

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

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Federal Aviation
Administration



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**



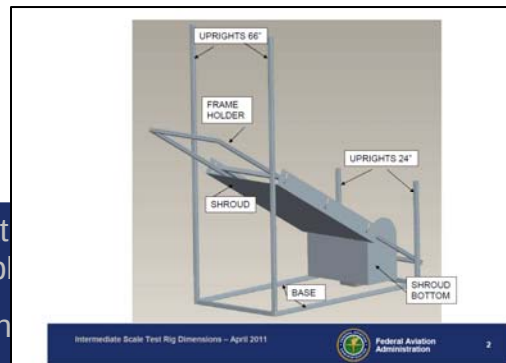
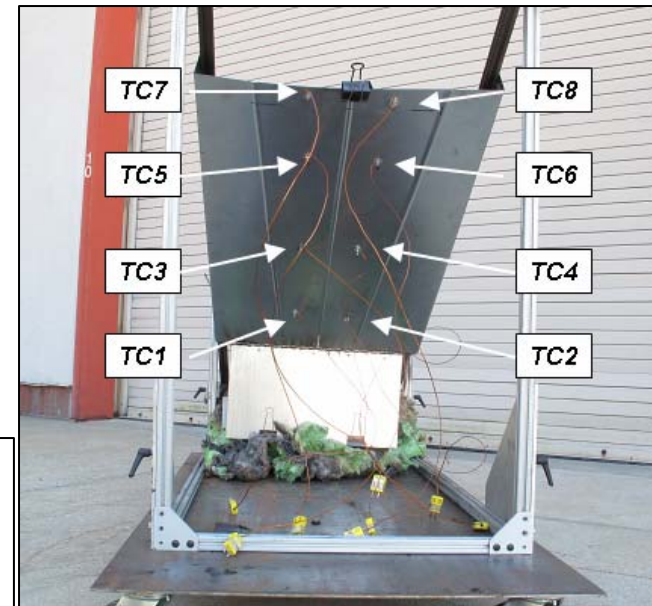
Part 1 - Objective

- **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



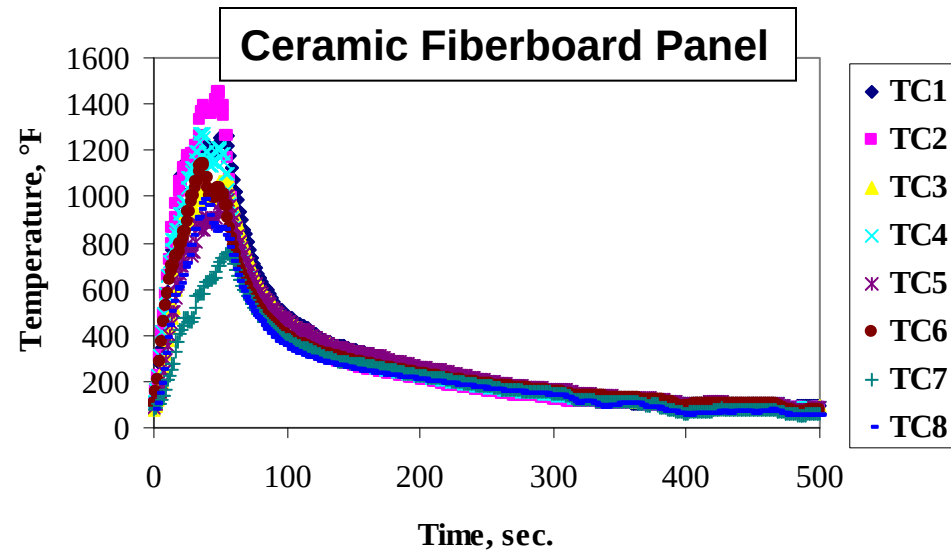
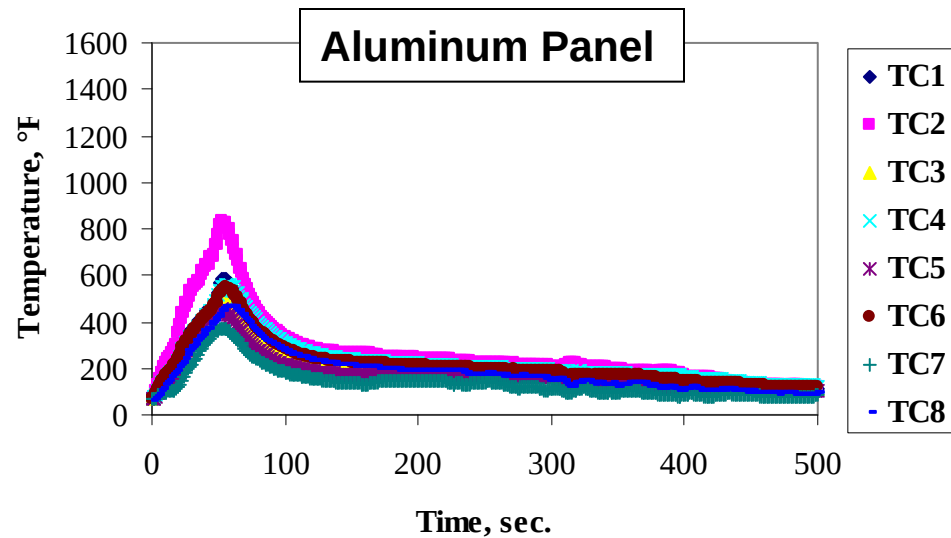
Intermediate Scale Test Rig

- 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
- Plans for construction are now available on KSN site



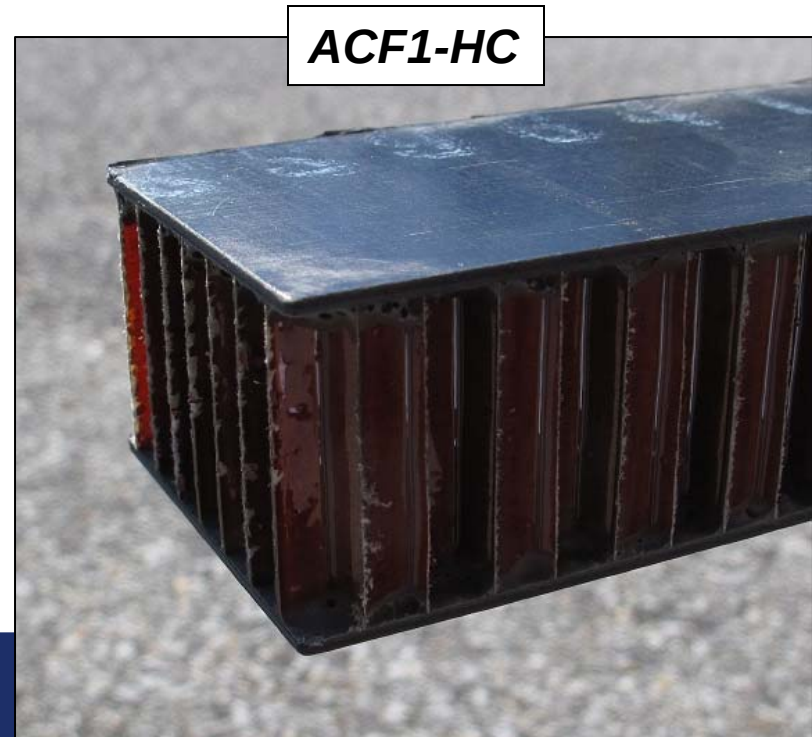
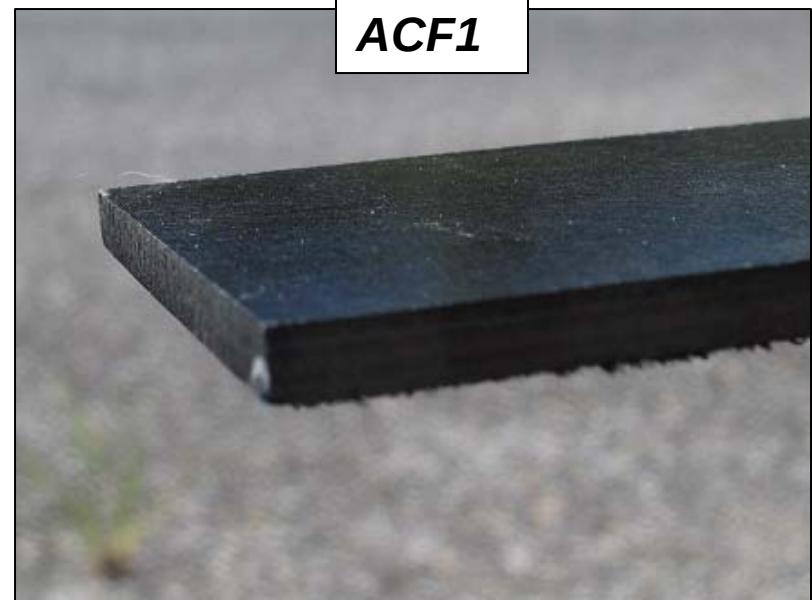
Baseline Test

- 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/m² aerial weight, prepregged with amine cured, toughened 356°F epoxy resin system
 - ACF2: carbon/epoxy panel unidirectional carbon tape, 1.79 g/cm³ density, prepregged with a toughened, 365°F cure epoxy system
 - ACF3: carbon/epoxy panel woven carbon fabric, 193 g/m² 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"

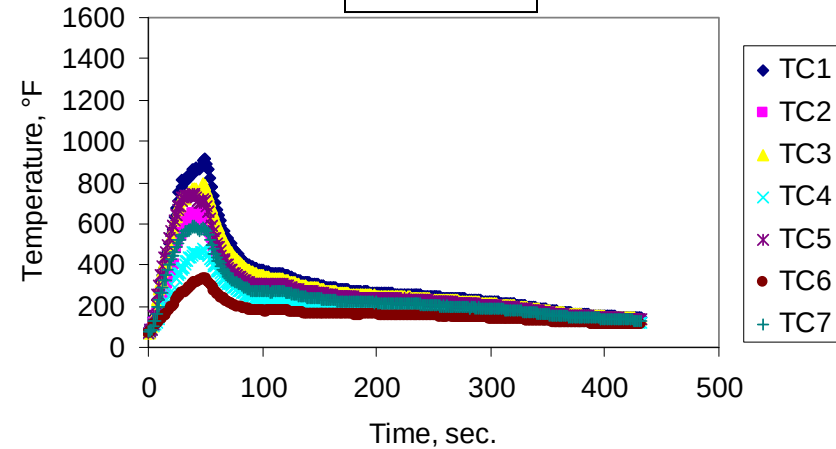


Intermediate Scale Test

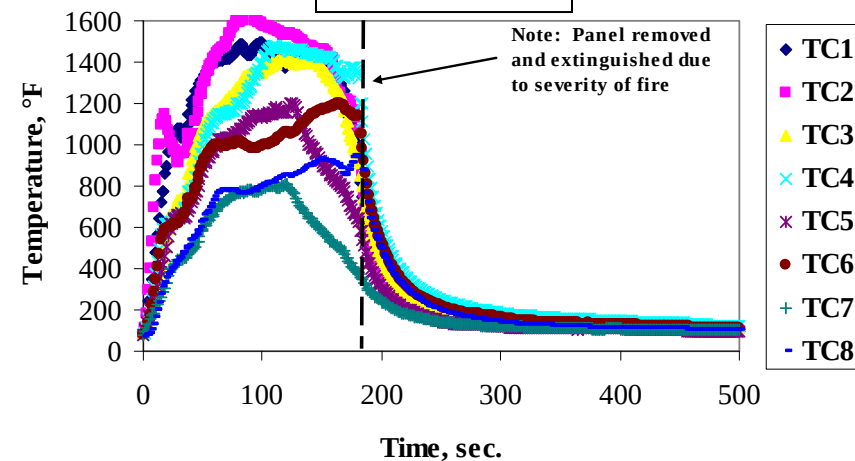
ACF1-HC



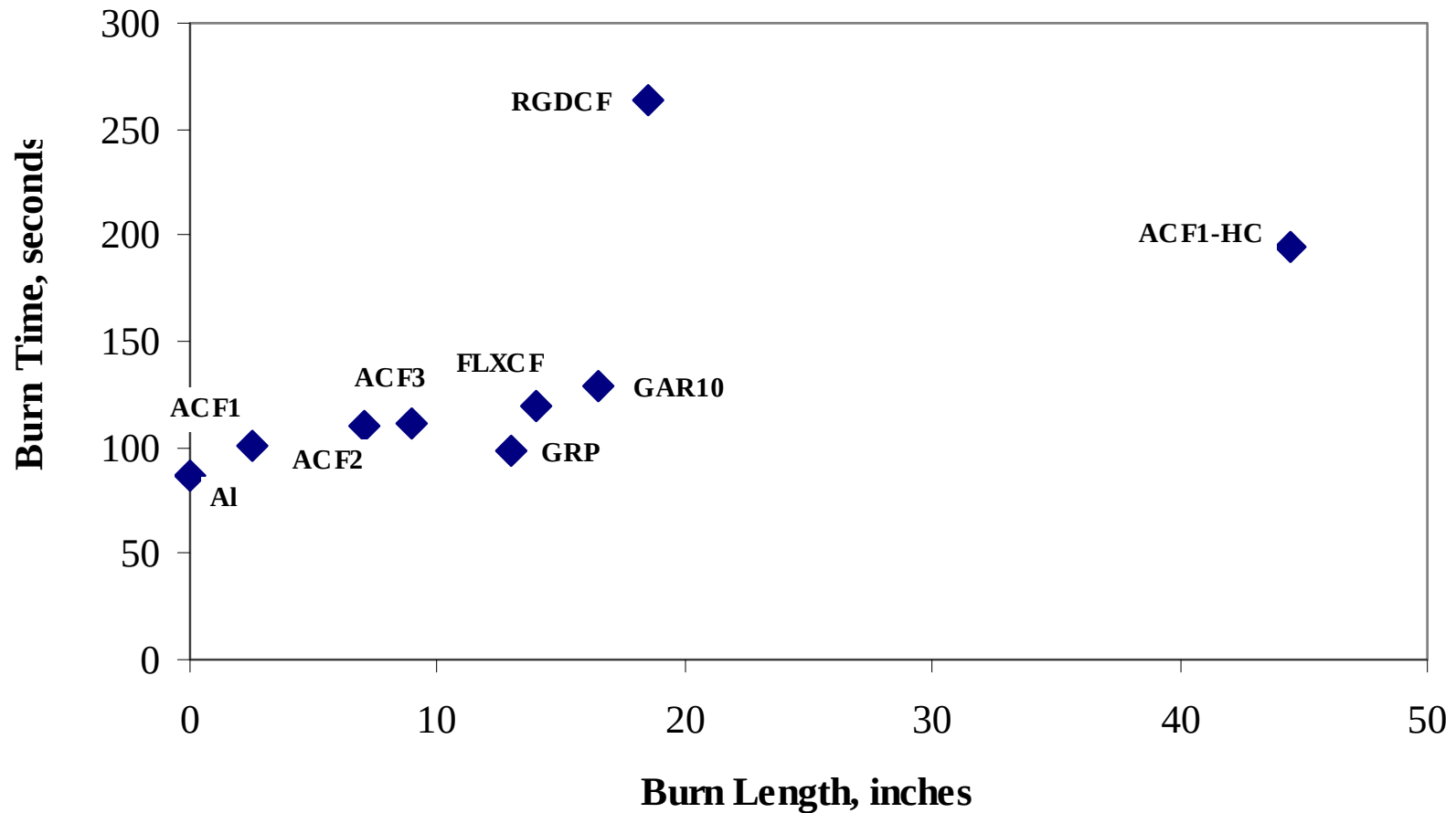
ACF1



ACF1-HC



Intermediate Scale Test Results

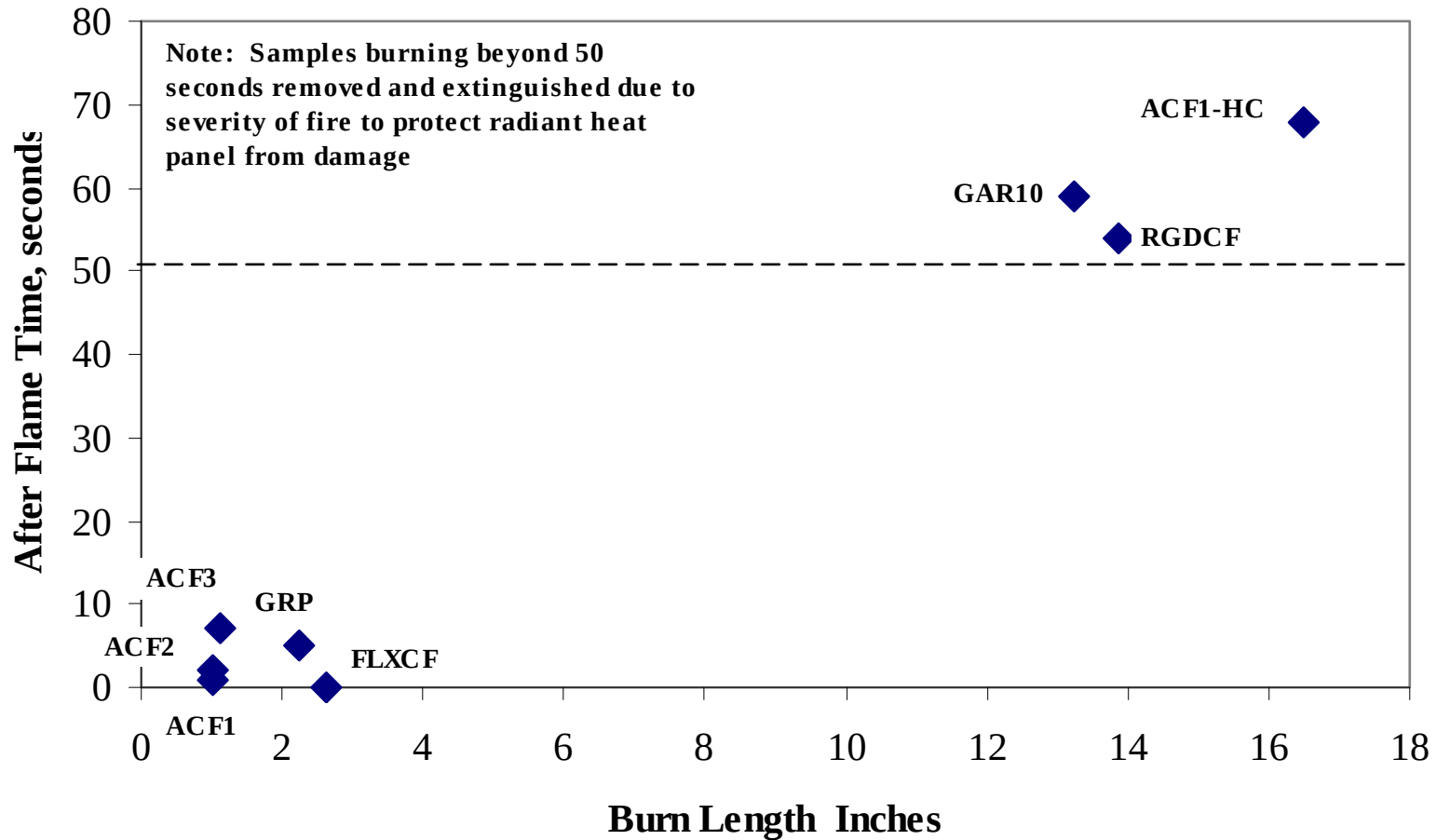


Radiant Panel Test Series #2

- 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

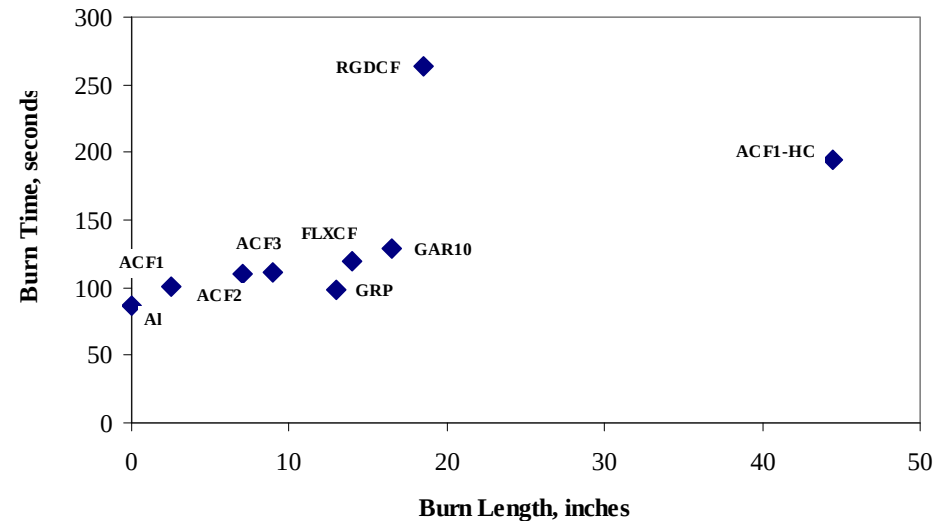


Radiant Panel Test Series #2

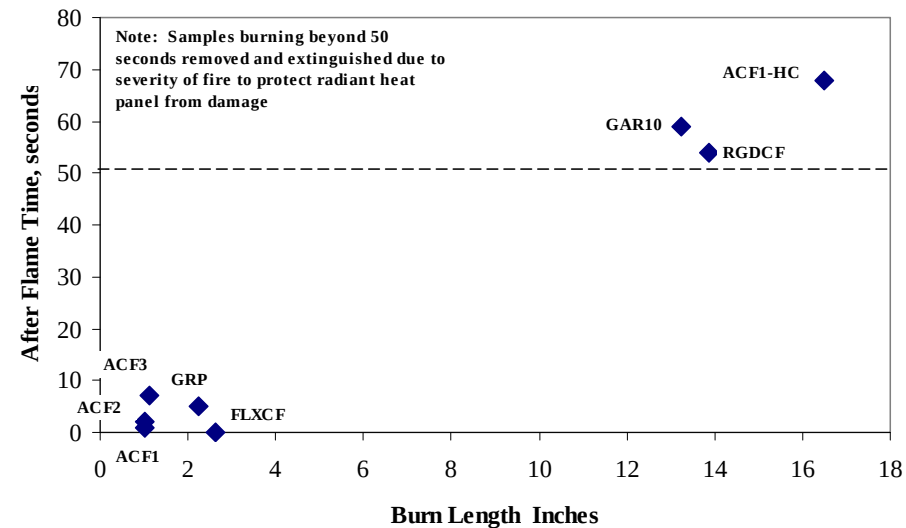


Radiant Panel Test Series #2 Results

Intermediate Scale Results



Radiant Panel #2 Results



Part 1 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.**



Part 1 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 flame propagation 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.



Part 1 – Next Steps

- **A study will be performed to determine the boundaries of the validity of the correlation**
- **Carbon/epoxy (ACF1) samples have been ordered over a range of thicknesses**
 - 4, 8, 24, 32 plies
- **Intermediate scale and lab scale tests will be performed to study the correlation**



Part 2 - Other Inaccessible Area Composites

- **One objective of Part 25 app. F activity is to require all materials in inaccessible areas to resist flame propagation when exposed to standard hidden fire source (foam block) except for:**
 - Small parts (defined by ARAC task group)
 - Materials that meet another test equal to or greater in severity than foam block test
 - Hierarchy of test methods needs to be established
- **This could potentially include backsides of sidewalls, stowbins, floor panels, and cargo liners**



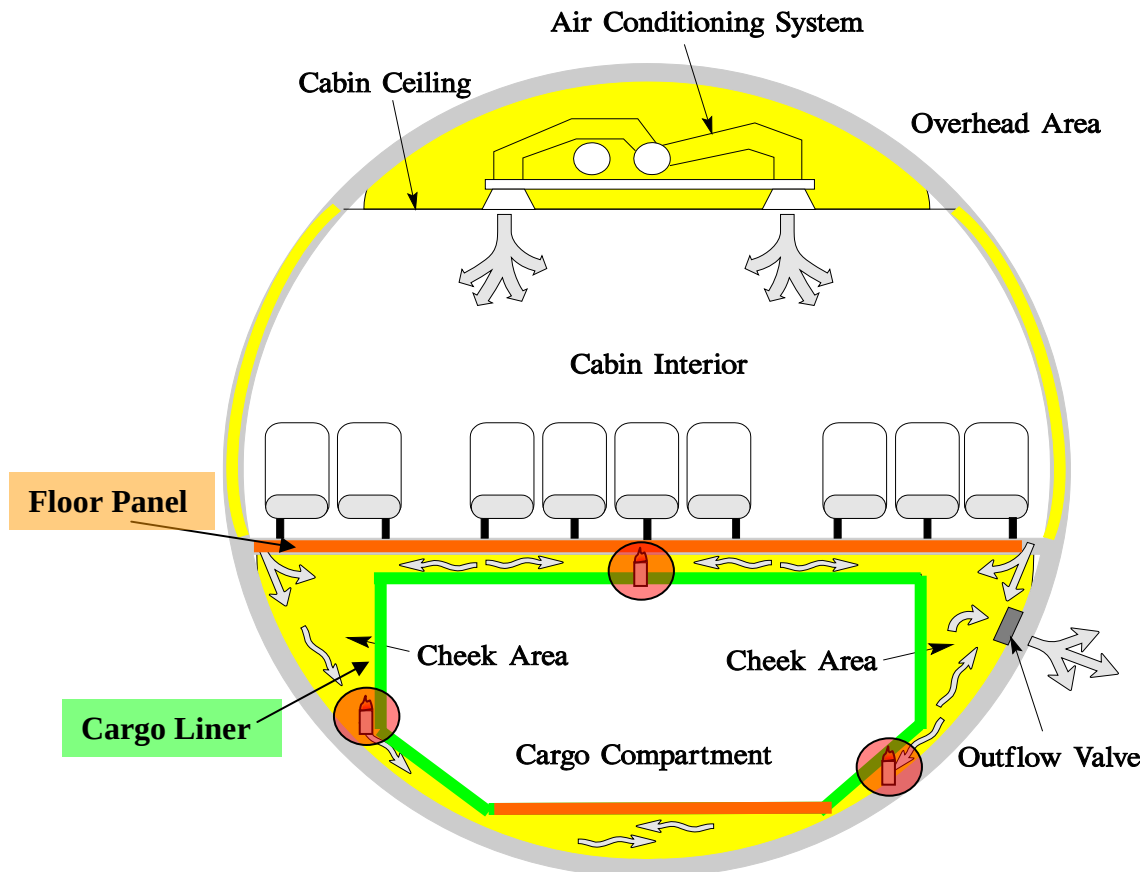
Foam Block Testing

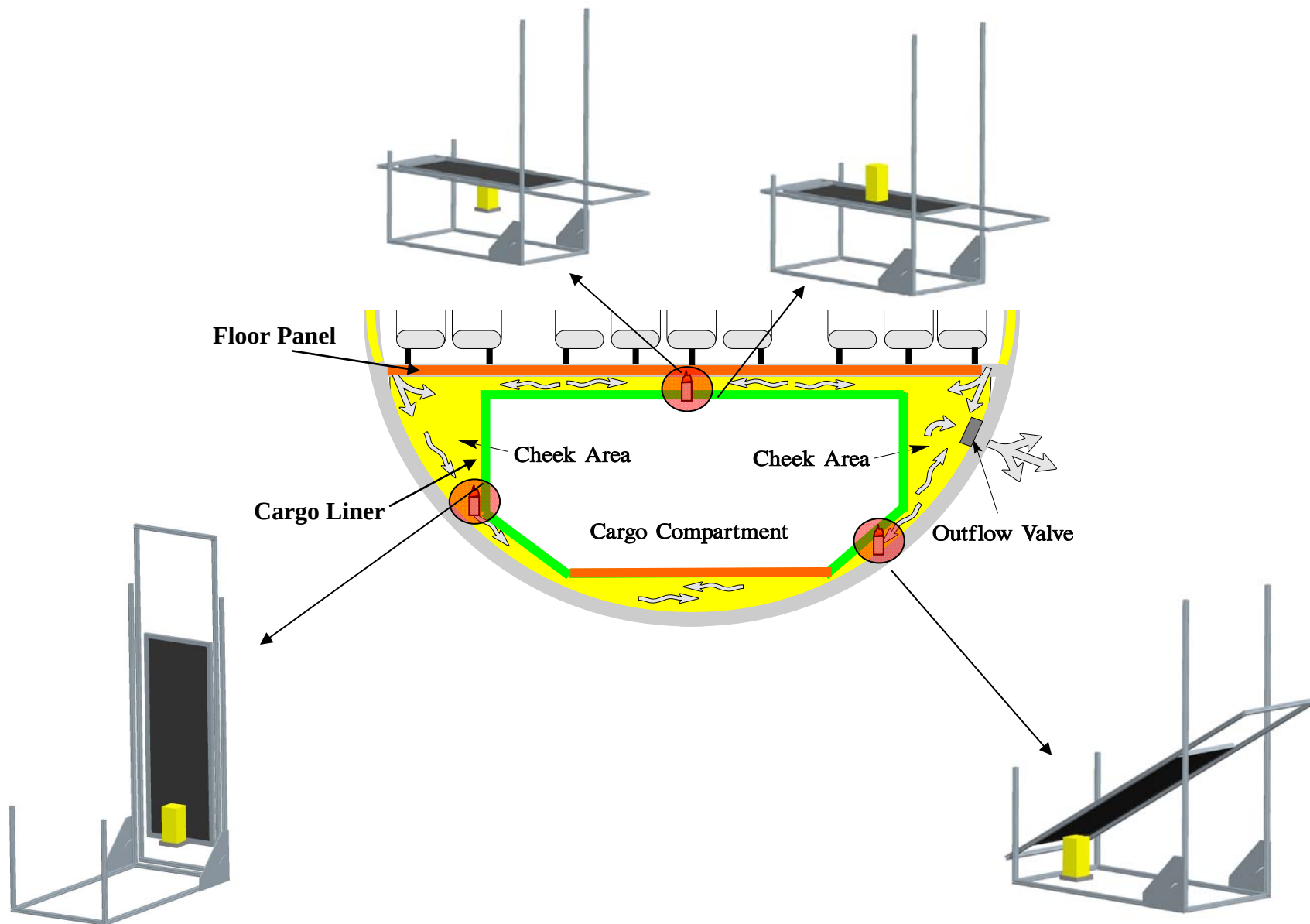
- A variety of typical cargo liners and floor panels were donated by task group member for evaluation at FAATC
- These materials are not as thick/robust as structural composites, therefore the foam block rig was used *without* the insulating shroud
- Two of each sample were available for testing, so two configurations similar to actual installations were chosen for each type of material



Test Materials

Component	Description/Configuration
FLOOR PANELS	
Floor Panel A	5lb Kevlar core, 2 plies of unidirectional carbon tape/epoxy
Floor Panel B	9lb Kevlar core, 4 plies of unidirectional carbon tape/epoxy
Floor Panel C	5lb Nomex core, 2 plies of unidirectional carbon tape/epoxy
Floor Panel D	8.5lb Aluminim core, 3 plies of unidirectional fiberglass tape/epoxy
Floor Panel E	5lb Nomex core, 2 plies of unidirectional fiberglass tape/epoxy
CARGO LINERS	
Cargo Liner 1	Woven fiberglass cloth reinforced phenolic laminate-rigid, general purpose liner
Cargo Liner 2	Woven fiberglass cloth reinforced phenolic laminate-rigid, high impact liner
Cargo Liner 3	Woven fiberglass cloth reinforced phenolic laminate-rigid, high wear resistant liner
Cargo Liner 4	Woven fiberglass cloth reinforced phenolic laminate-rigid laminate, high strength
Cargo Liner 5	Woven fiberglass cloth reinforced phenolic laminate-rigid laminate
Cargo Liner 6	Polymer urethane coated fabric - flexible, 14.0 ± 1.0 oz/yd ²
Cargo Liner 7	Polymer urethane coated fabric - flexible, 32.0 ± 3.0 oz/yd ² meeting RP test





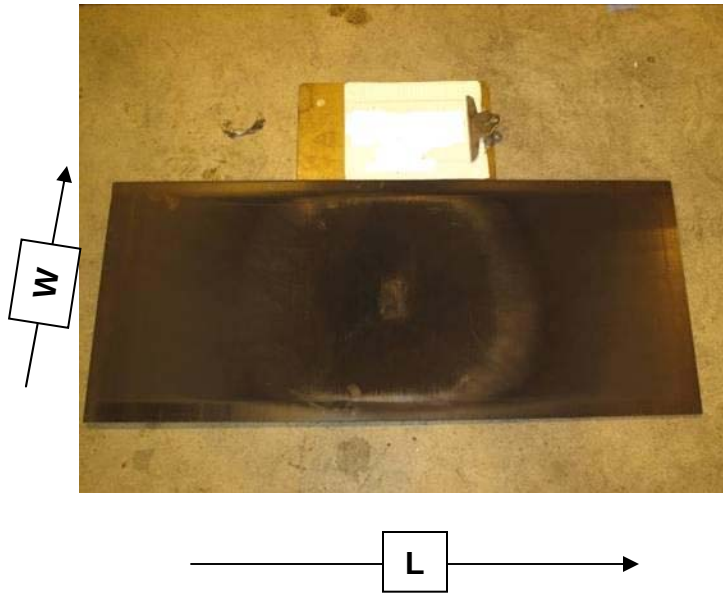
Floor Panel “A” - Horizontal



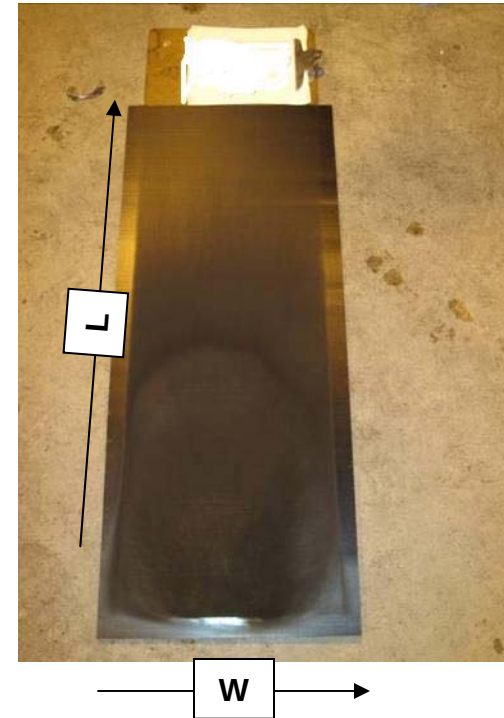
Floor Panel “A” - 30°



Floor Panel “A” - Horizontal



Floor Panel “A” - 30°



Floor Panel Results

Component	Horizontal		30deg	
FLOOR PANELS	L (in.)	W (in.)	L (in.)	W (in.)
Floor Panel A	20.25	15	19.5	15
Floor Panel B	19	15	16	13
Floor Panel C	17.24	15	17	14.5
Floor Panel D	14	12.5	13.5	10.5
Floor Panel E	14	13.5	14.75	11.5



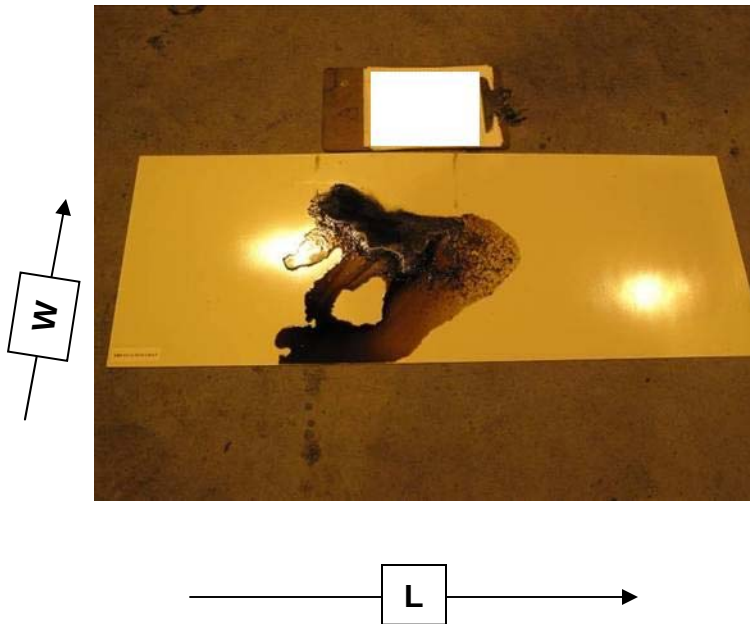
Cargo Liner “3” - Horizontal



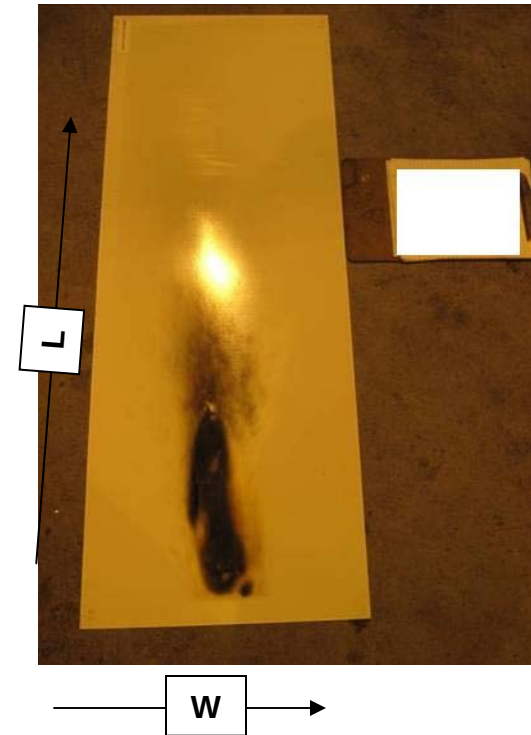
Cargo Liner “3” - Vertical



Cargo Liner “3” - Horizontal



Cargo Liner “3” - Vertical



Cargo Liner Results

Component	Horizontal		Vertical	
CARGO LINERS	L (in.)	W (in.)	L (in.)	W (in.)
Cargo Liner 1	3.75	2.75	13.5	5.25
Cargo Liner 2	6.5	8.75	13	5
Cargo Liner 3	11	7	12	3.5
Cargo Liner 4	11.25	7.25	7	3.5
Cargo Liner 5	9	10.5	12	2.75
Cargo Liner 6			13.5	3.75
Cargo Liner 7	11.5	9.5	0	0

Summary – Cargo Liners & Floor Panels

- **In the configurations tested, neither the floor panels nor cargo liners showed signs of flame damage beyond the initial foam block impingement area**
- **The current constructions of cargo liners (glass/phenolic, etc.) and floor panels (glass-carbon/epoxy, etc.) do not seem to be a threat for flame propagation**



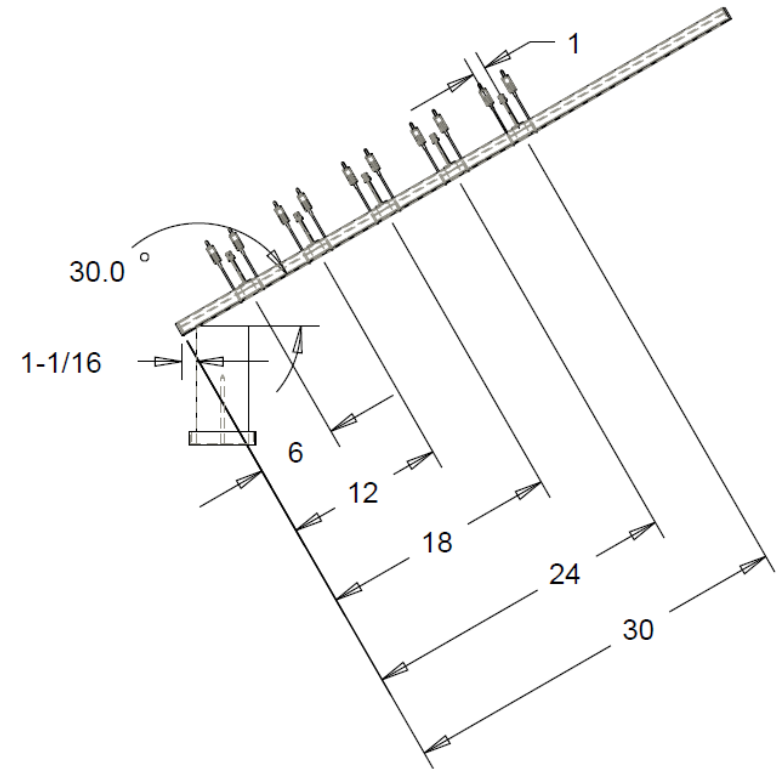
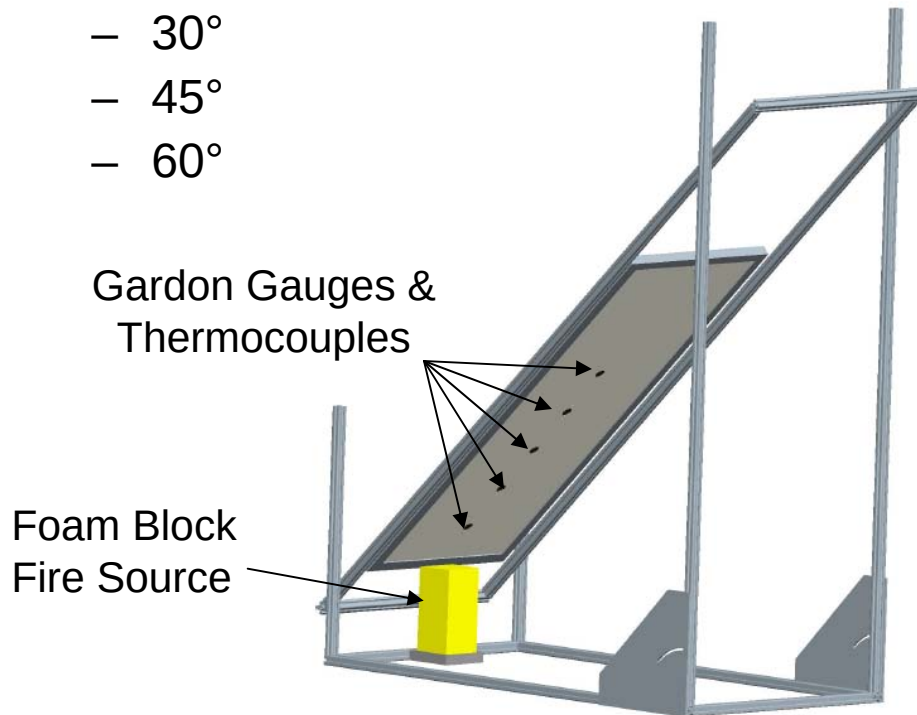
Part 3 – Foam Block Characterization

In an effort to characterize the standard fire source for other inaccessible area materials, an experiment was set up to measure the heat flux gradient experienced by a sample exposed to a flaming foam block

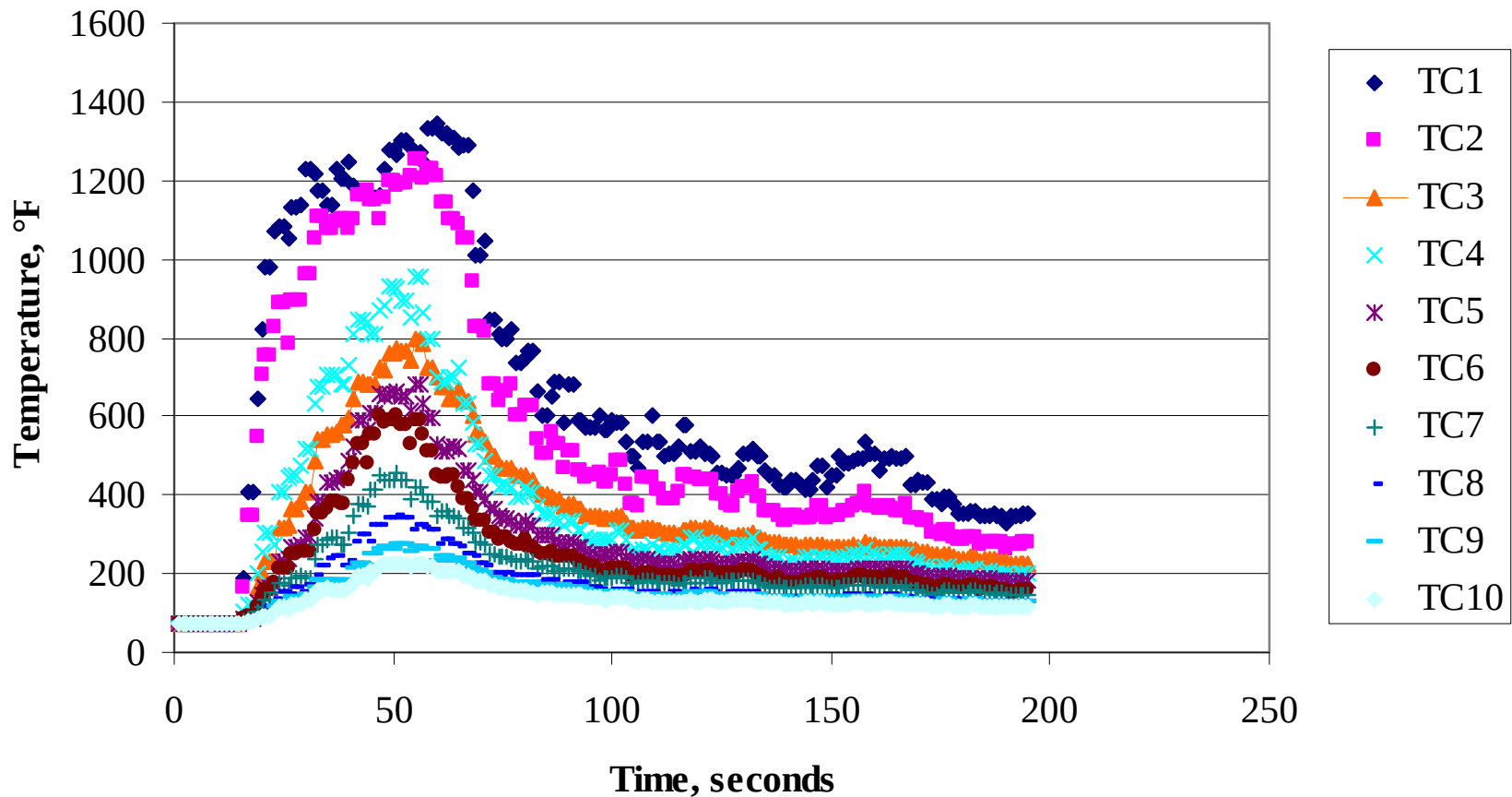


Foam Block Characterization

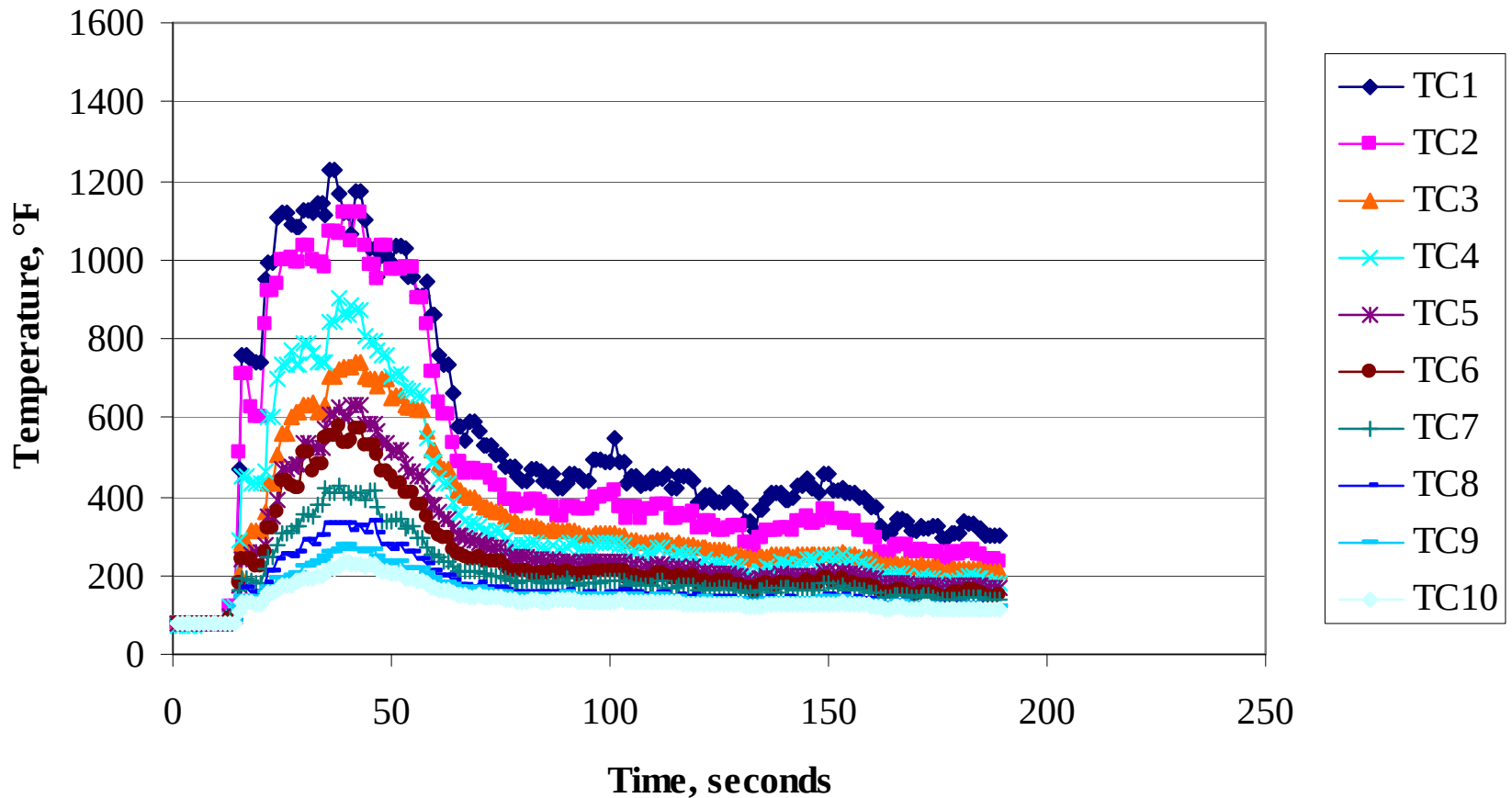
- **Measurements were taken on the foam block**
 - Heat Flux (5 points)
 - Temperature (10 points)
- **Various angles were tested**
 - 30°
 - 45°
 - 60°



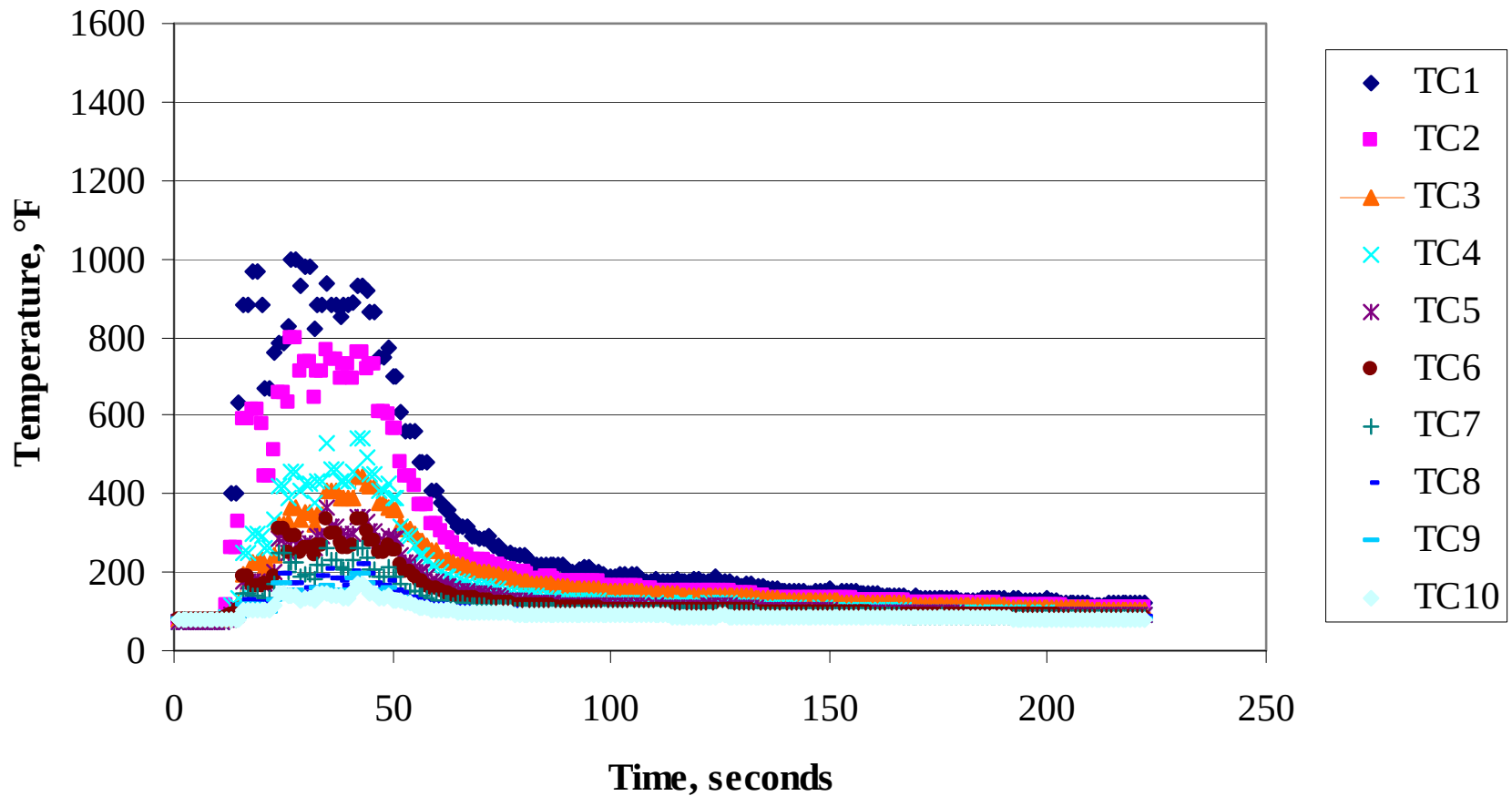
Temperature - 30°



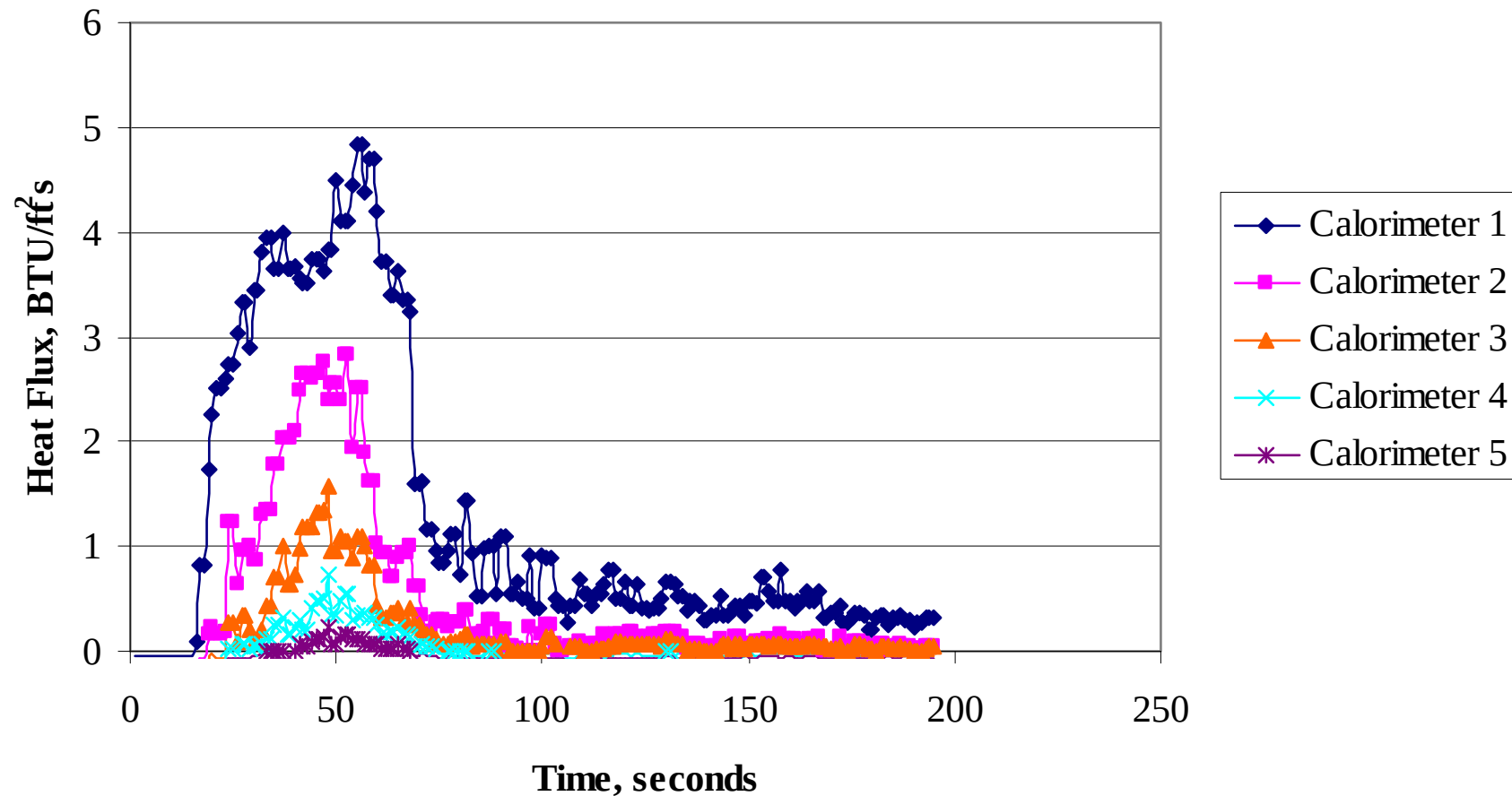
Temperature - 45°



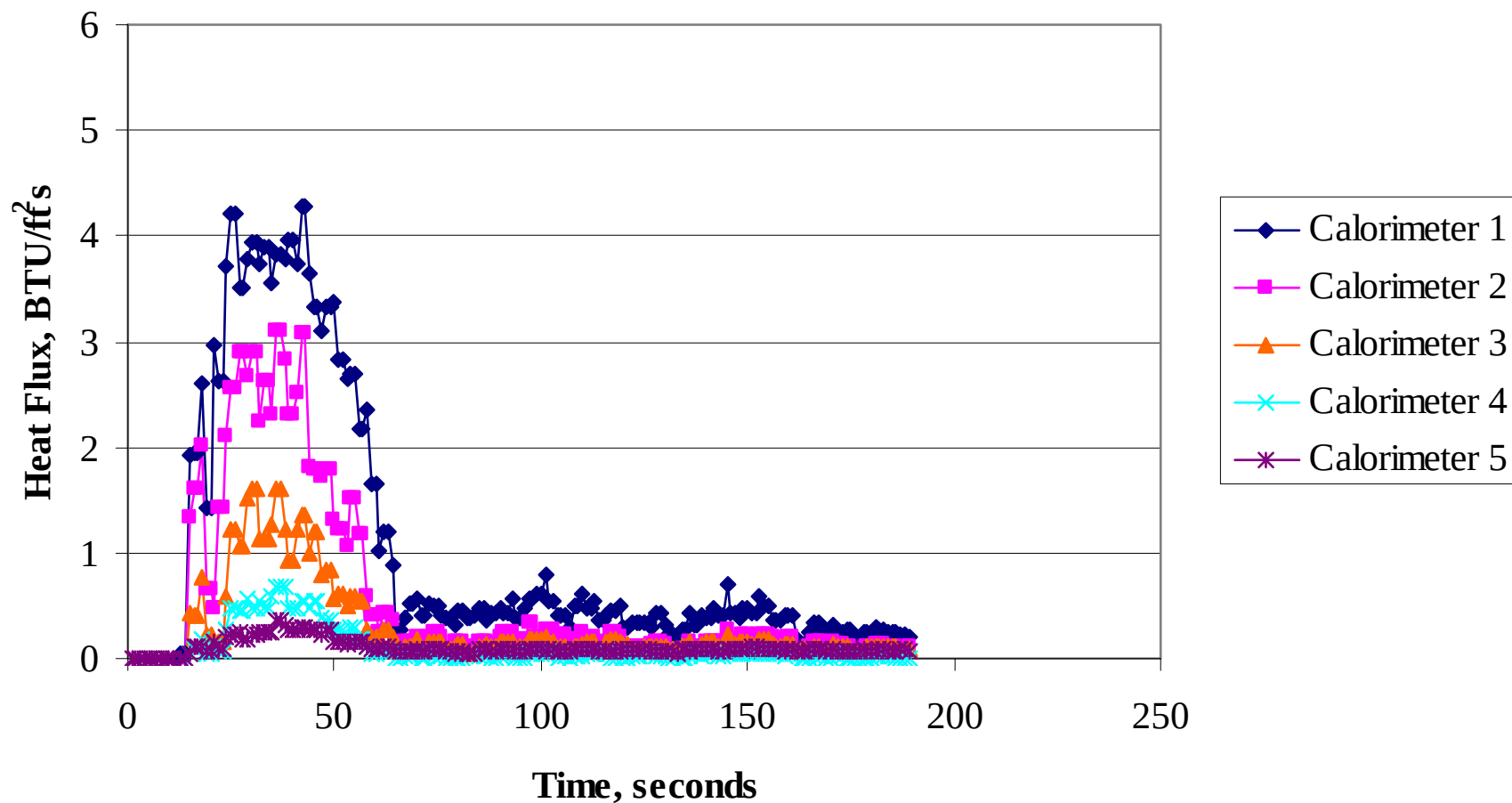
Temperature - 60°



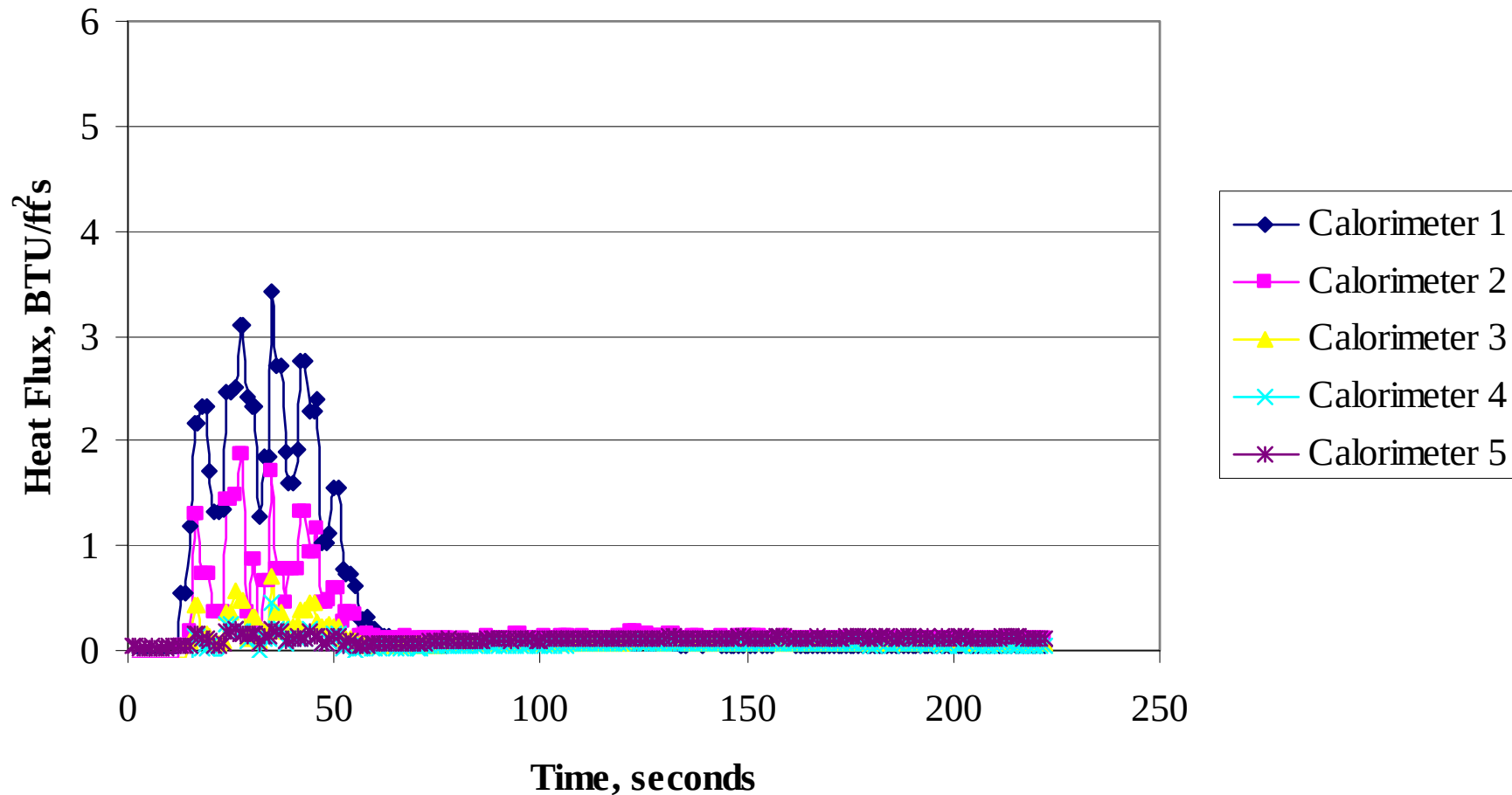
Heat Flux - 30°



Heat Flux - 45°



Heat Flux - 60°

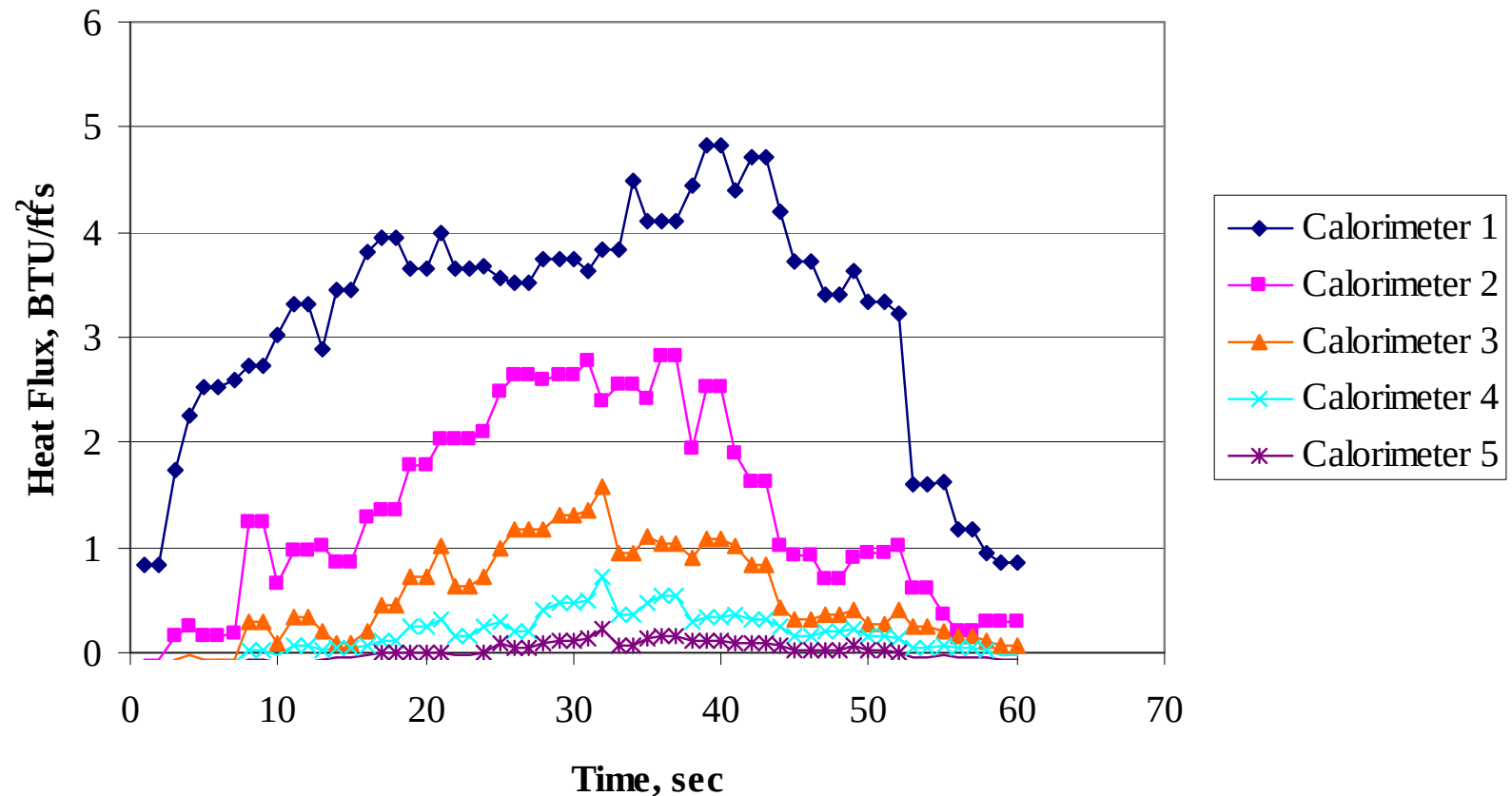


Comparison

Orientation	Max Heat Flux (BTU/ft ² s)	Max Temperature (°F)	Peak Width (seconds)
30°	4.83	1342.08	58
45°	4.27	1228.93	50
60°	3.42	999.47	38



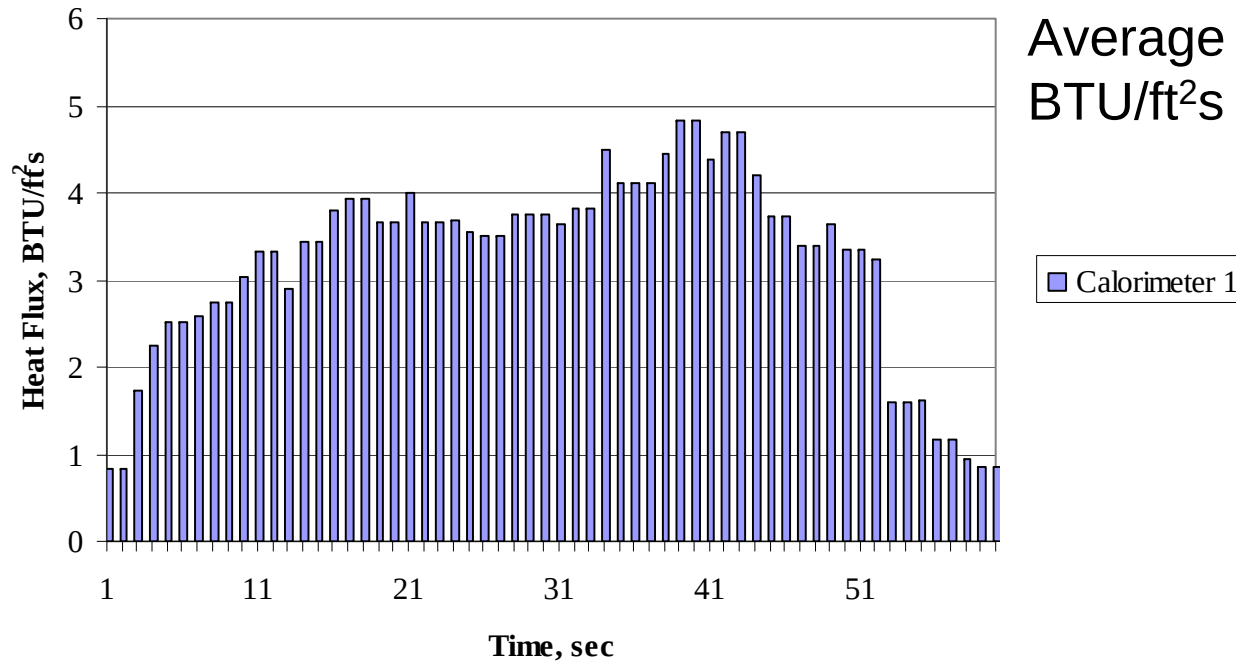
Heat Flux – 30°, 60 sec. Period



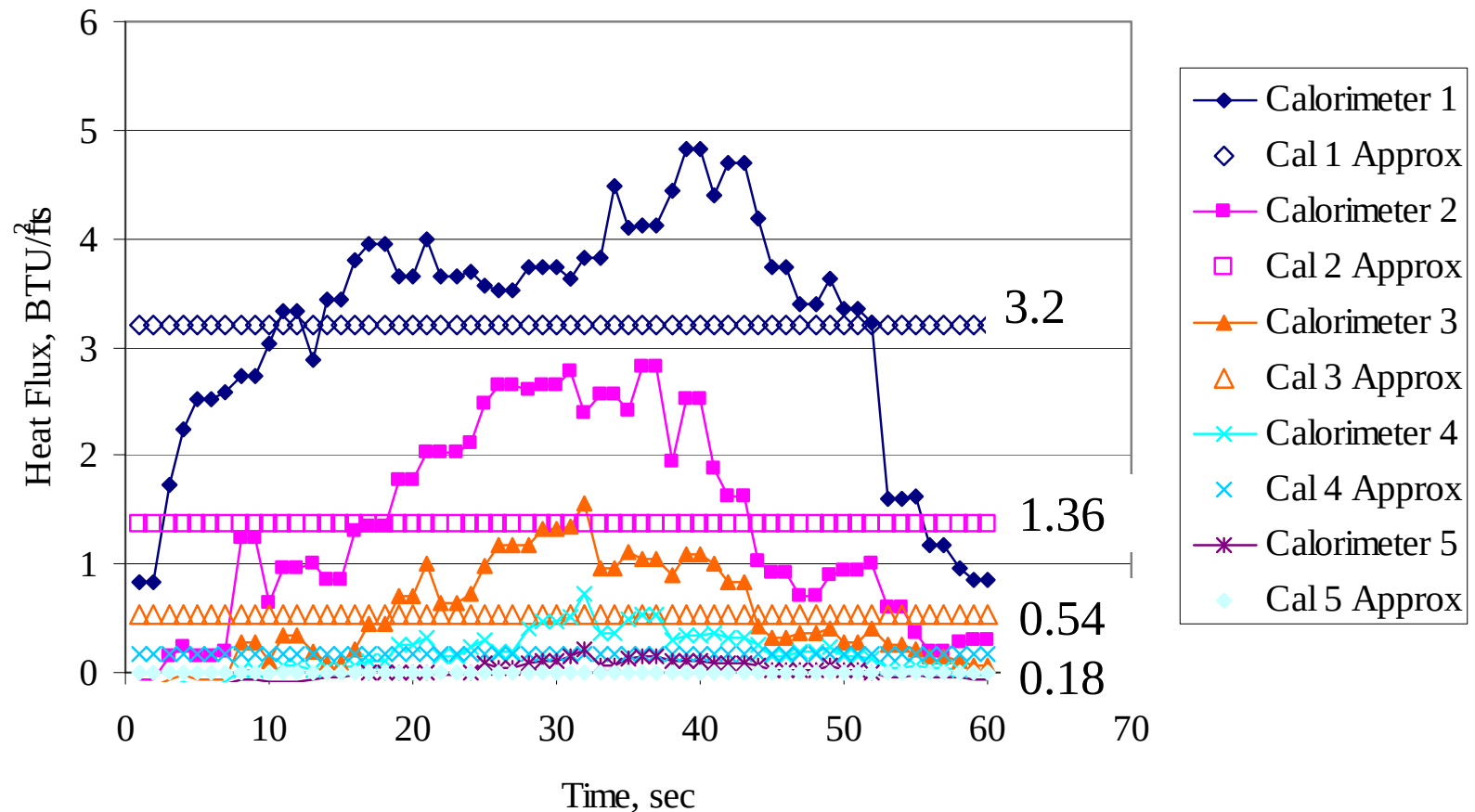
Calorimeter 1

Total Heat = area under curve
= 191.85 BTU/ft²

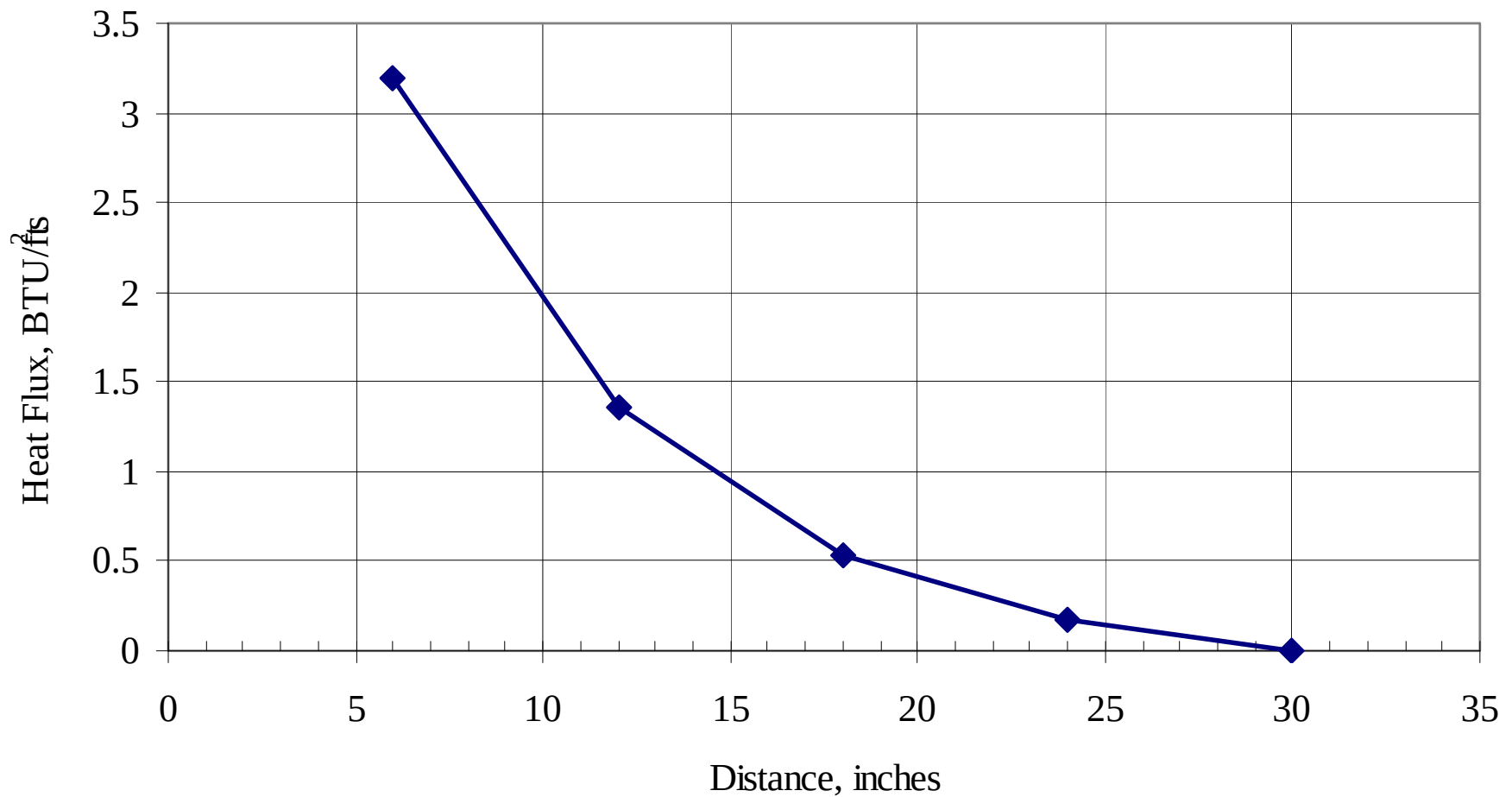
Average Heat Flux = 3.20
BTU/ft²s



Estimated Heat Flux – 60 sec. Period



Heat Flux Gradient



Part 3 - Summary

- The standard fire source was characterized with gardon gauge and thermocouple measurements in various orientations
- The 30° orientation saw the highest heat flux, temperature, and longest duration of exposure
- The heat flux gradient was characterized for the 30° orientation and can be used to scale the effect of the foam block on a test sample

