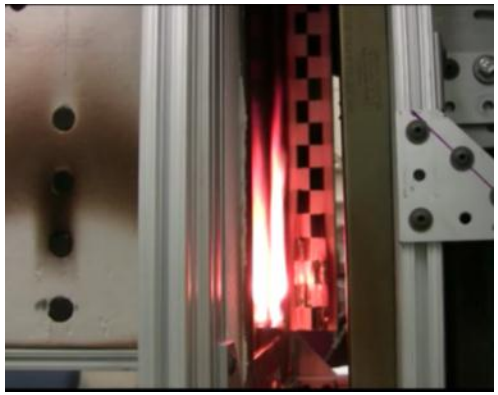
Development of a Lab-Scale Fire Test Method for Composite Structure

Federal Aviation Administration





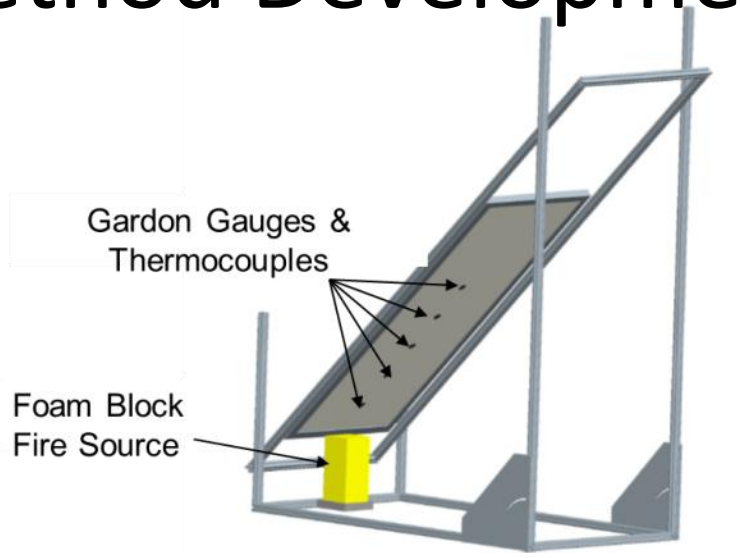
Presented to: IAMFTWG, Indianapolis, IN, USA
By: Robert I. Ochs
Date: October 16-17, 2012

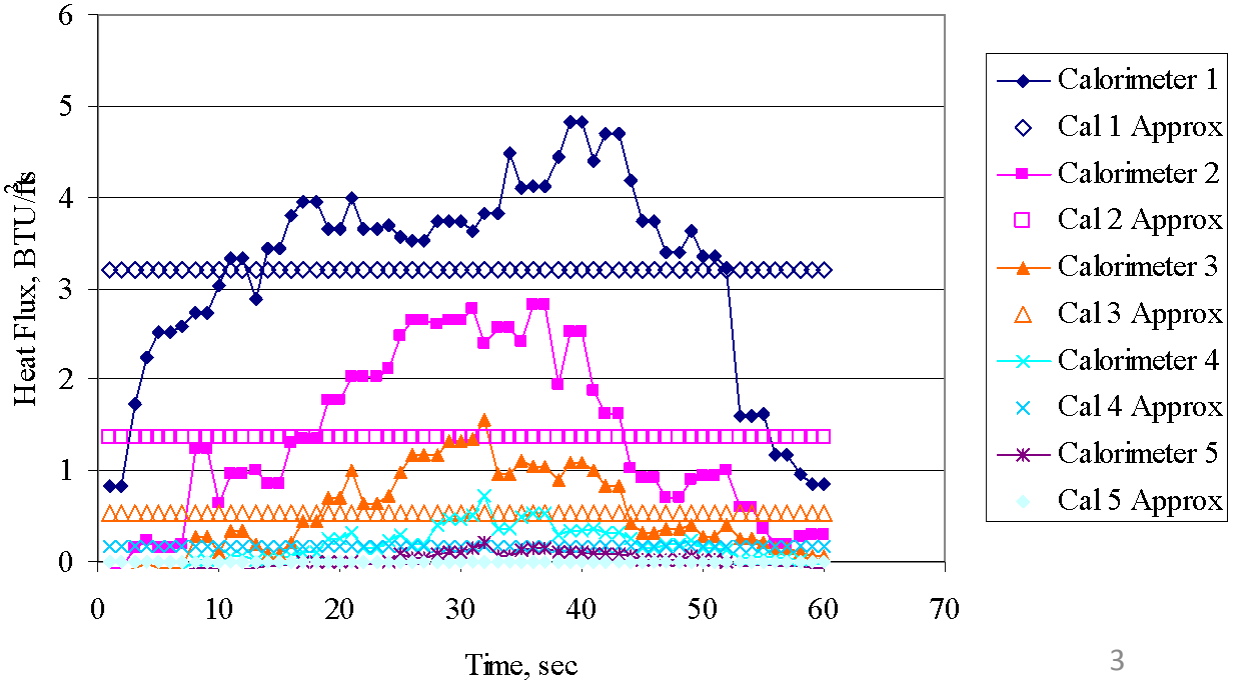
Objective

- Develop a lab-scale test method for composite structure
  - Representative of the threat
    - Moderate fire about the size of the block of foam fire
  - Relatively simple
    - Radiant heat source + Pilot ignition
  - Low cost
    - Small sample size
  - Can be adapted to other inaccessible area materials
    - Ducts
    - Wire Insulation
    - Other composites that are not small parts as defined in regulations

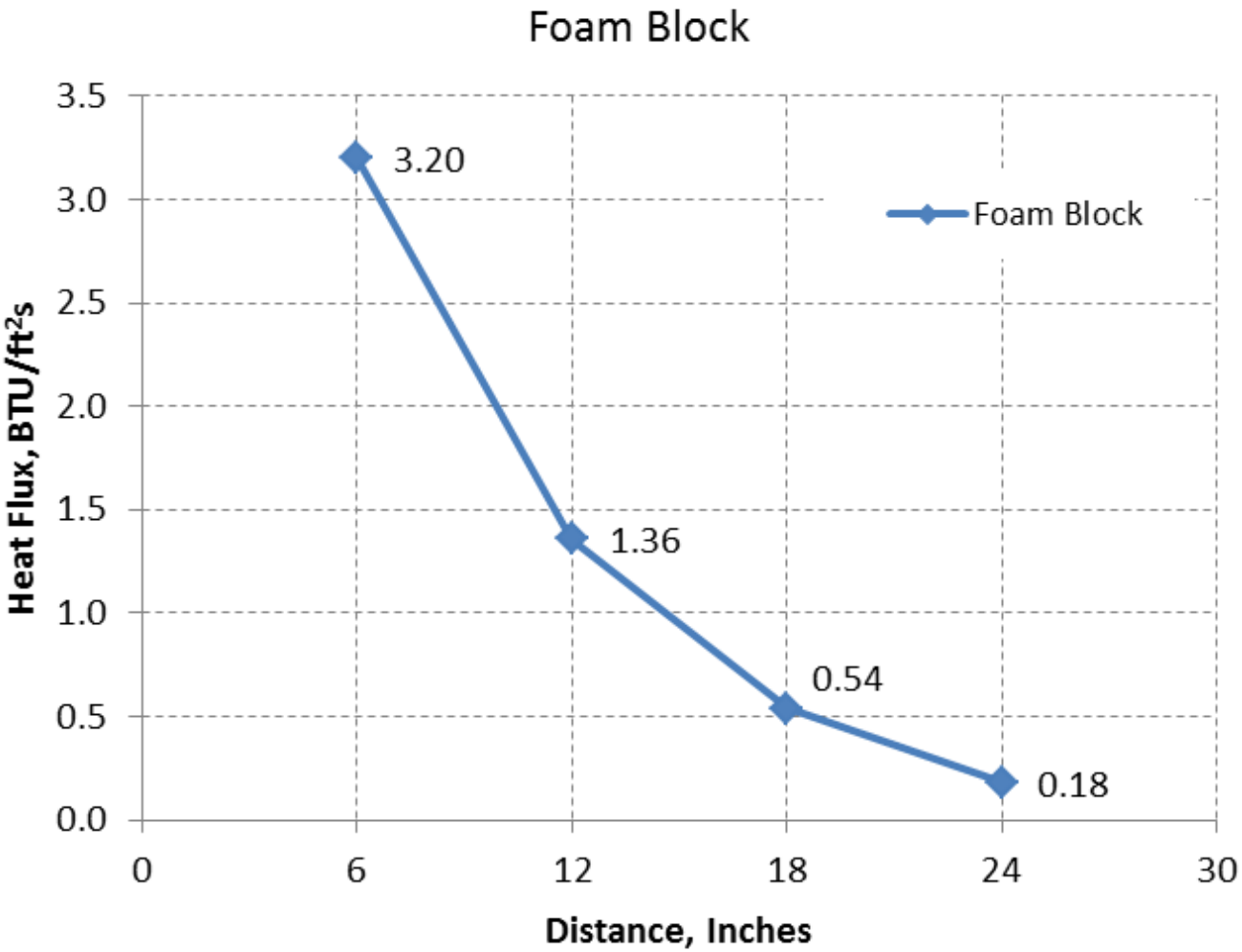
Lab-Scale Test Method Development

- The foam block fire source was characterized by measuring the heat flux gradient along an insulated board for the duration of the foam burning event
- This heat flux gradient will then be used to impose a similar heat flux on a smaller sample in a lab-scale test apparatus





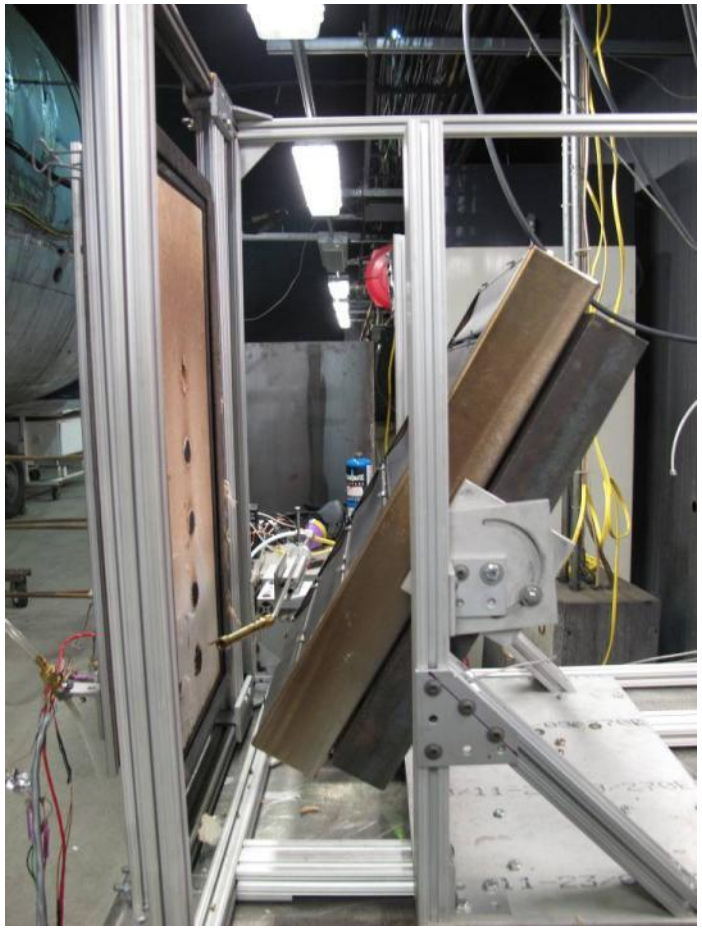
Foam Block Heat Flux Gradient



Vertical Radiant Panel (VRP) Development

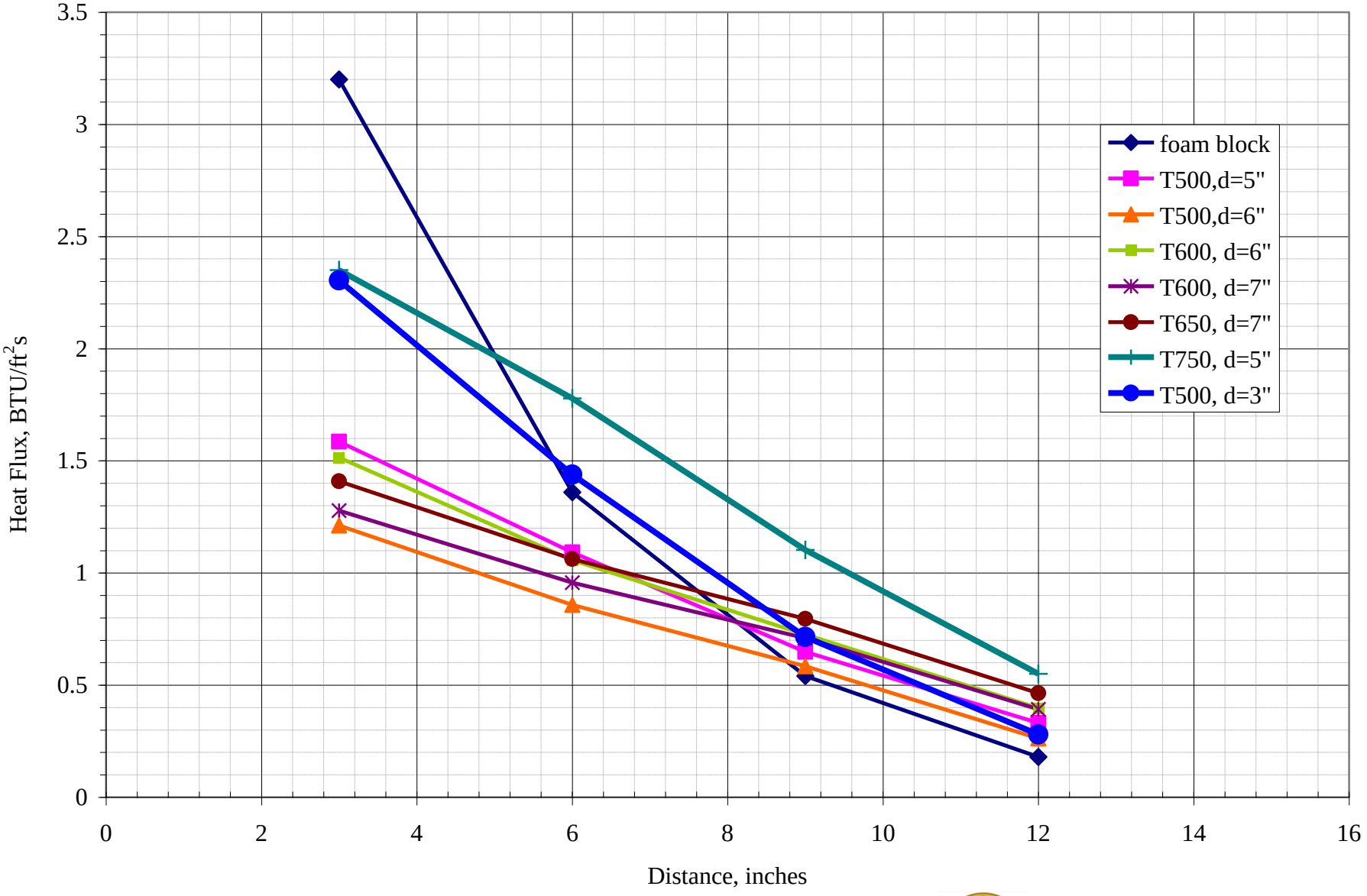
- Objective: to develop a “new” radiant panel type test that will:
  - Simulate conditions of a foam block test
    - Incident heat flux on sample
    - Duration
    - Geometry
  - Correlate results from foam block test
    - Use current database of materials already tested
      - Aerospace/non-aerospace grade composites (1/8” thick)
      - Aerospace grade carbon epoxy, varying thicknesses
      - Cargo liners and floor panels, varying thicknesses

VRP Configuration



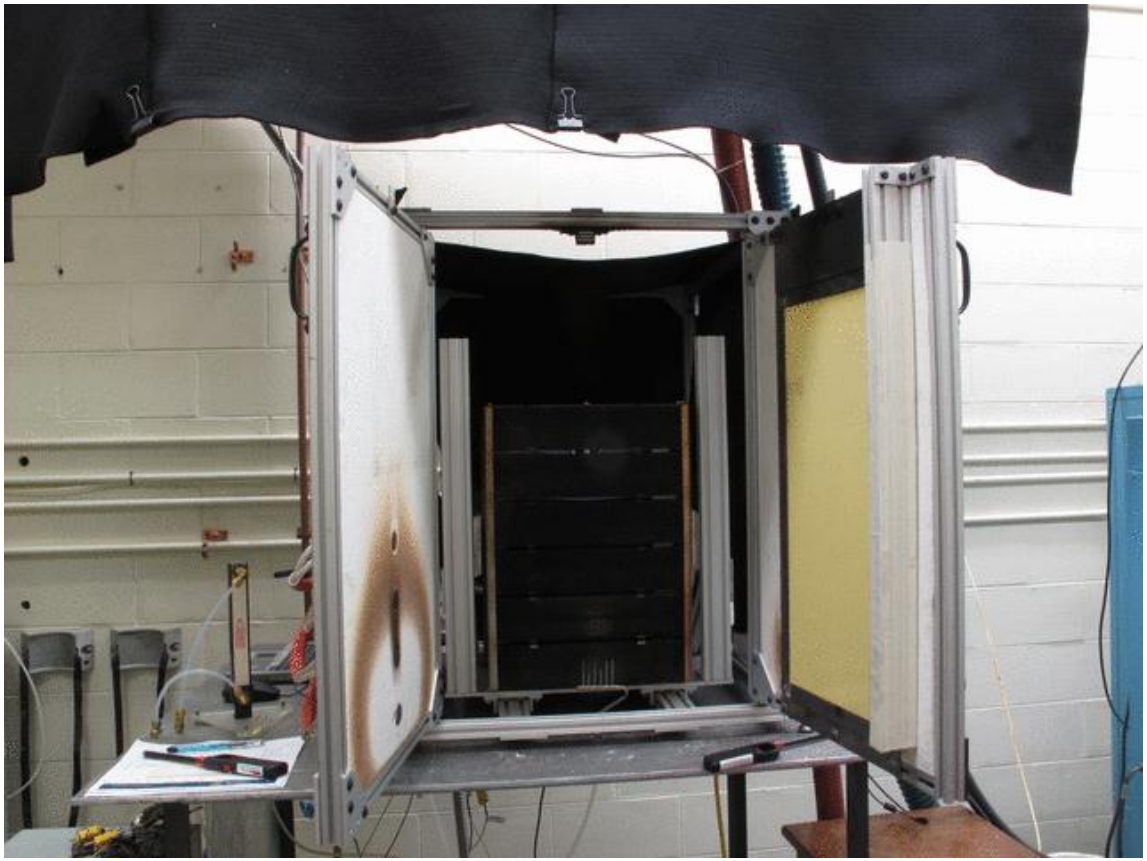
- Heat flux gradient
  - A tilted panel was used to attempt to achieve the same measured gradient as the foam block test
  - Furthest backward tilt (70°) could not achieve steep enough gradient
  - Zero position heat flux too low
- Next attempt:
  - Separate emitter strips into 3 individually controlled pairs to control the heat flux gradient

Bottom 2 Strips Only

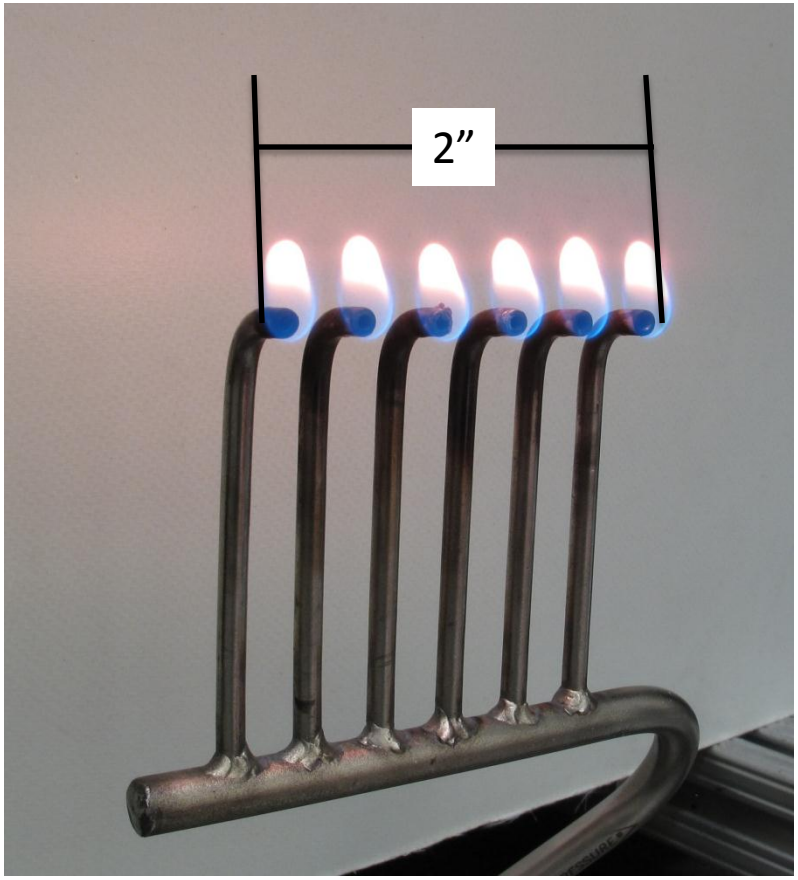


Modifications to VRP

- Swivel doors added to make switching between calibration and testing quick and easy

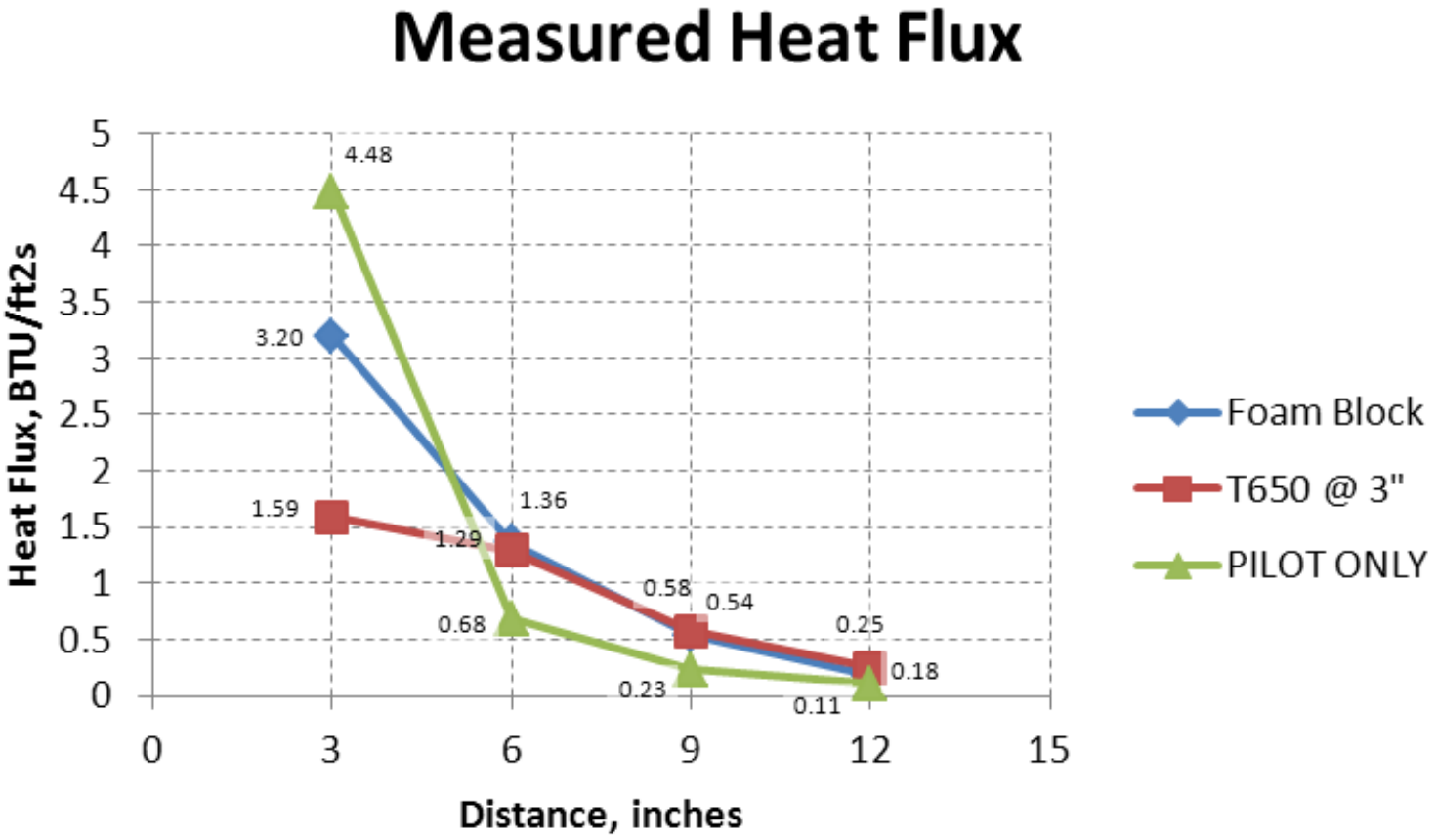


Unidirectional NBS Chamber Pilot Burner

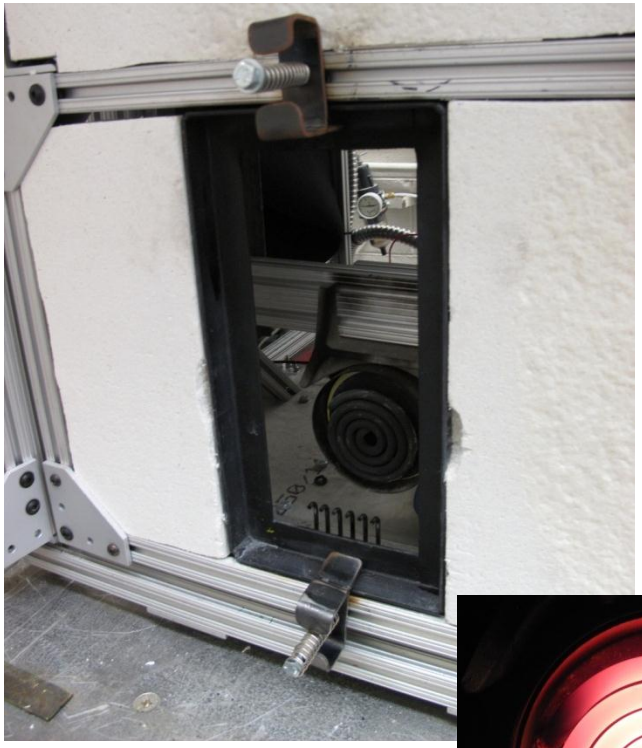


50 ccm @ 20 psig propane

Multiple Flamelet Burner

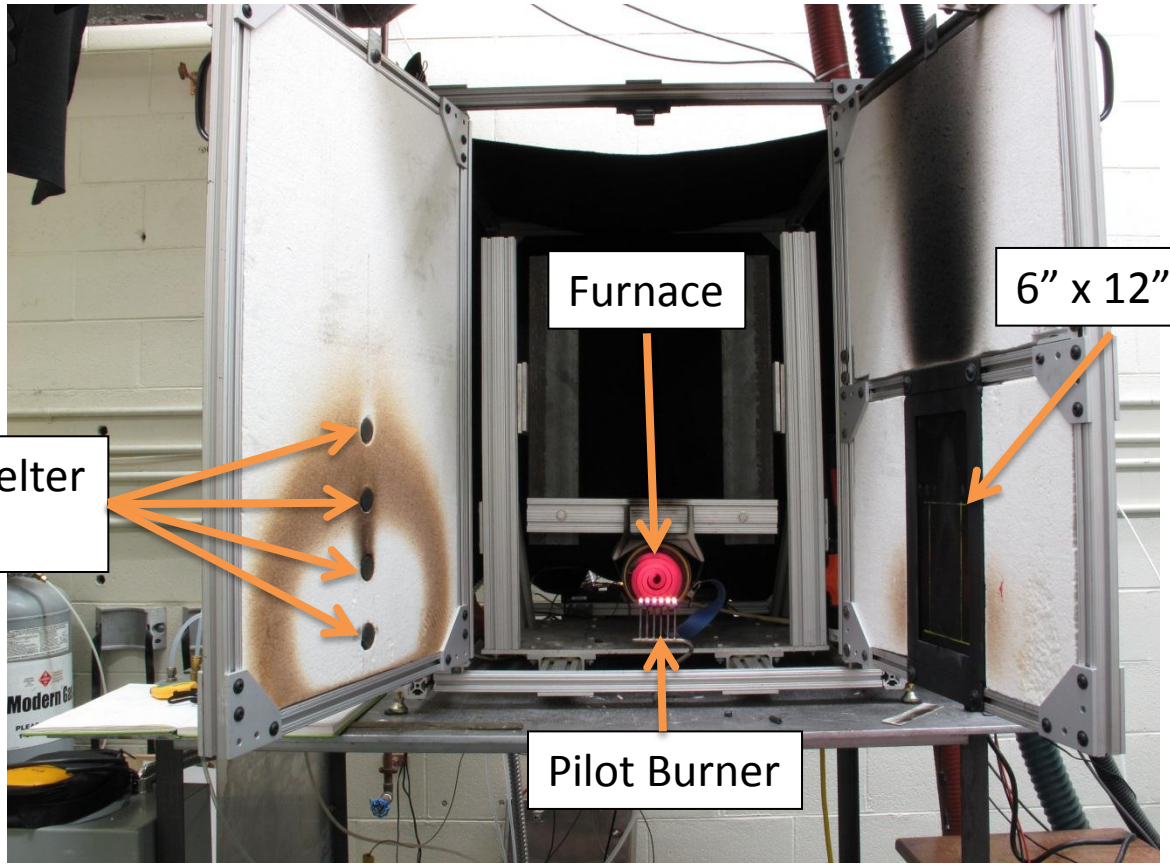


Recent Modifications

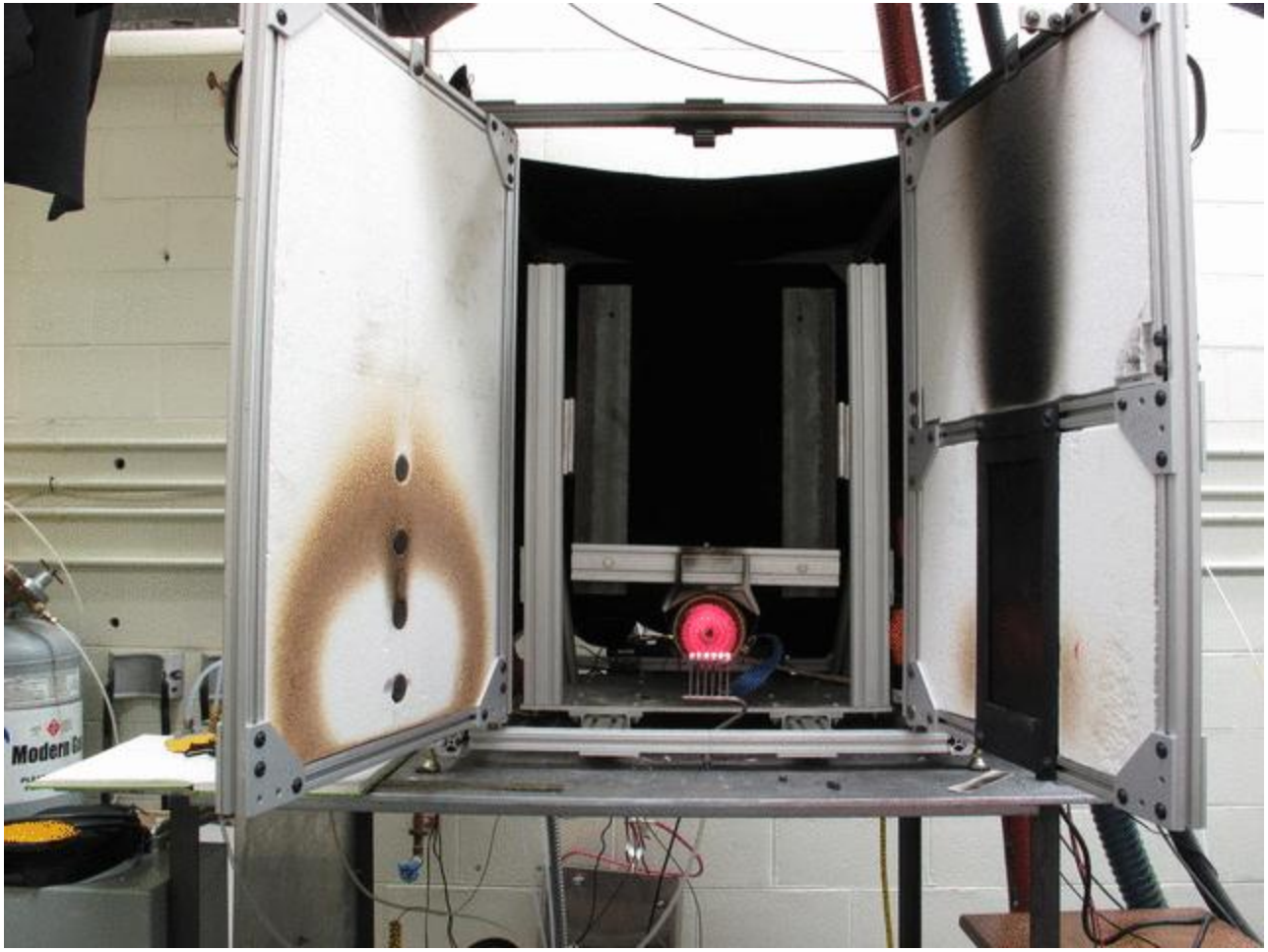


- NBS furnace is widely used in FAA fire test community
  - Smoke chamber
  - Slide test
- Provides steady, intense thermal radiation
- Runs on 110V ac, no special power requirements
- Controlled with variable AC transformer instead of backside TC and temp controller

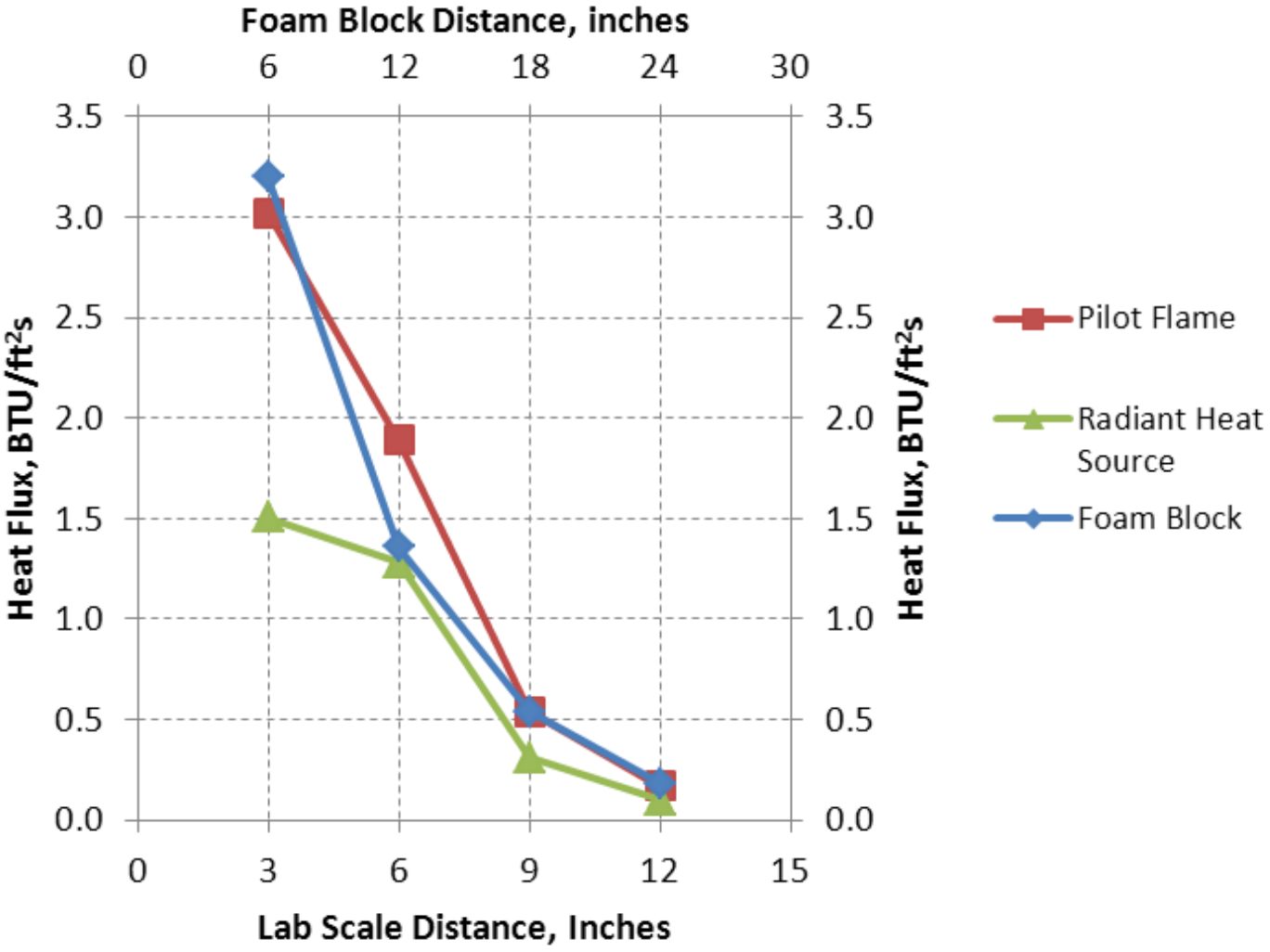
Recent Modifications



Recent Modifications

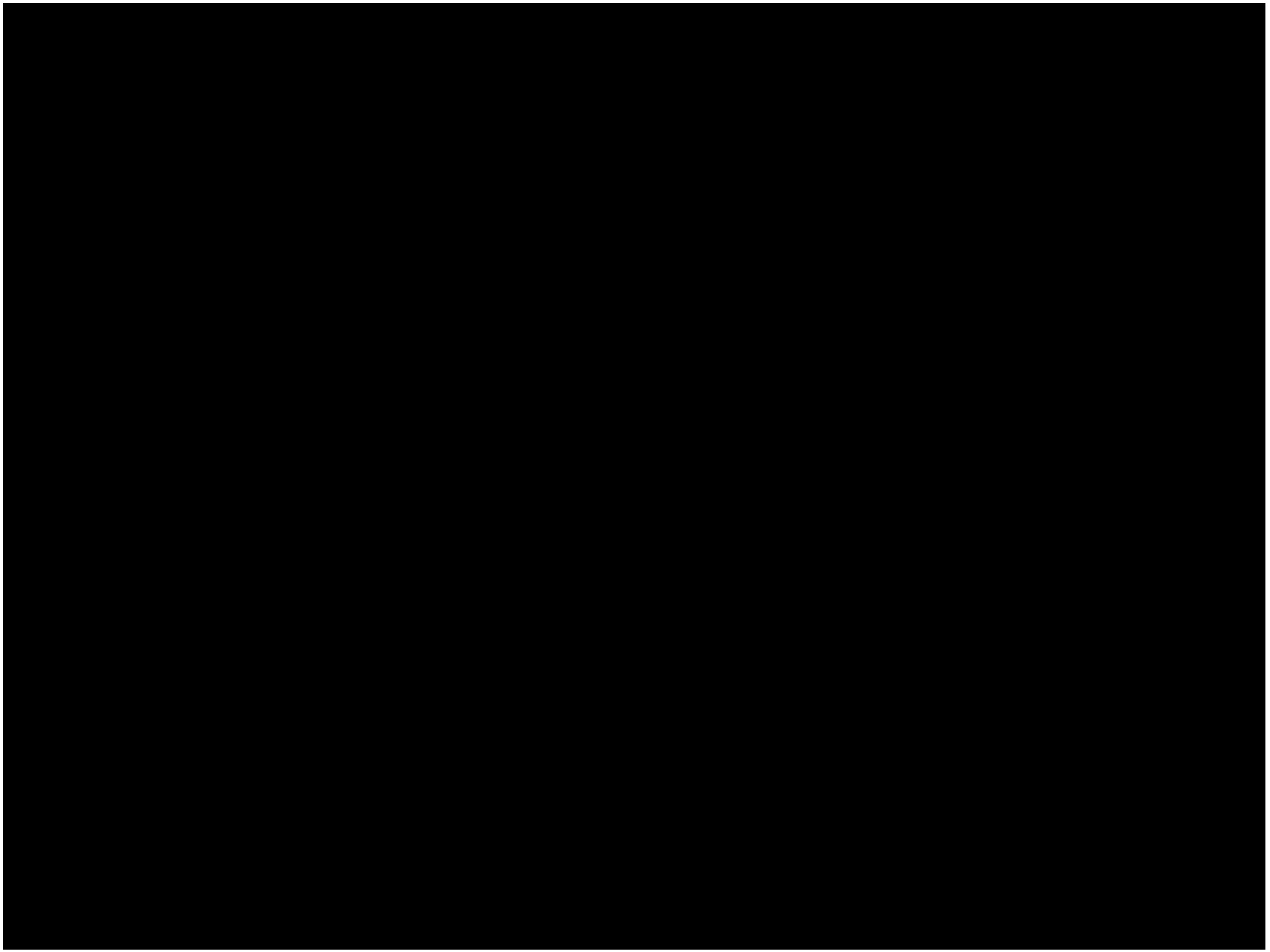


Measured Heat Flux

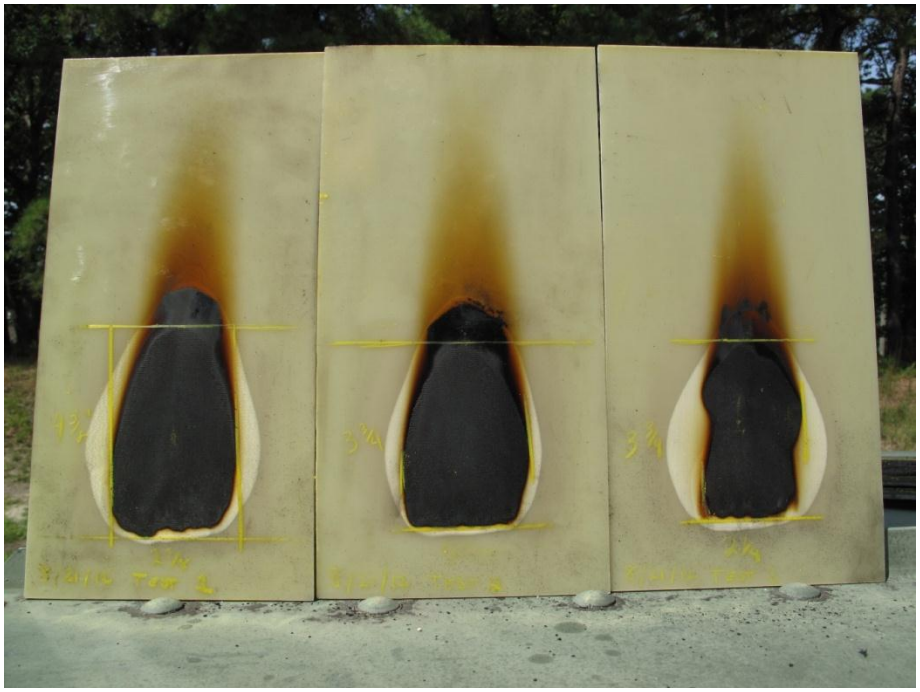


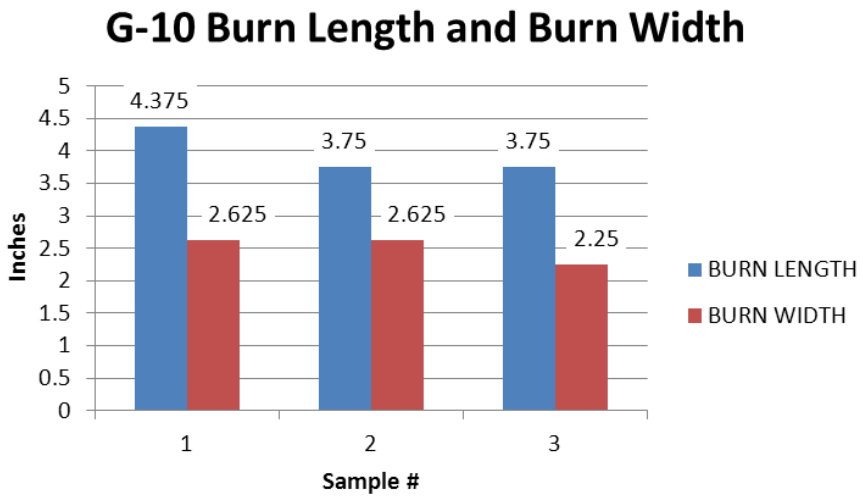
Recent Testing

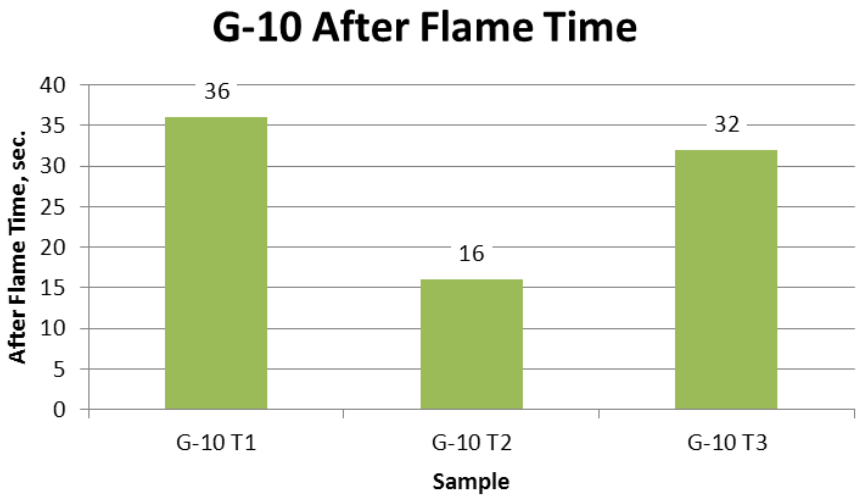
	Procedure
1	Set Heat Flux Gradient, 5 minute average of each calorimeter
2	Install Pilot Burner
3	Install Sample
4	Ignite Pilot Burner, set propane pressure and flow rate
5	Swing away calorimeter door
6	Swing in sample door, start timer
7	Impinge flame and expose sample to radiant heat for 60 sec.
8	At 60 sec., pilot burner is turned off, sample remains exposed to radiant heat and allowed to burn
9	Test is terminated when flames extinguish, sample is removed and allowed to cool
10	Once sample is cool, degreaser is used to wipe away sooted areas
11	Burn length and width are measured, and after flame time is assessed from video



G-10 Glass Epoxy

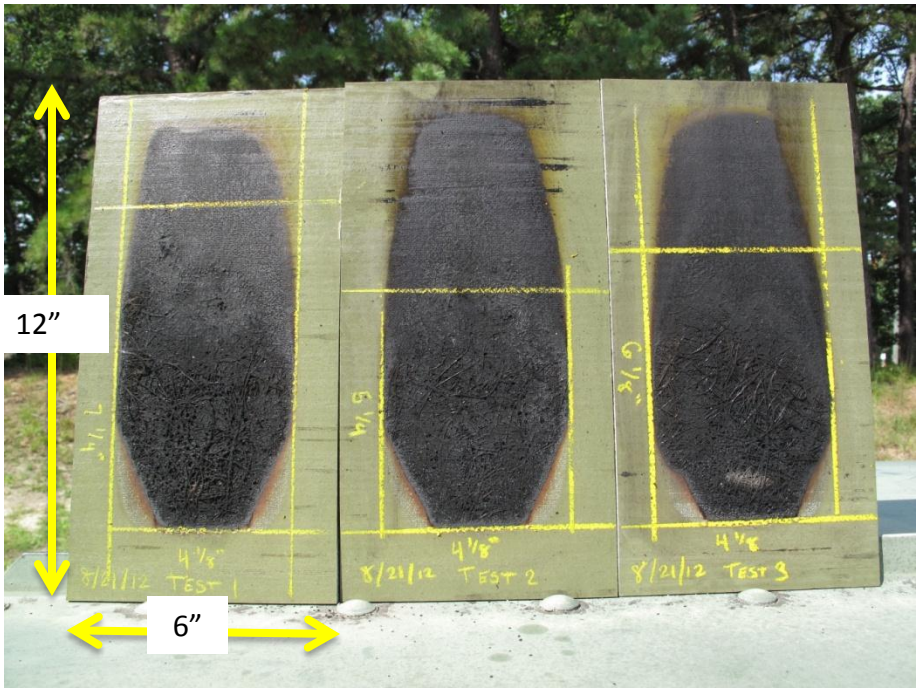


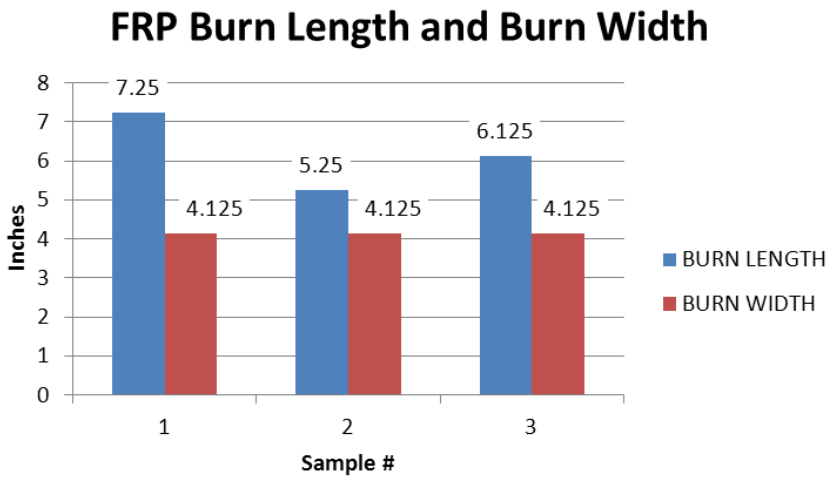


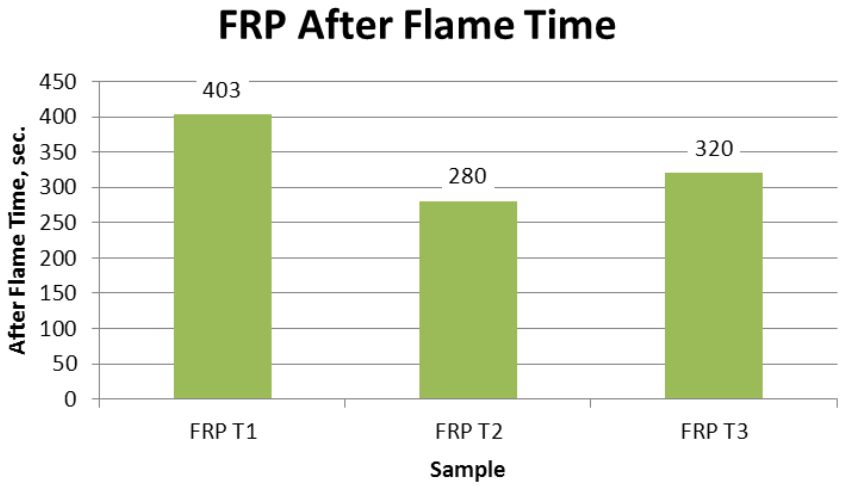


- BL_{avg}=3.95”
  - %sd=9.11%
- BW_{avg}=2.5”
  - %sd=8.66%
- AF_{avg}=28 sec.
  - %sd=37.8%

Fiber Reinforced Polyester

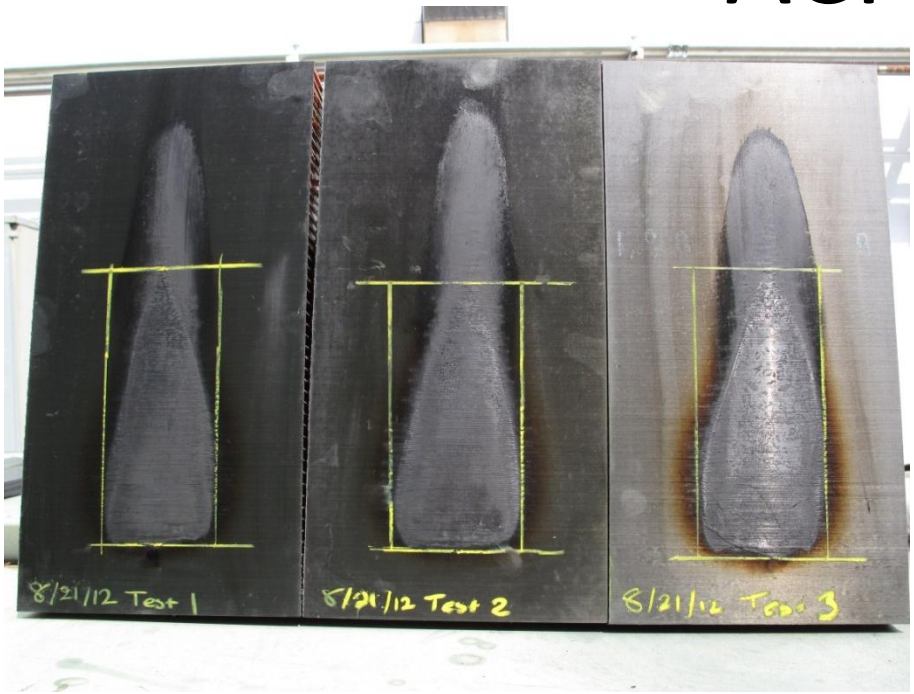


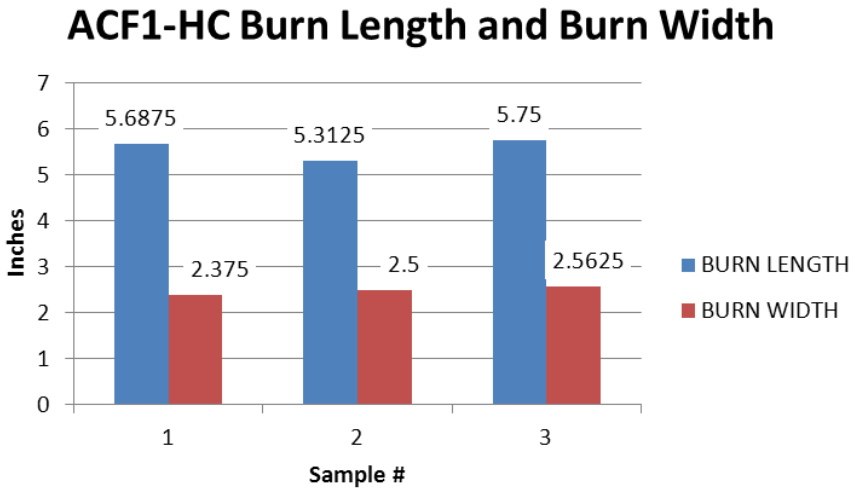


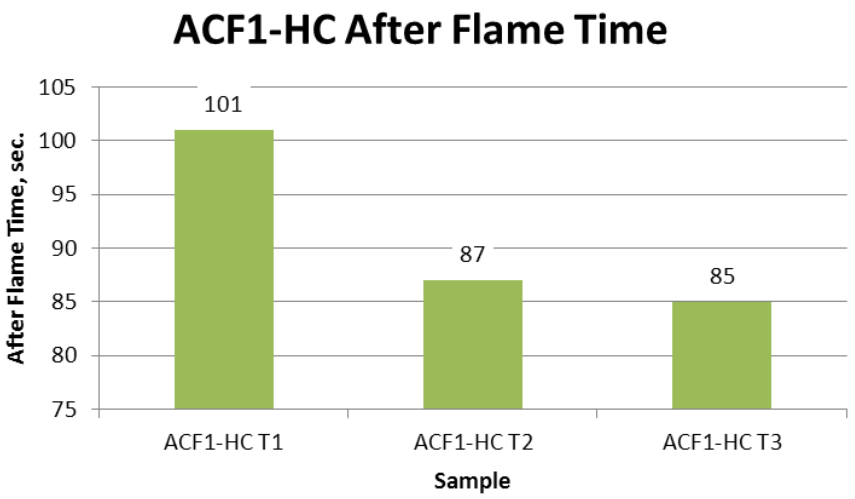


- BL_{avg}=6.208”
  - %sd=16.14%
- BW_{avg}=4.125”
  - %sd=0%
- AF_{avg}=334.3 sec.
  - %sd=18.75%

ACF1-HC

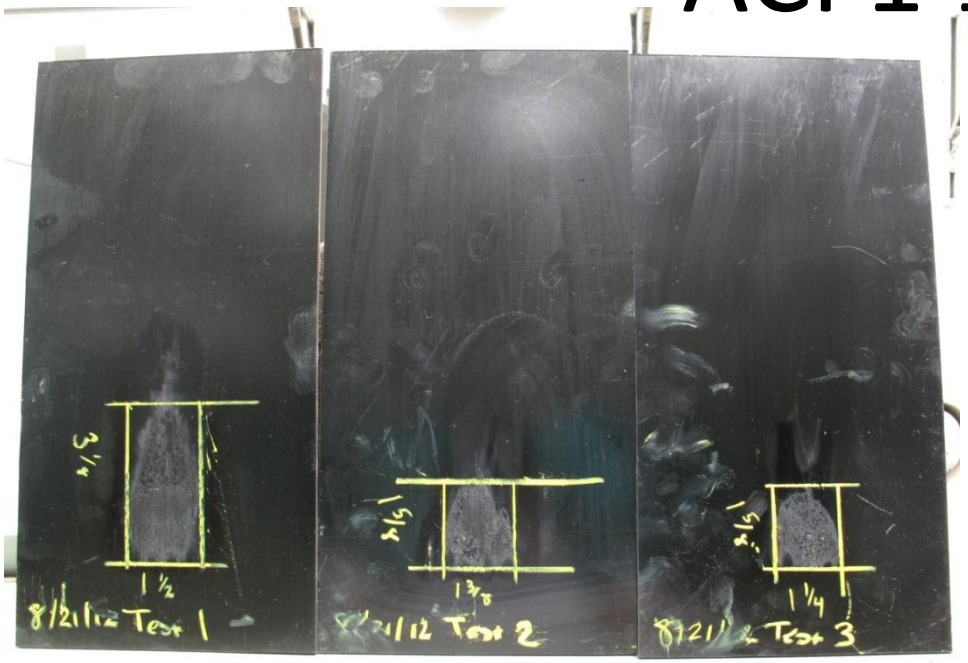


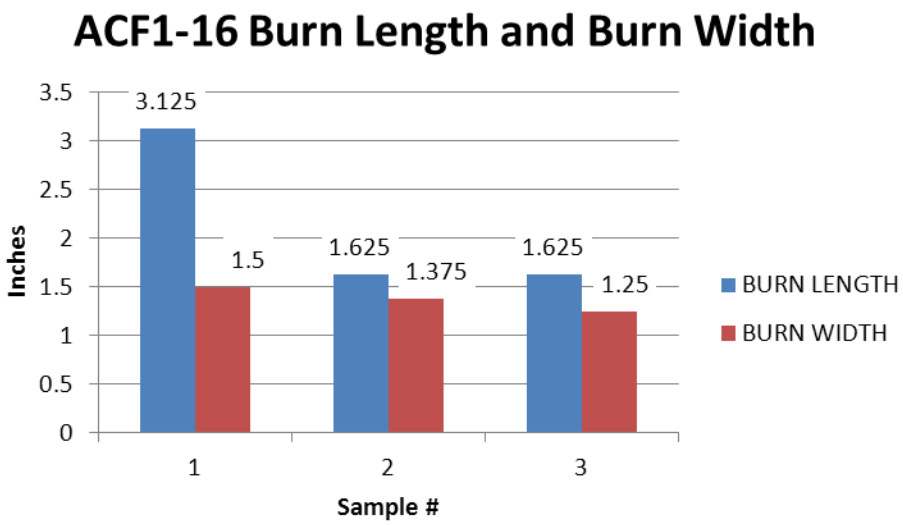




- BL_{avg}=5.58”
  - %sd=4.23%
- BW_{avg}=2.48”
  - %sd=3.85%
- AF_{avg}=91 sec.
  - %sd=9.57%

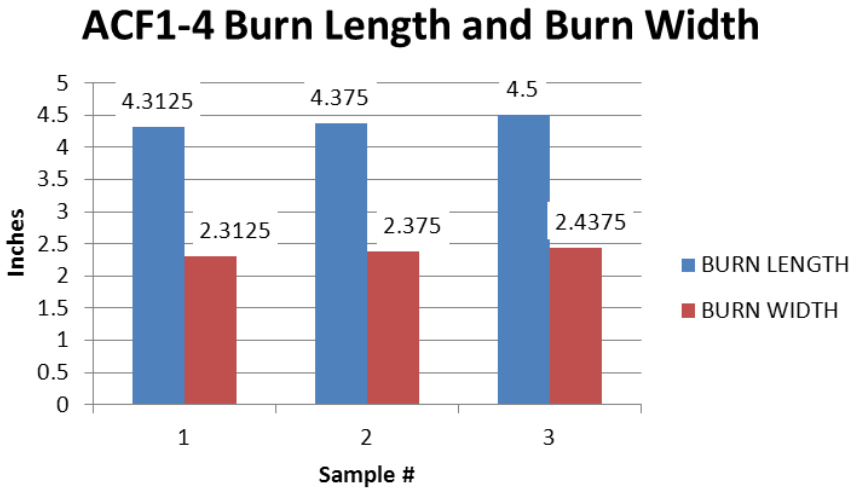
ACF1 16 ply

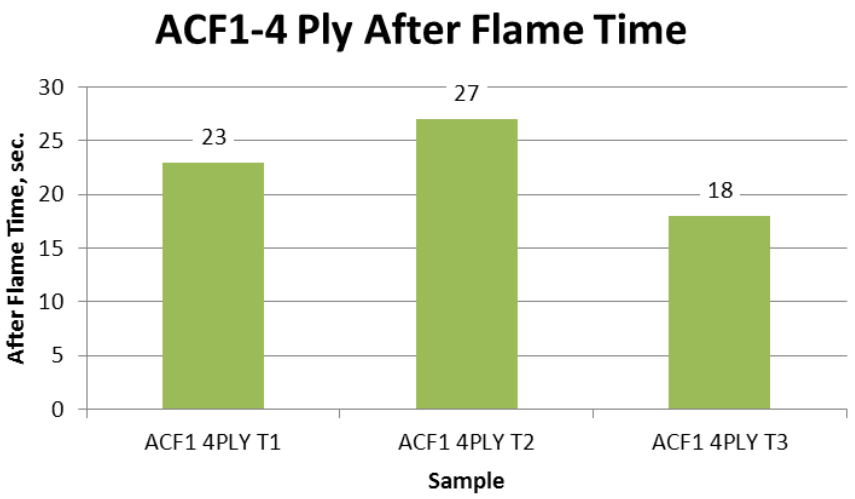




- BL_{avg}=2.125”
  - %sd=40.75%
- BW_{avg}=1.375”
  - %sd=9.09%
- AF_{avg}=9.5 sec.
  - %sd=126.53%

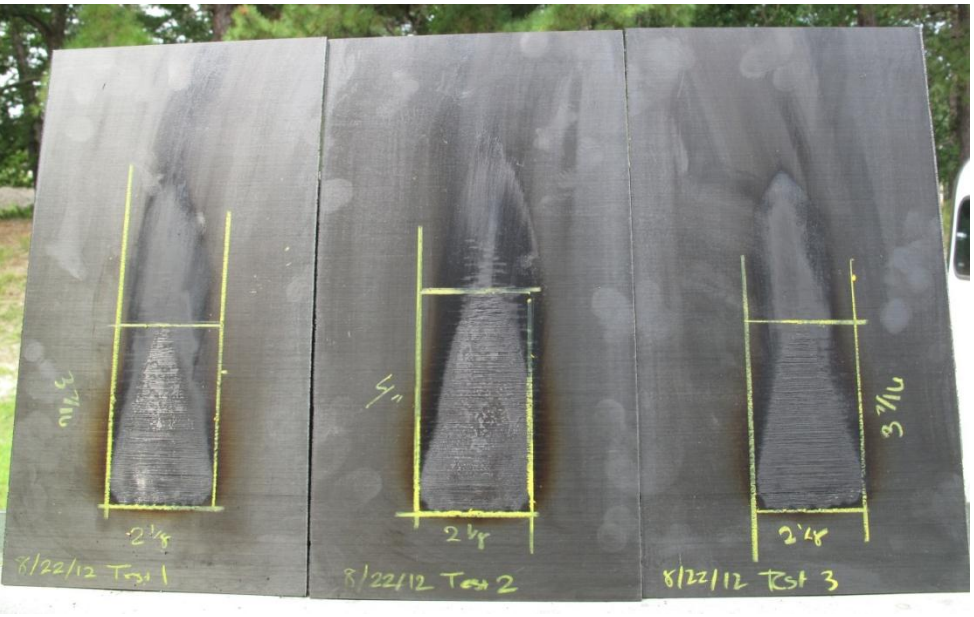
ACF1 4 ply

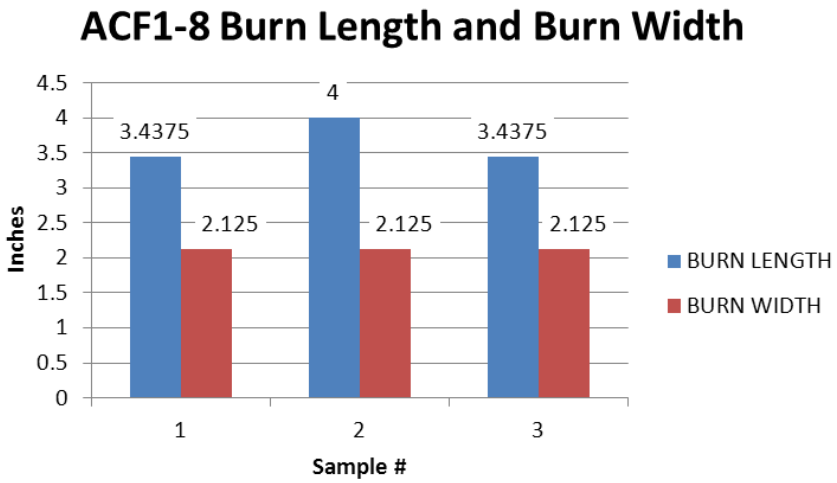




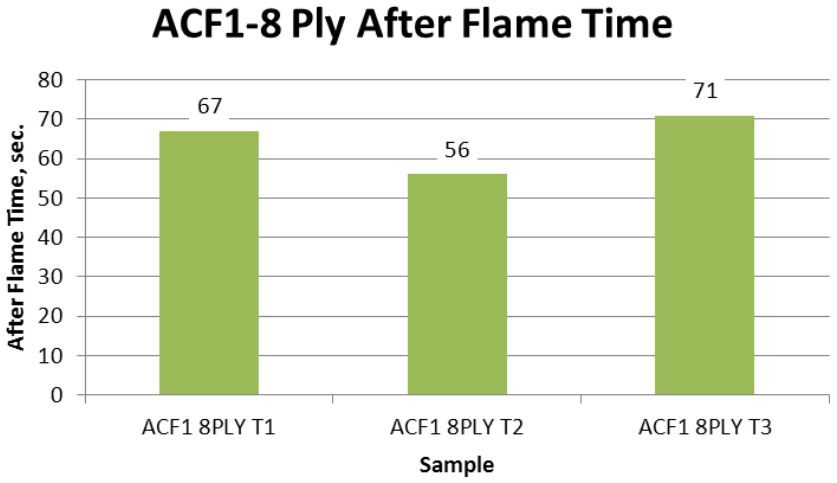
- BL_{avg}=4.395”
  - %sd=2.17%
- BW_{avg}=2.375”
  - %sd=2.63%
- AF_{avg}=22.67 sec.
  - %sd=19.89%

ACF1 8 ply

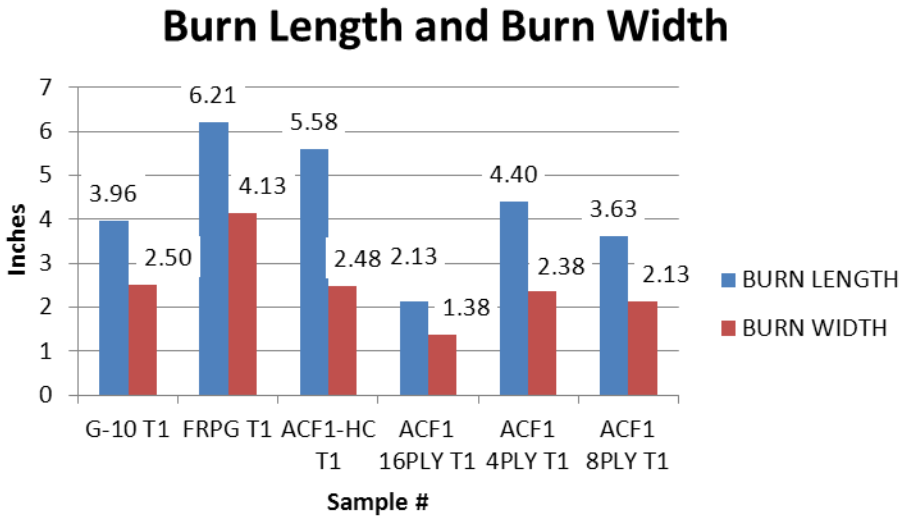


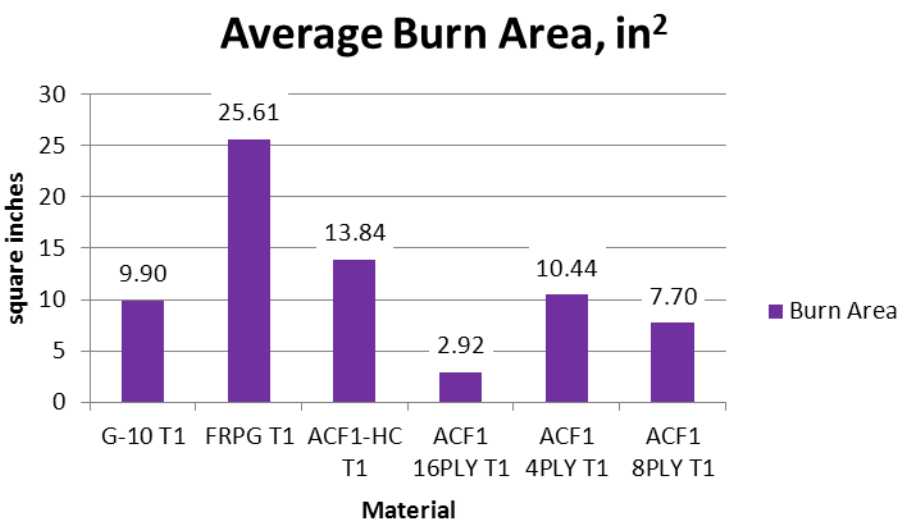


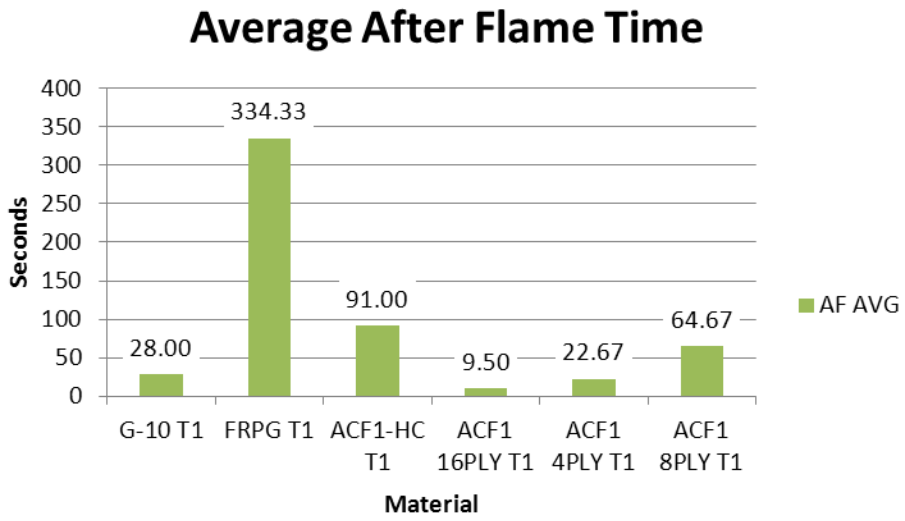
- BL_{avg}=3.625”
  - %sd=8.95%
- BW_{avg}=2.125”
  - %sd=0%
- AF_{avg}=64.67 sec.
  - %sd=12.011%



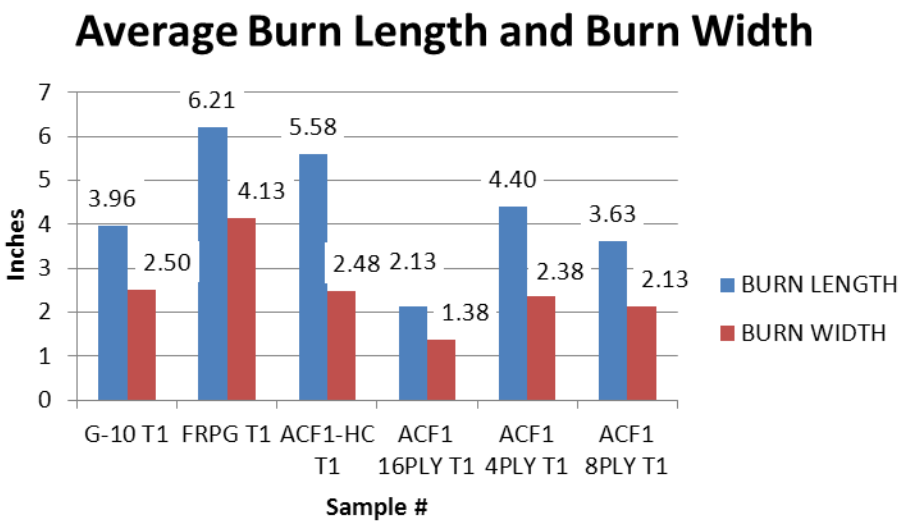
Average Results

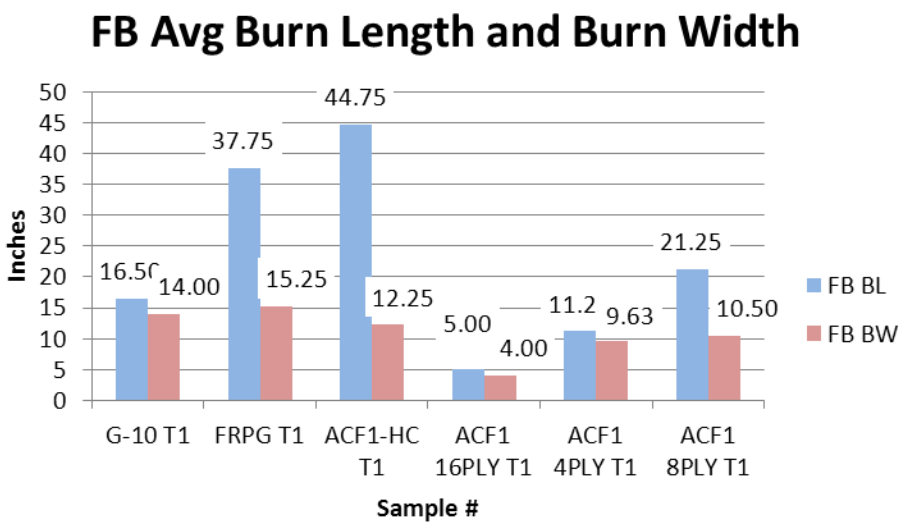




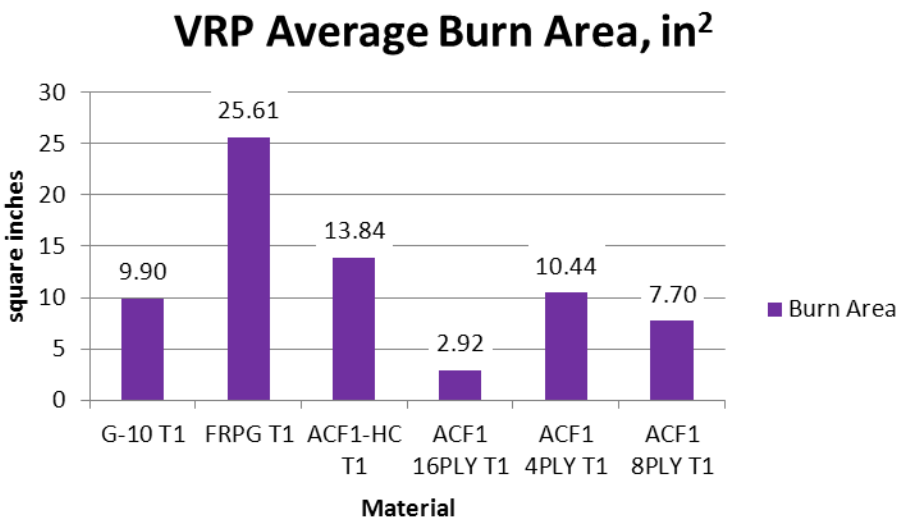


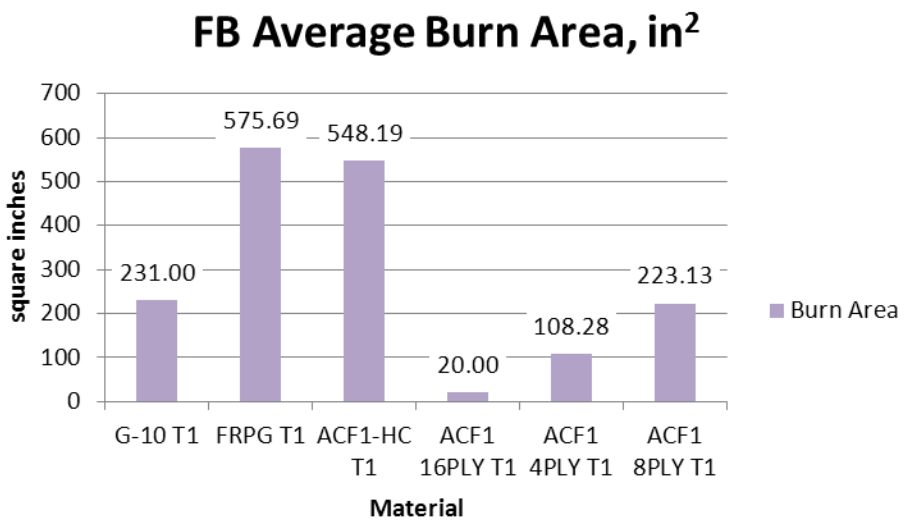
VRP vs. Foam Block Burn Length & Width



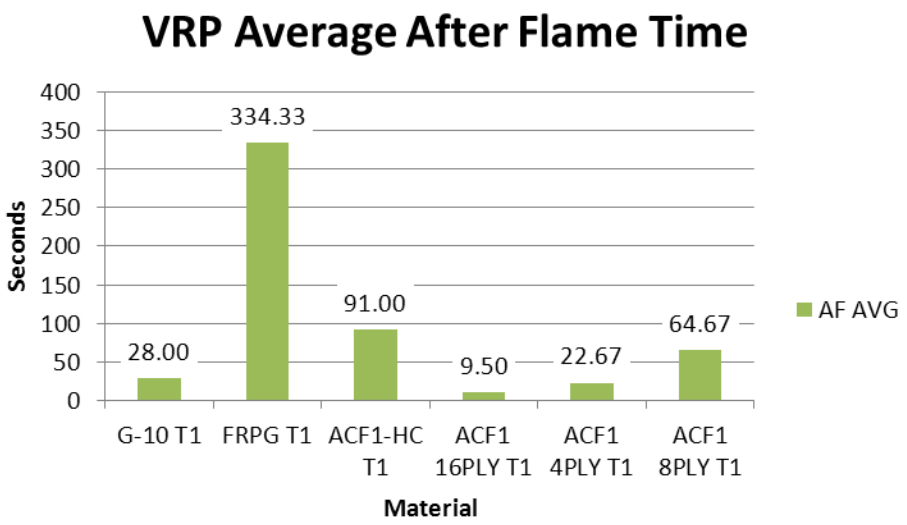


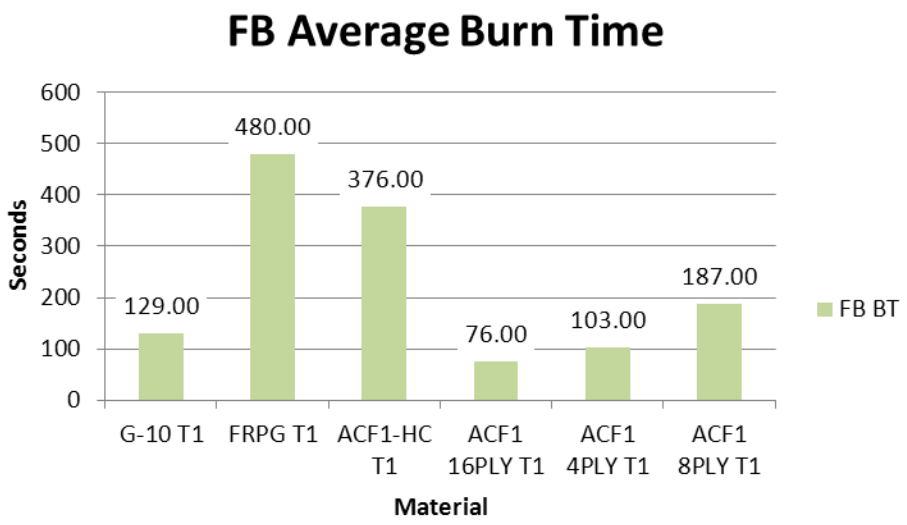
VRP vs. Foam Block Burn Area





VRP vs. Foam Block Burn Time



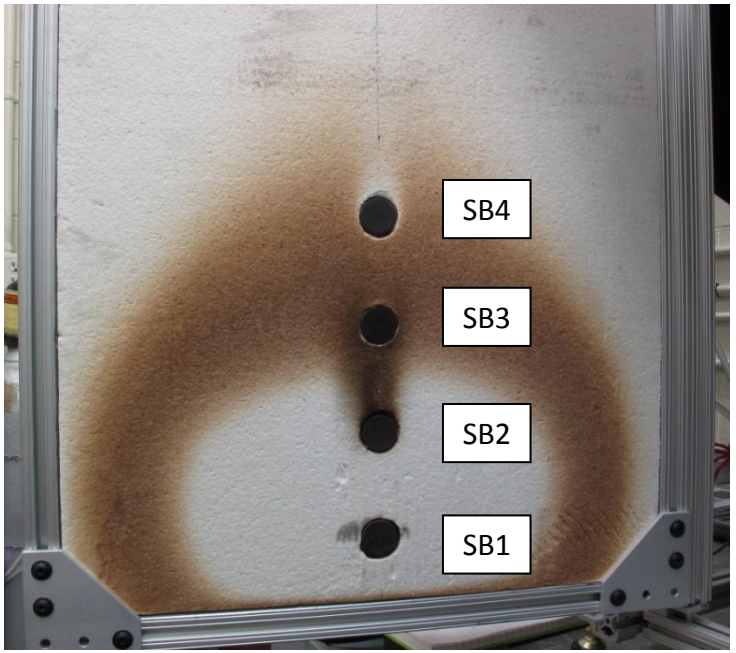


Recent Testing – Summary

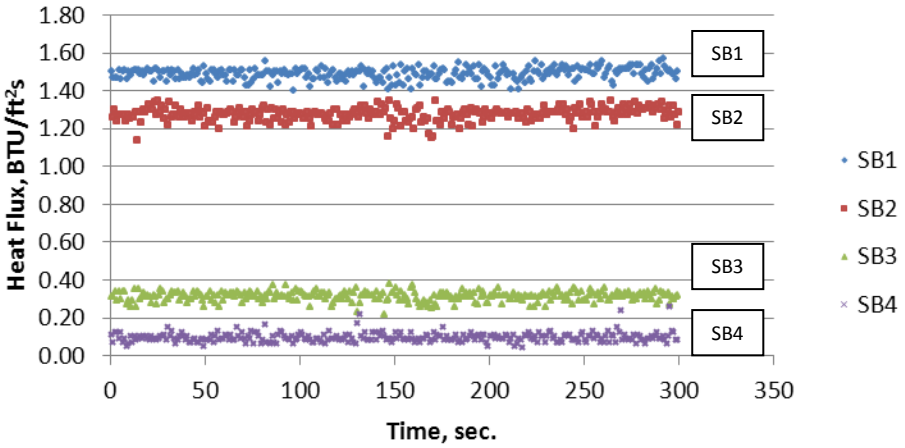
- Fairly good repeatability was found for most sample sets
  - Average %SD
    - Burn Length: 13.56%
    - Burn Width: 4.04%
    - After Flame: 37.43%
  - More tests need to be performed to standardize a procedure, environmental influences, etc.
- Lab scale test results generally correlate with intermediate scale testing

Effect of Drafts on Heat Flux

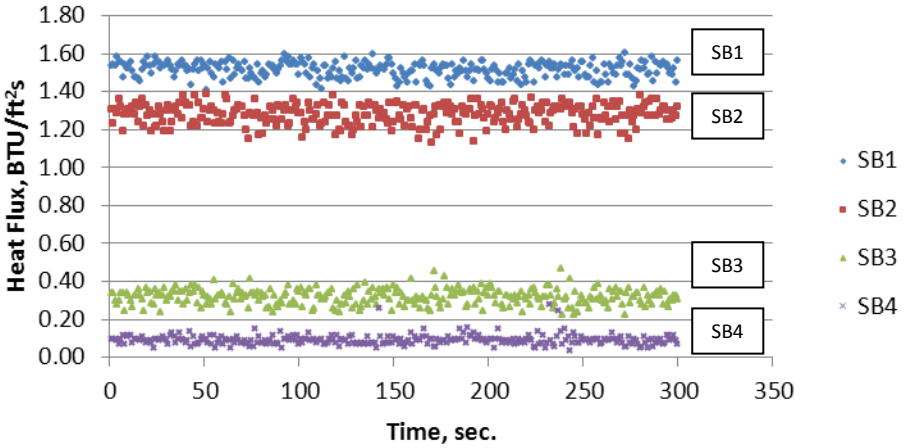
- Three scenarios were tested to determine the effect of enclosing the apparatus on air drafts near the sample or heat flux gauge surfaces
  1. Baseline: Partially shrouded, no exhaust fans
  2. Partially shrouded, exhaust fans approximately 6’ above top of apparatus gently drafting air out of room
  3. Fully shrouded, no exhaust fans



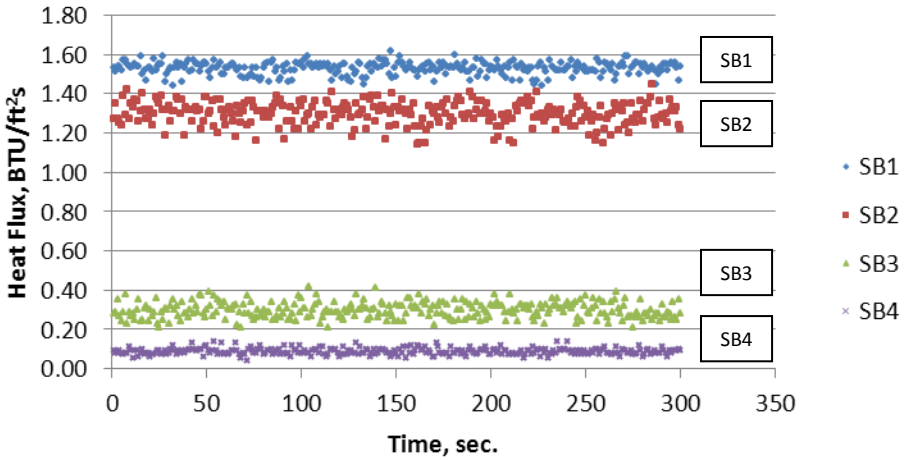
#1: Baseline - 5 minute sample

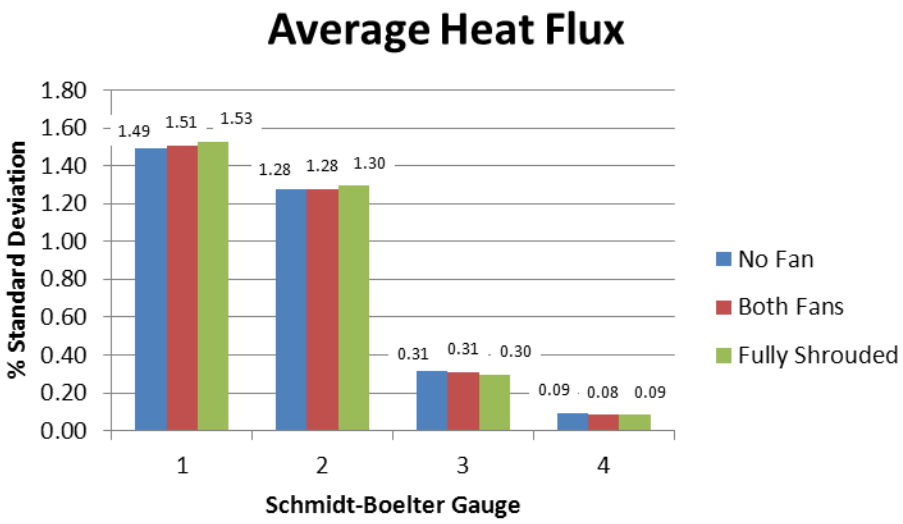


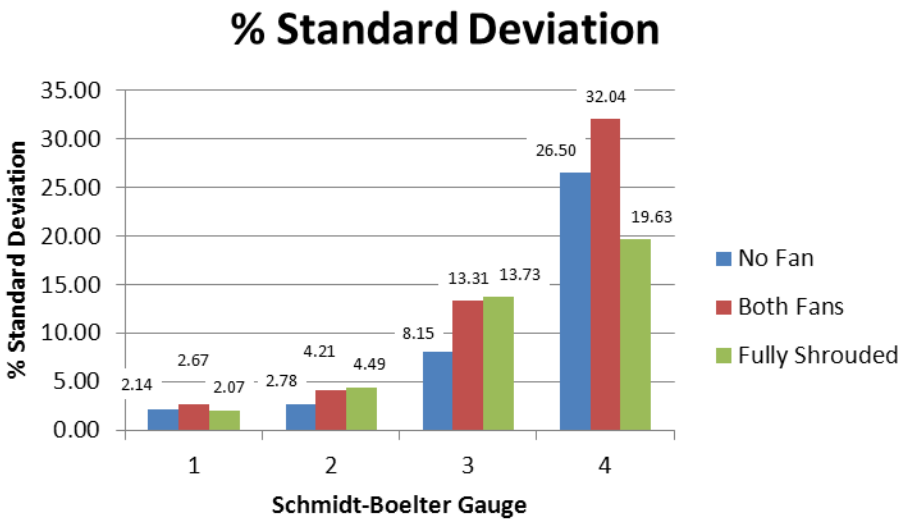
#2: Fans on - 5 minute sample



#3: Fans off fully enclosed - 5 minute sample




Average Heat Flux
% Standard Deviation
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.49
1.51
1.53
1.28
1.28
1.30
0.31
0.31
0.30
0.09
0.08
0.09
1
2
3
4
Schmidt-Boelter Gauge
No Fan
Both Fans
Fully Shrouded


% Standard Deviation
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2.14
2.67
2.07
2.78
4.21
4.49
8.15
13.31
13.73
26.50
32.04
19.63
1
2
3
4
Schmidt-Boelter Gauge
No Fan
Both Fans
Fully Shrouded

Heat Flux Fluctuations

- Bottom 2 flux gauges have less relative fluctuation than the top 2
- The average measured values at each SB gauge changed little from test to test
- Burn tests can be performed to determine the actual effect on test results
- The final design will specify how to enclose the apparatus to standardize air currents and fluctuations

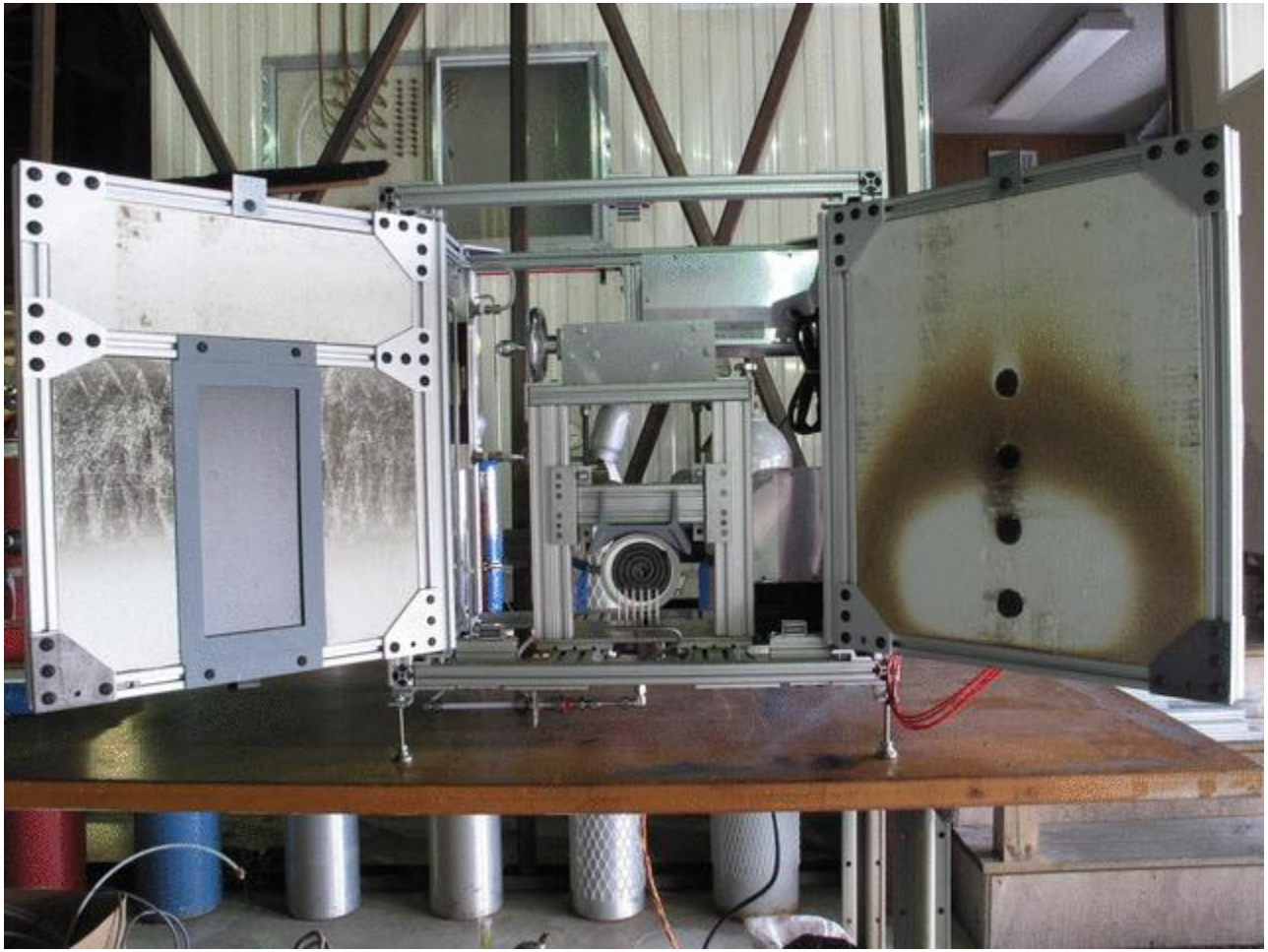
Next Steps

- Furnace comparison
  - Spiral tubular heating elements were ordered from different manufacturers to determine the difference in measured heat output at the same power settings, distance
- Calibration
  - Determine if specification of power (voltage, current), distance from heat flux gauge, and furnace specifications will adequately represent the desired incident flux
    - Removing HFG from calibration procedure would reduce cost of running test and eliminate uncertainty of calibration and use of HFG
  - Mapping of furnace with HFG on a traverse
    - Monitor input voltage and current while traversing SB gauge to map heat flux vs. input power, distance
    - Determine repeatability
      - Different day
      - Different furnace

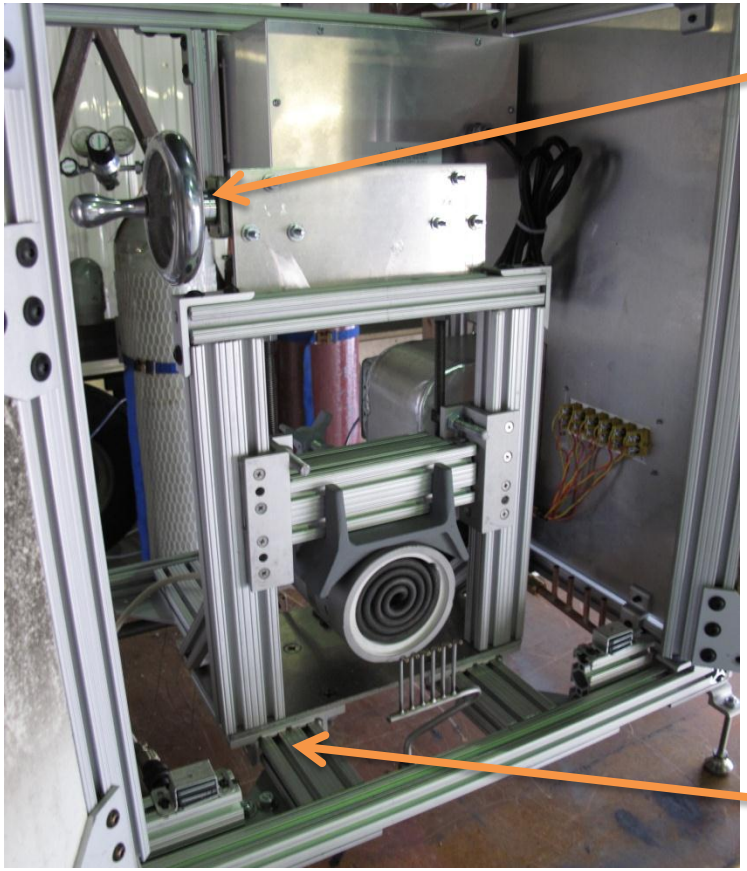
Next Steps cont.

- Version 2.0
  - Once design and test parameters are confirmed, perform repeatability testing
    - Will be receiving large quantity of 6” x 12” carbon fiber composite samples of varying ply thicknesses, layups, fibers, and epoxies
  - Construct one or more units
    - Perform comparative testing on multiple units to determine reproducibility

Version 2.0

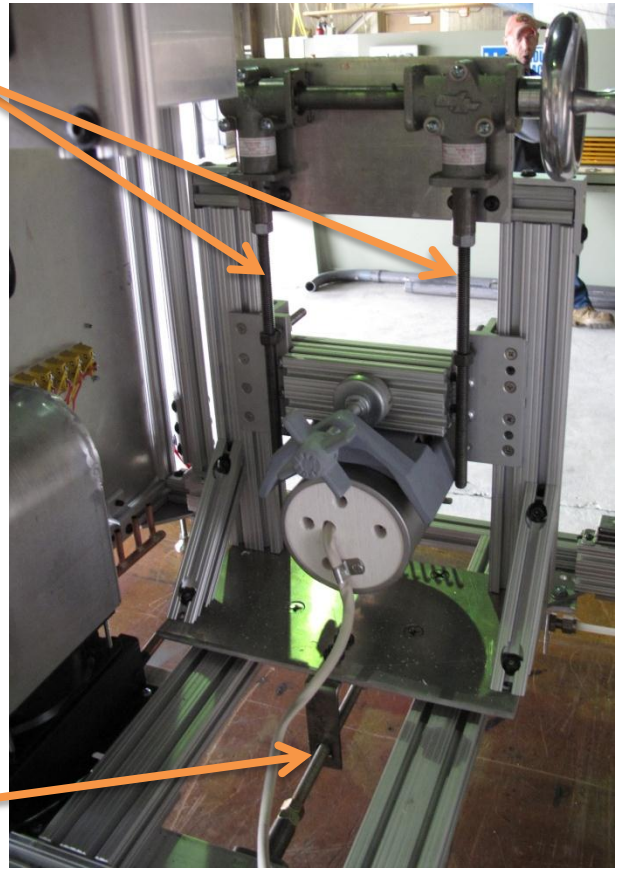


Version 2.0

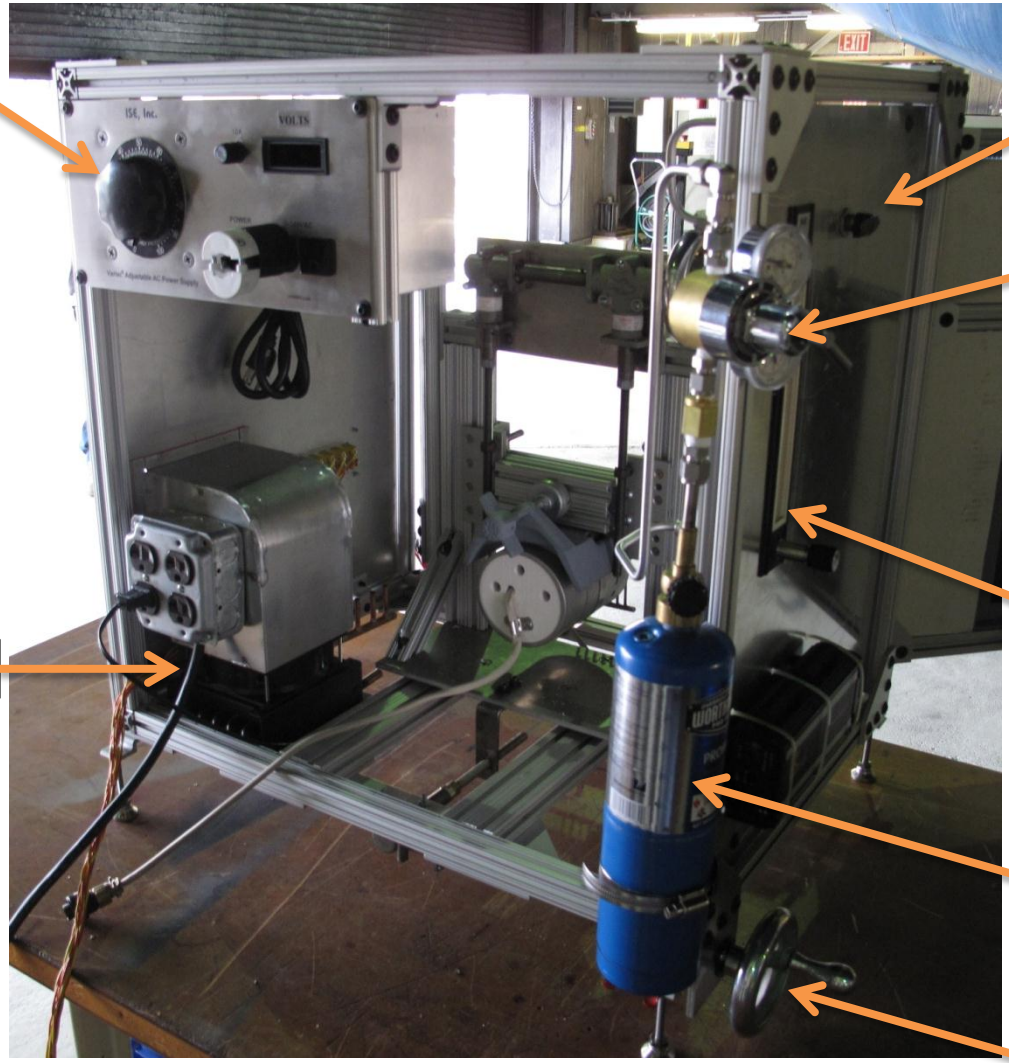


Furnace height adjustment

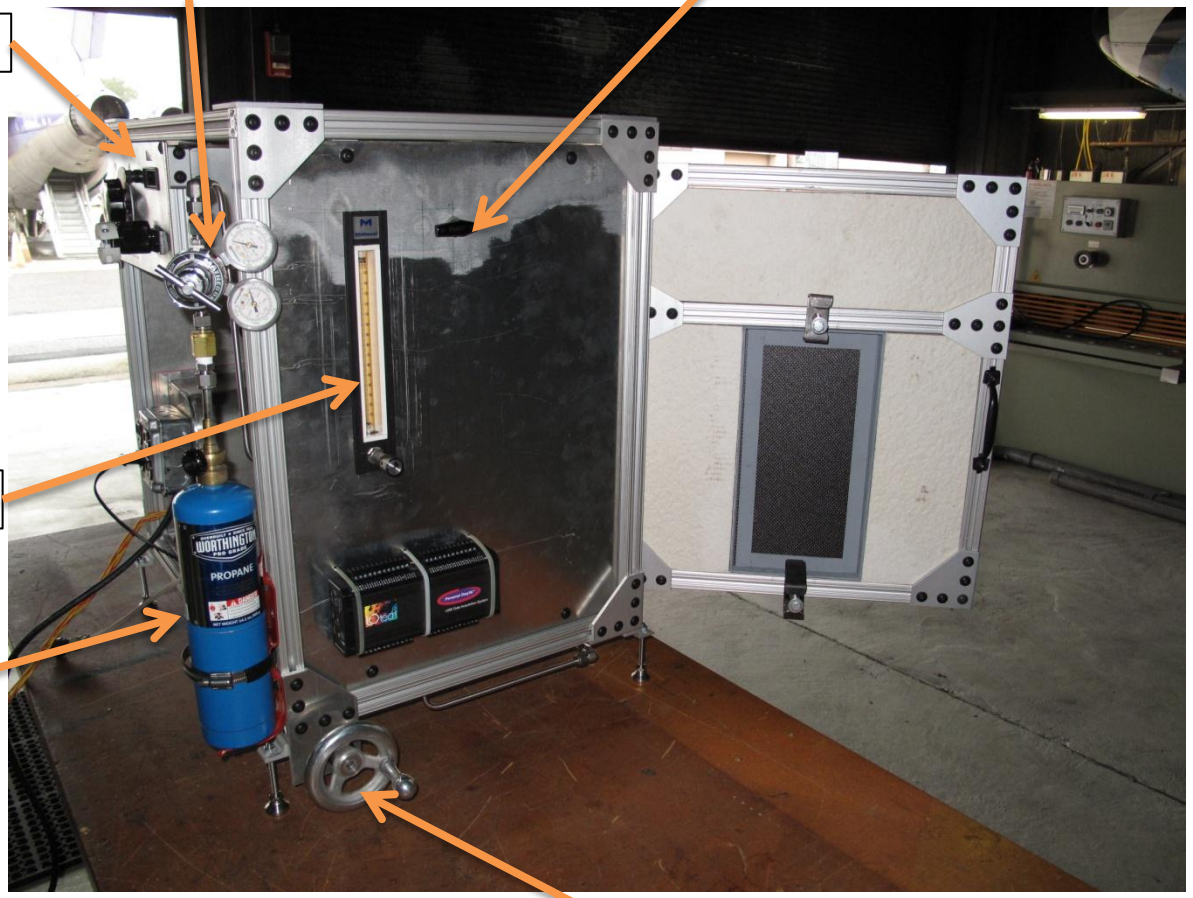
Furnace distance adjustment



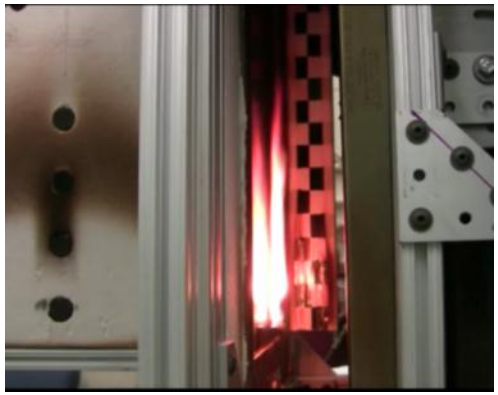
Version 2.0


Variable AC Transformer
Pilot burner gas on/off valve
Propane gas pressure regulator
Propane gas flow meter
Cooling fan for SB gauge water
Propane gas for Pilot burner
Furnace distance adjustment

Version 2.0


Propane gas pressure regulator
Pilot burner gas on/off valve
Variable AC Transformer
Propane gas flow meter
Propane gas for Pilot burner
Furnace distance adjustment
PROPANE





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