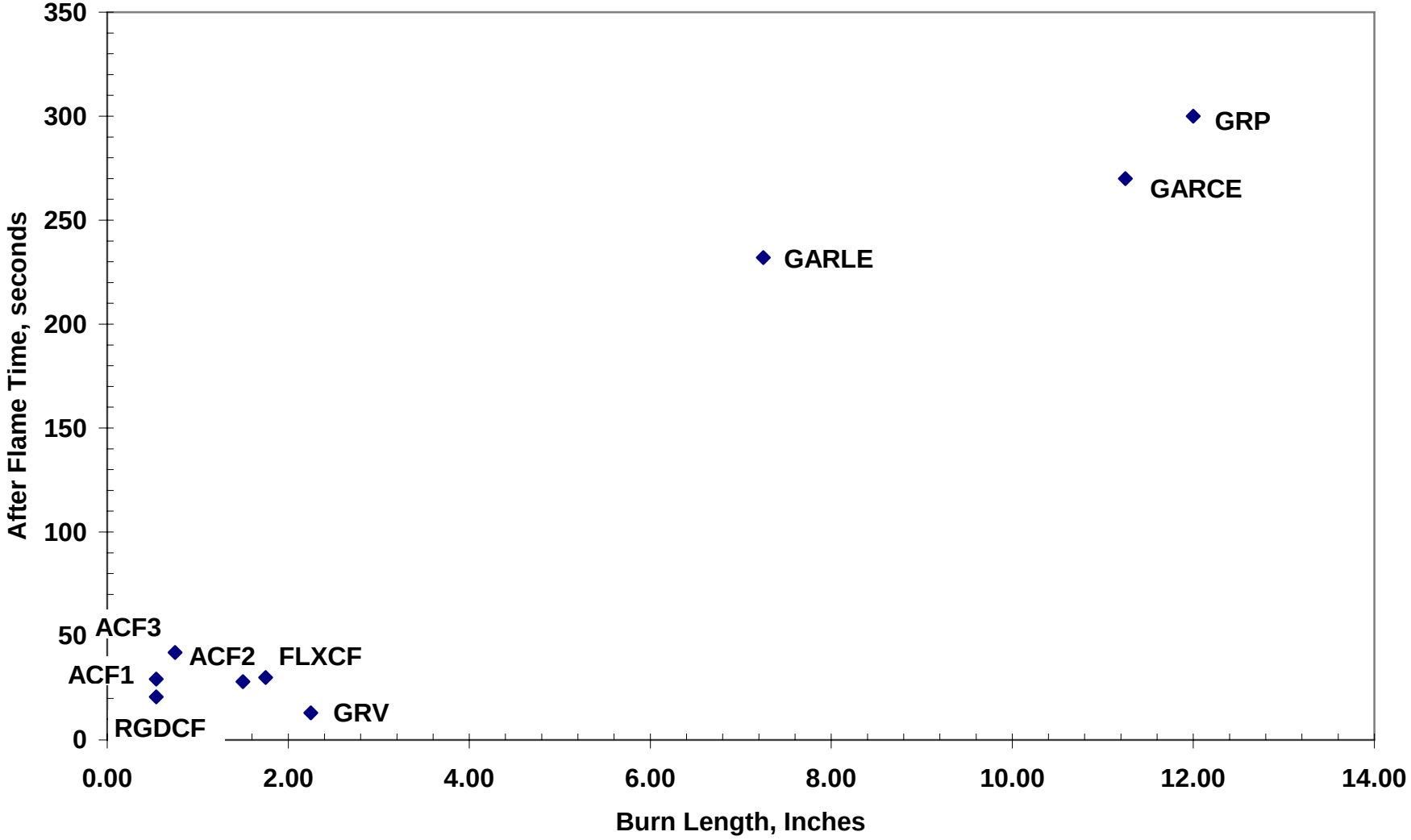
Intermediate Scale Test Results



Intermediate Scale Testing – Analysis

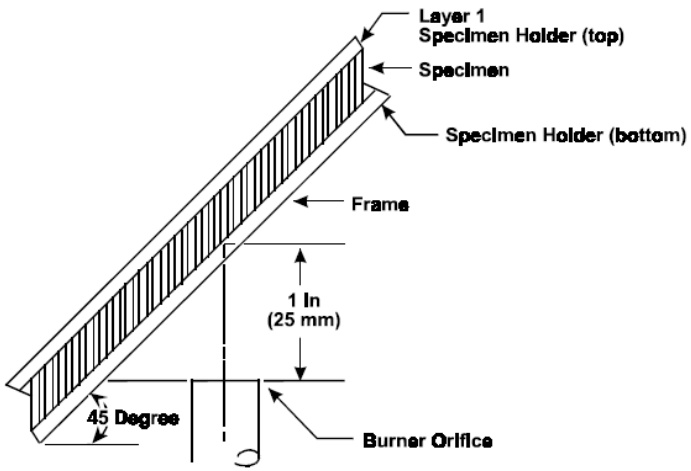
- **The test rig is capable of simulating a hidden area in an aircraft cabin**
  - Test rig provides an insulated area with plentiful oxygen and room for measurable flame propagation
- **Thermocouple data can be used to determine the duration of panel burning (peak width)**
  - Magnitude of temperature measurements can not be used to determine intensity
  - Temperature measurements indicate resultant heat not lost to or through panel
- **Aluminum panel provides a baseline for the test series**
  - Foam block duration is about 90 seconds
  - Any burn time beyond 90 seonds indicates panel interaction
- **Material performance:**
  - ACF 1 and 2 perform very well with minimal burn area or burn time beyond aluminum
  - ACF 3 and 4 are moderate performers and have small burn areas but longer burn times
    - ACF4 with intumescent coating performed better than without
  - Fiberglass samples GRV and GRP did not burn much longer beyond aluminum but had moderate burn areas
  - Non-aerospace carbon fibers RGDCF and FLXCF had significant burn areas while FLXCF had a short burn time and RGDCF had a significant burn time
  - Garolite materials GARCE and GARLE were poor performers, with total consumption of GARCE and moderate burn time but long burn area for GARLE

60 Second Vertical Bunsen Burner Results

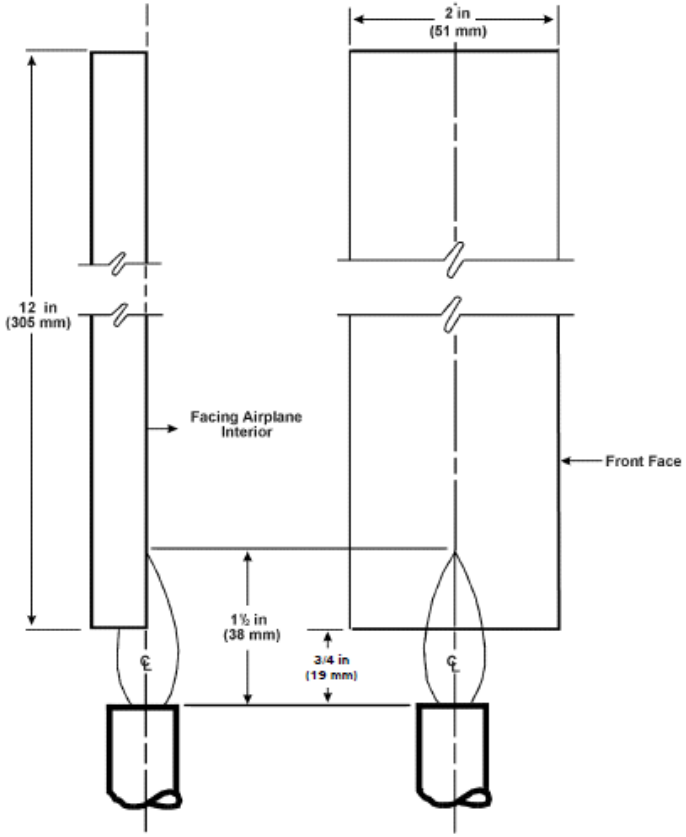


- **Discrepancy between VBB and intermediate scale test results**
  - Intermediate scale flame propagation test is a surface burning test
    - Only the outer layer of epoxy/resin is exposed to flame
    - Unless significant heat is present to delaminate first layer, inner layers will remain intact
  - VBB is an edge test
    - Exposure of the entire thickness of the composite panel to the flame results in more epoxy/resin being exposed to heat
    - Jets of high pressure resin vapor shoot out sideways and down from the exposed edge
  - 45° BB may be more applicable for comparison with the intermediate scale test rig
  - Radiant panel test is surface test as well, more severe than 45° BB

45° BB Test Configuration



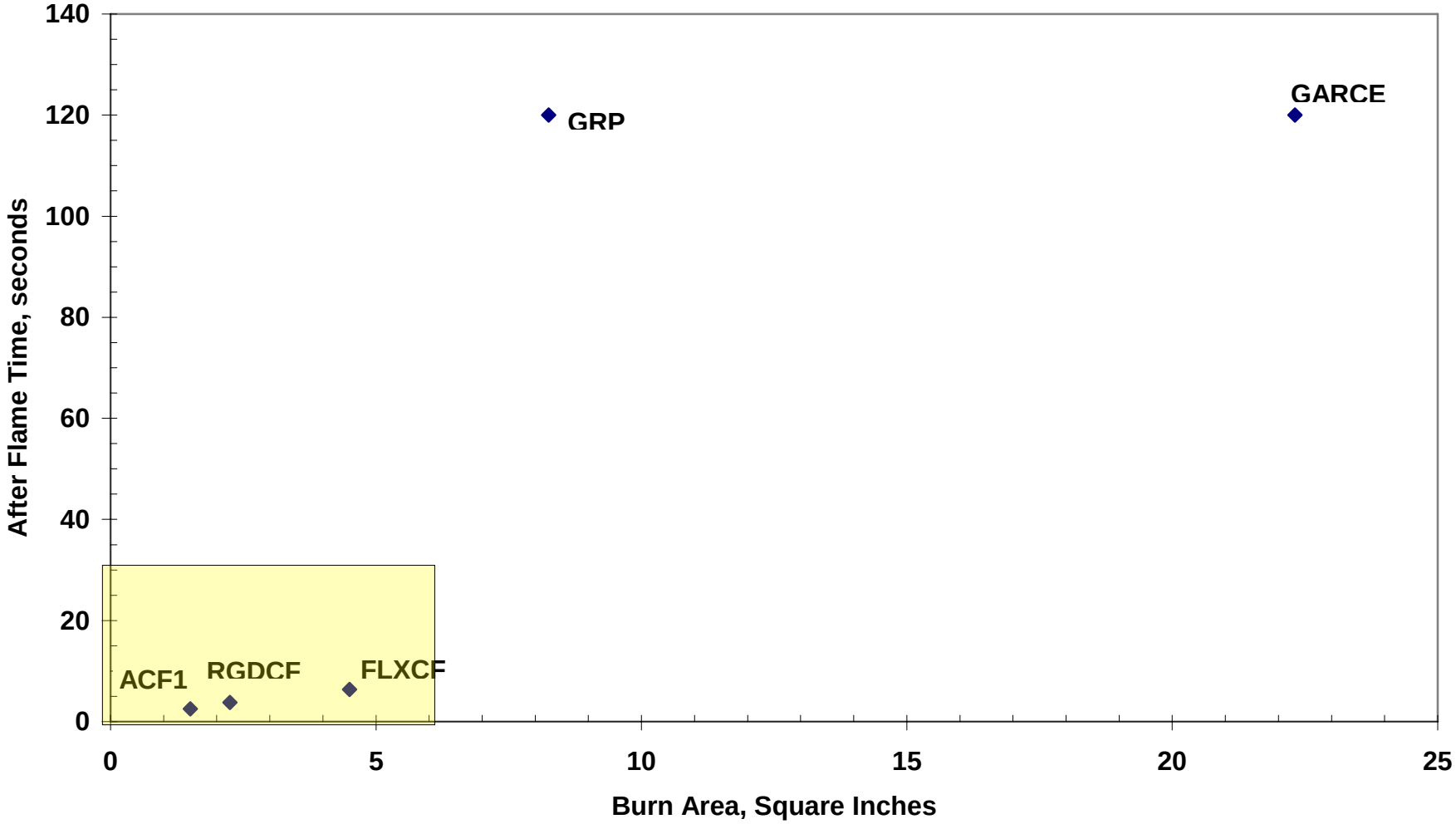
VBB Test Configuration



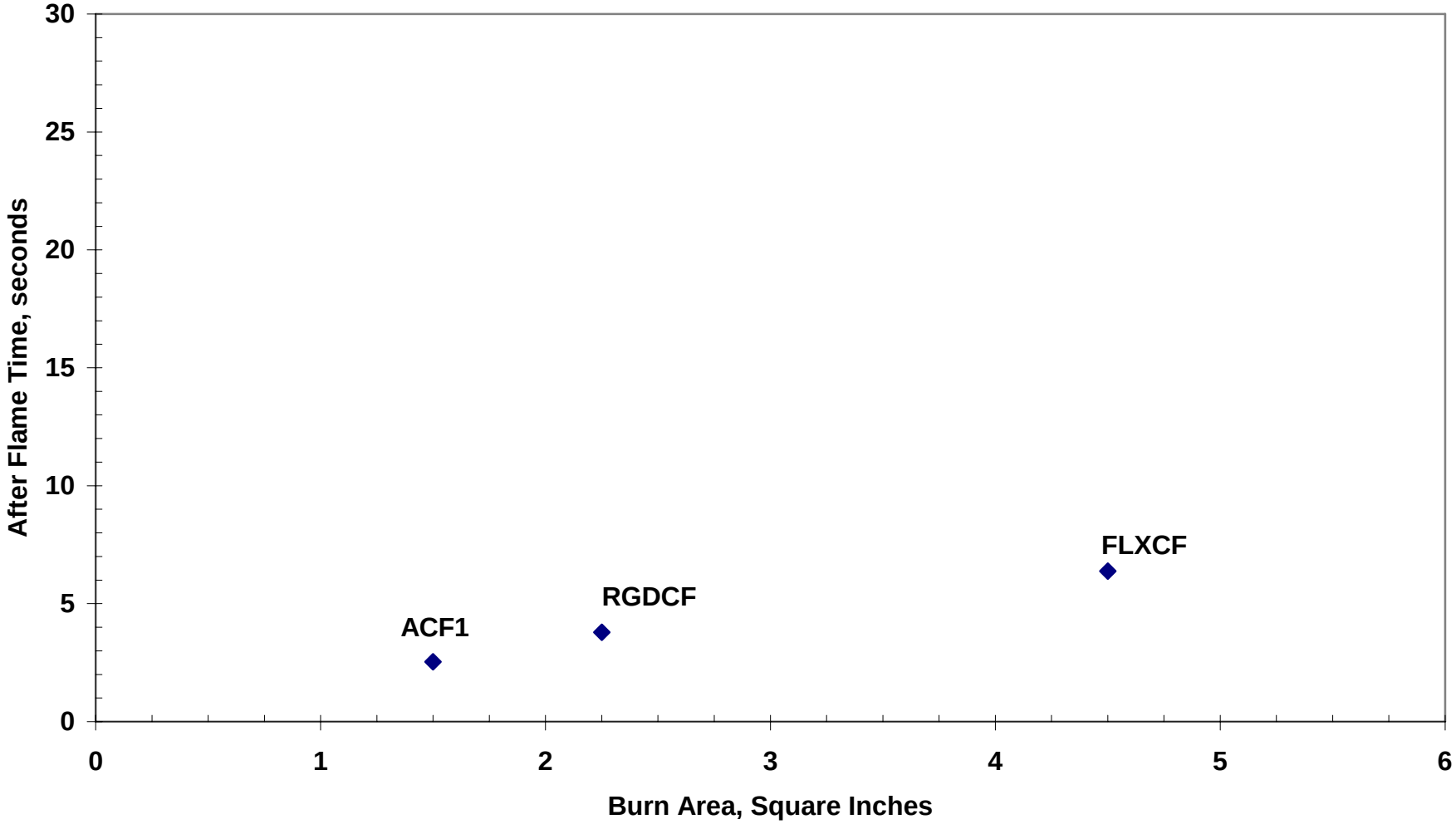
Radiant Panel Tests – Initial Settings

- **1.5 BTU/ft^{2}s at "zero position"**
- **1 minute pre-heat of sample**
- **15 second flame impingement time**

Radiant Panel Test Results
1 minute pre-heat, 15 second flame impingement



Radiant Panel Test Results
1 minute pre-heat, 15 second flame impingement



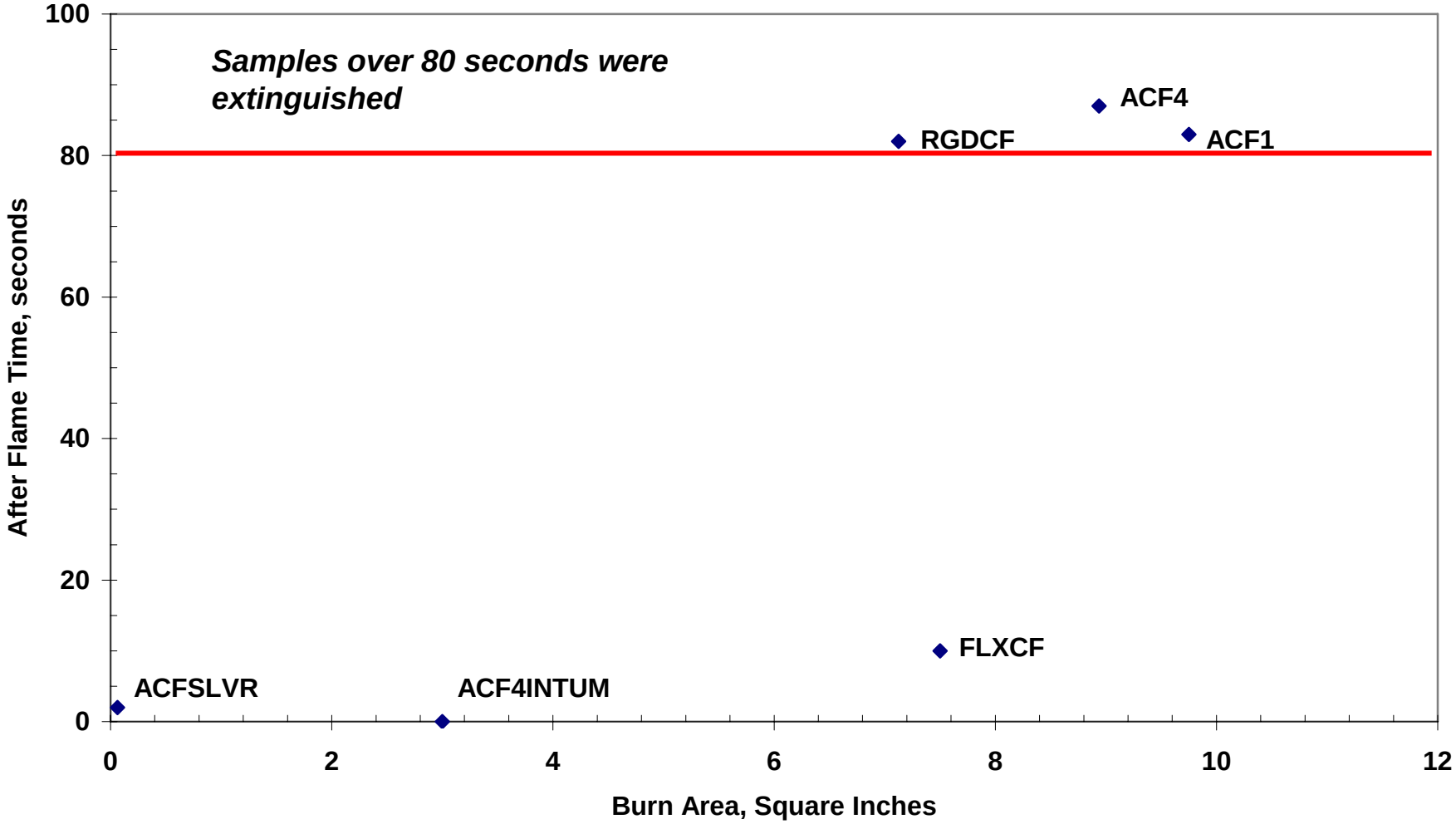
ACF1 15 sec.

ACF1 30 sec.

Radiant Panel Settings - Experimental

- **1.5 BTU/ft^{2}s at “zero position”**
- **1 minute pre-heat of sample**
- **30 second flame impingement time**

Radiant Panel Test Results
1 minute pre-heat, 30 second flame impingement



ACF1 30 sec. rad panel vs. ACF1 w/silver paint 30 sec. rad panel

Radiant Panel Testing - Analysis

- **1 minute pre-heat and 15 second flame impingement**
  - ACF1 was an excellent performer
  - GRV was a poor performer
    - Edge became involved
  - Non aerospace carbon fiber RGDCF and FLXCF were moderate performers
  - Need to test remaining ACF samples for better correlation
- **1 minute pre-heat and 30 second flame impingement**
  - ACF1, RGDCF, ACF4 were poor performers with extremely long burn time but small burn areas
  - Treating the surfaces of ACF1 and ACF4 with silver paint and intumescent coating, respectively, significantly enhanced their performance in this test
    - Same effect was noted in intermediate scale with ACF4 and intumescent coating

Summary

- **Intermediate and lab-scale tests were performed on composite materials**
  - Intermediate scale testing was able to discriminate between poor performing non-aerospace materials and fire resistant aerospace grade materials
  - The limited radiant panel testing performed shows similar trends but more work is needed
- **Material construction is big factor in fire performance**
  - For woven fabric reinforcements, tighter weaves seem to prevent deep flame penetration and long burn times
  - Unidirectional laminates can allow deep flame penetration depending on flame impingement time
  - Surface treatments such as paint, coatings, or barriers seem to be effective in preventing heat conduction through the thickness and flame penetration, significantly enhancing fire performance
  - If edges are involved, burn times and burn areas seem to increase significantly

Upcoming Work

- **Continue radiant panel tests**
- **Gather sandwich panel materials for testing**

Composites Task Group

- **Discussions about configuration of composite panels in actual aircraft**
  - Surface coatings?
  - Exposed edges?
- **Comments, criticism, assistance welcome!**

Questions, Comments, Concerns?

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