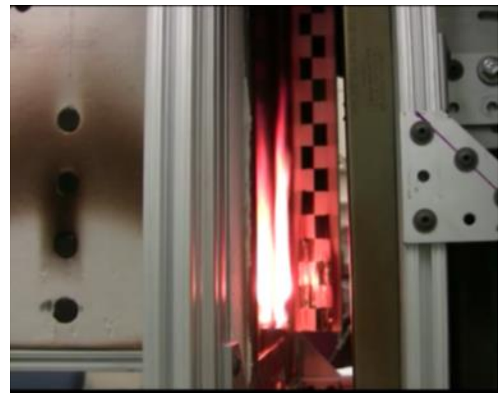
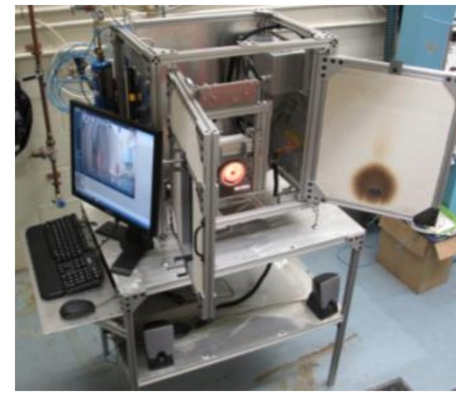
Composite Flame Propagation Update

Federal Aviation Administration



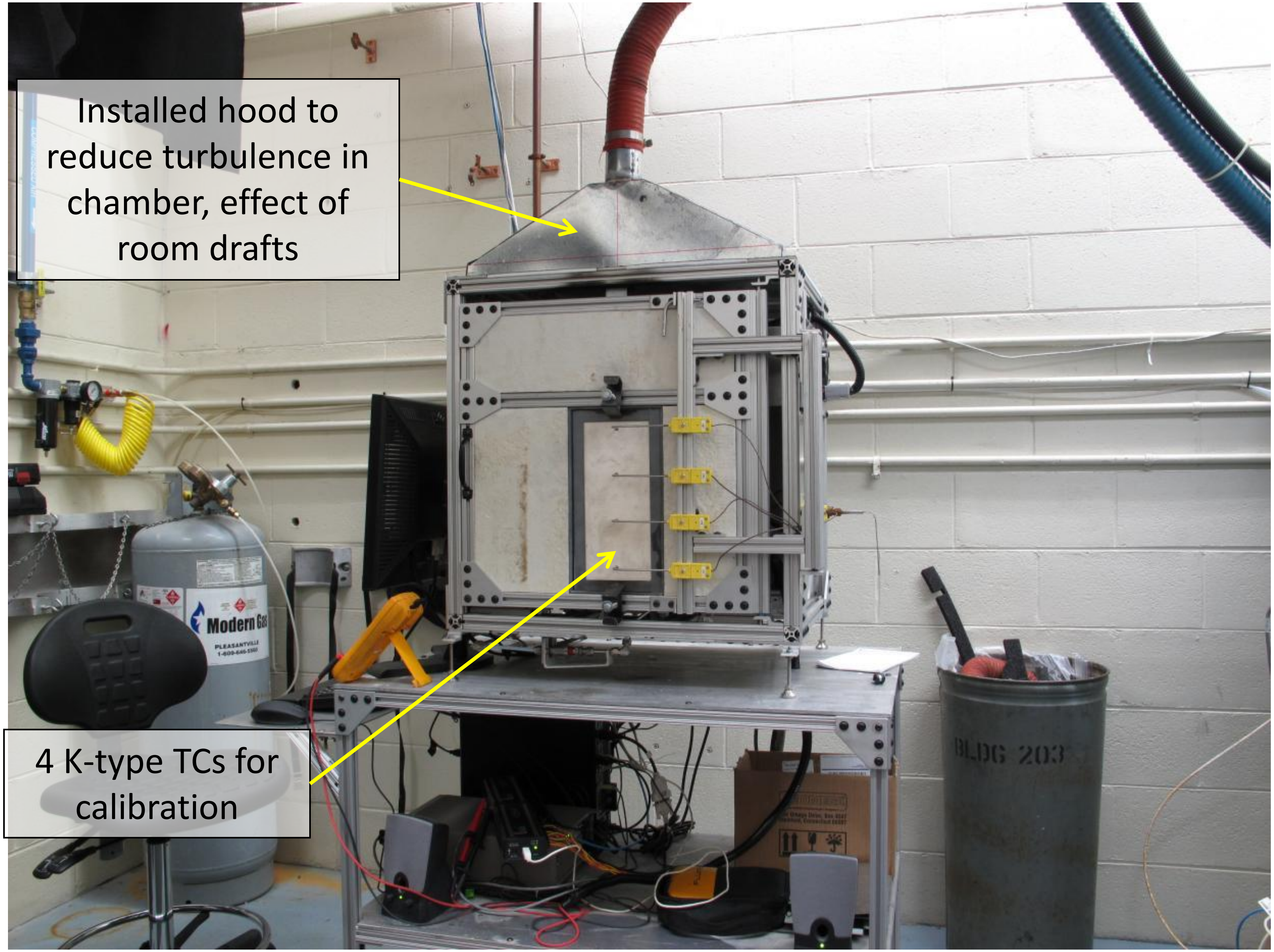
Presented to: IAMFTWG
By: Robert I. Ochs
Date: June 19-20, 2013, Manchester, UK

Objective

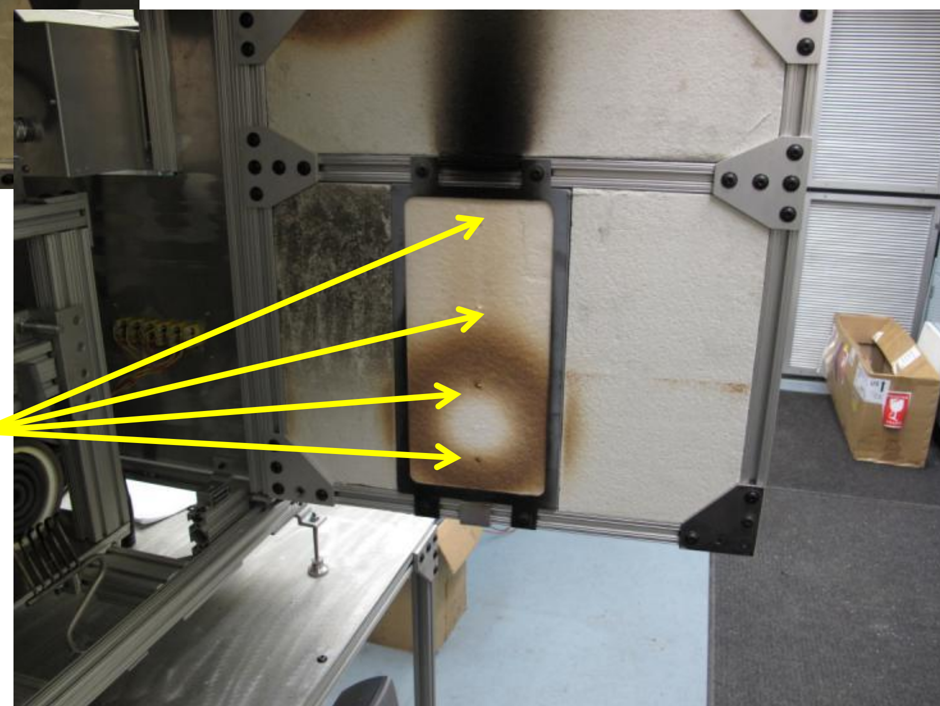
- Develop an apparatus capable of measuring flame propagation of composite materials
  - Intended for composites in hidden areas
    - Primary structure (fuselage)
    - Ducts, wires, other materials possible
  - Test parameters scaled from foam block
    - Intensity (heat flux, temperature)
    - Duration

Review of March Meeting

- Using TCs rather than HFGs for assessment of chamber stabilization
- TC measurements are not intended as calibration requirement
- Measured furnace power (AC true RMS voltage, current measurement) to be used for apparatus set up
- Burn length, width, after flame time are measureable test parameters.


Installed hood to reduce turbulence in chamber, effect of room drafts
4 K-type TCs for calibration
Modern Gas
BLDG 203

TCs can swing out of the way to open door, can be used to measure backside sample temp during test



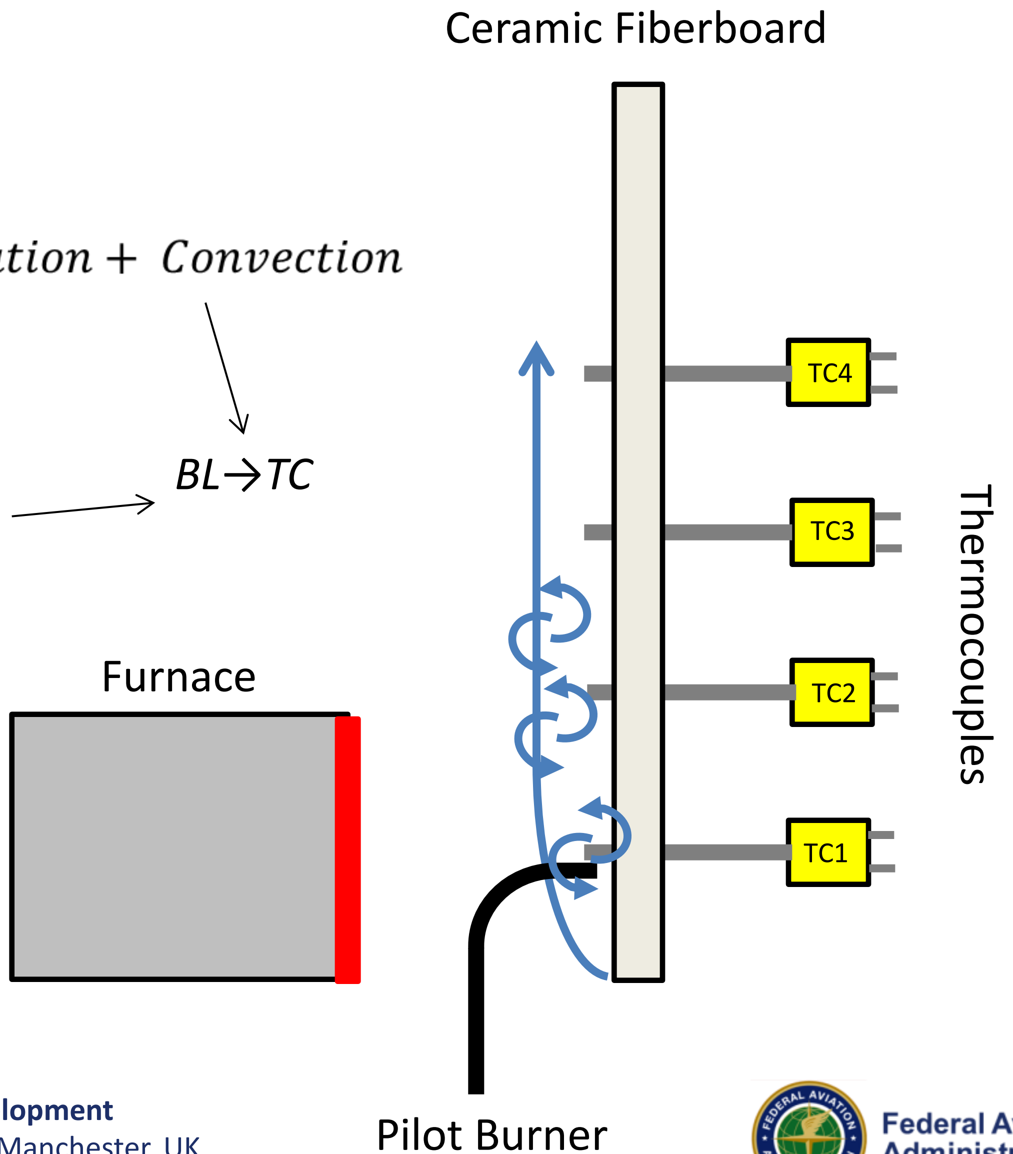
TC locations on ceramic board

What are the TCs measuring?

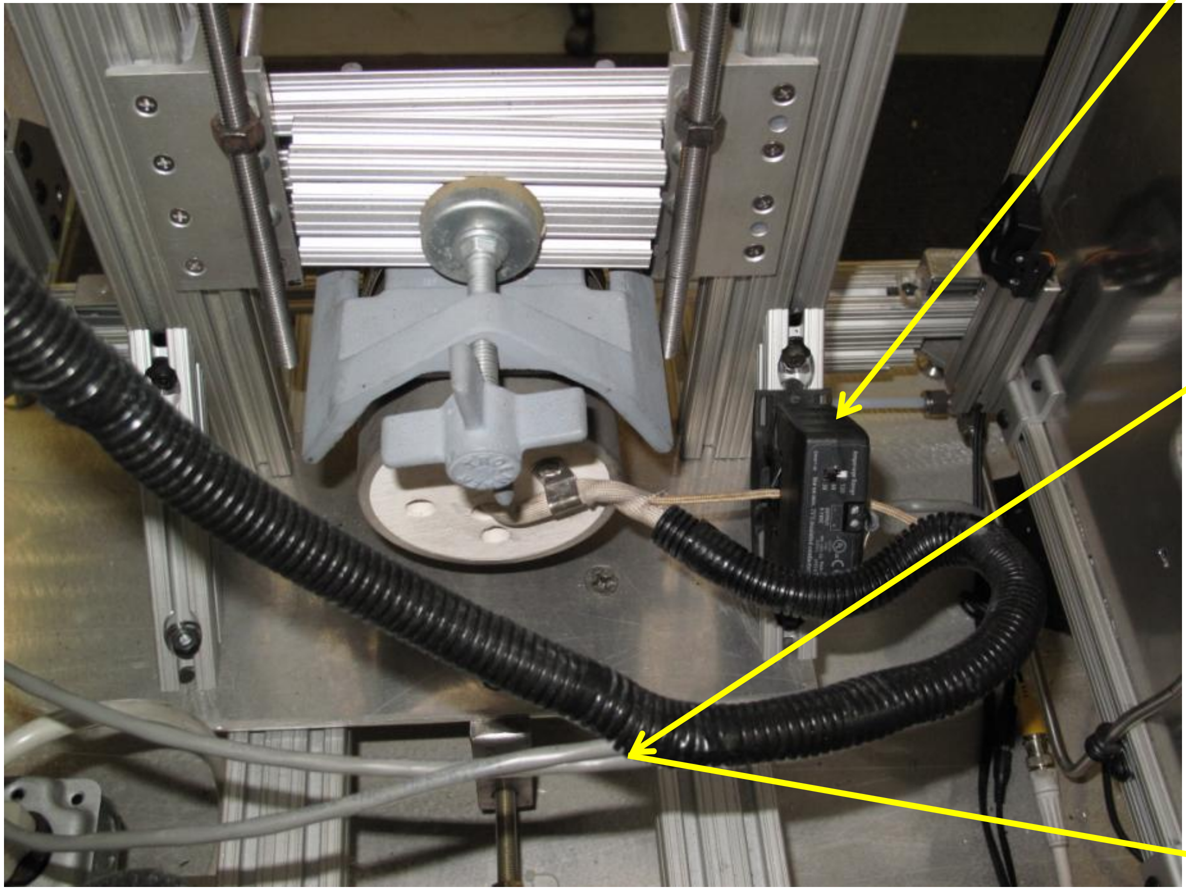
$$T_{measured} = \sum Radiation + Convection$$

Furnace→TC
Furnace→Board
TC→Surroundings

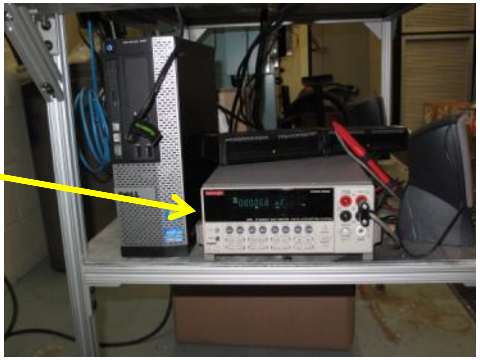
BL→TC



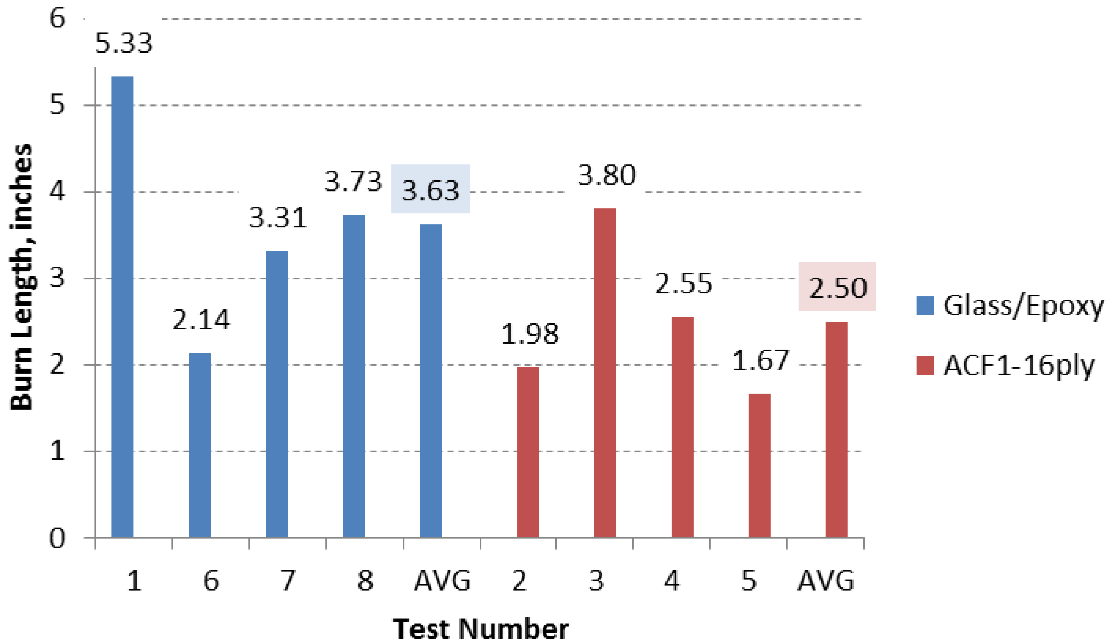
Around-conductor current probe converts true RMS AC current to 0-5 VDC signal for DAS



AC voltage is measured close to the furnace, signal is sent to DMM for true RMS AC voltage measurement



Test Results – Burn Length



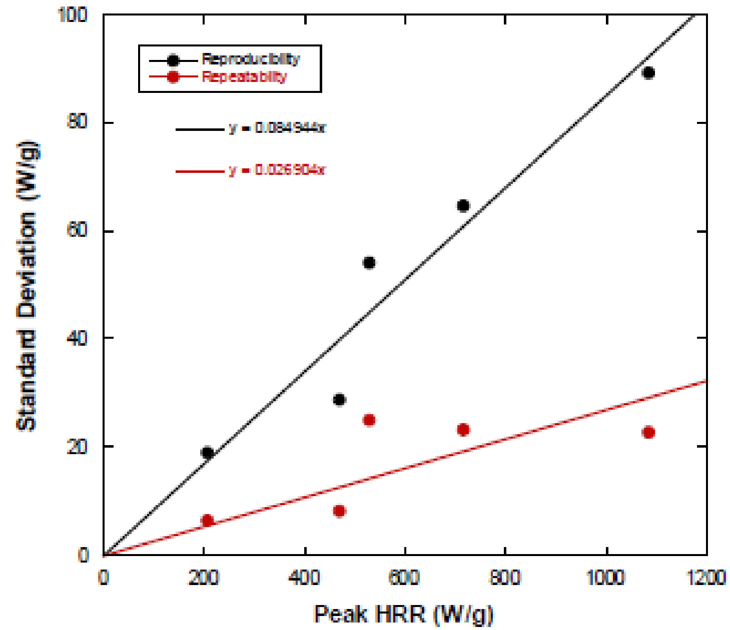
- Overall, mean burn length shows that G-10 tends to propagate more than ACF1
- Previous foam block tests
  - G10: 16.5”
  - ACF1: 2.5-6.0”
- Consistency is not there yet
  - G10
    - %SD: 36.3%
  - ACF1
    - %SD: 37.6%

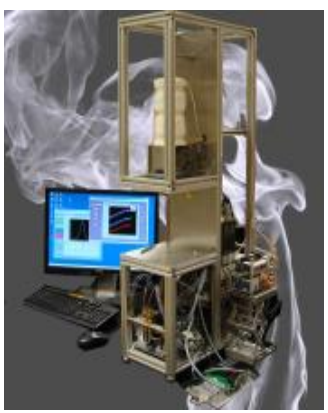
What's New

- Determine repeatability of material flammability properties
  - Cone calorimeter (CC) and Microscale Combustion Calorimeter (MCC)
- Change pilot flame to premixed
  - Reduction of buoyancy and footprint may lead to increased repeatability of ignition
- Vary pilot impingement time, determine effect on repeatability and severity
- Find "standard" material to assess apparatus consistency
  - Schneller OSU panel
- Construct and test additional apparatuses to determine reproducibility of test
- Develop drawings for apparatus

Microscale & Cone Calorimeters

- Objective: use CC and MCC as tools to determine consistency of material flammability properties
  - Heat release rate
  - Heat capacity
  - Time to ignition
  - Time to extinguishment
  - Etc.
- MCC was found to have excellent repeatability from test to test (Walters & Lyon, 2012)
  - Standard deviation (σ) found proportional to combustion property (P)
  - Repeatability coefficient of variation (COV) = slope of σ vs. P x 100
- CC repeatability from Janssens et al 2000
  - Peak HRR: r=17%
  - Total HR: r=8%

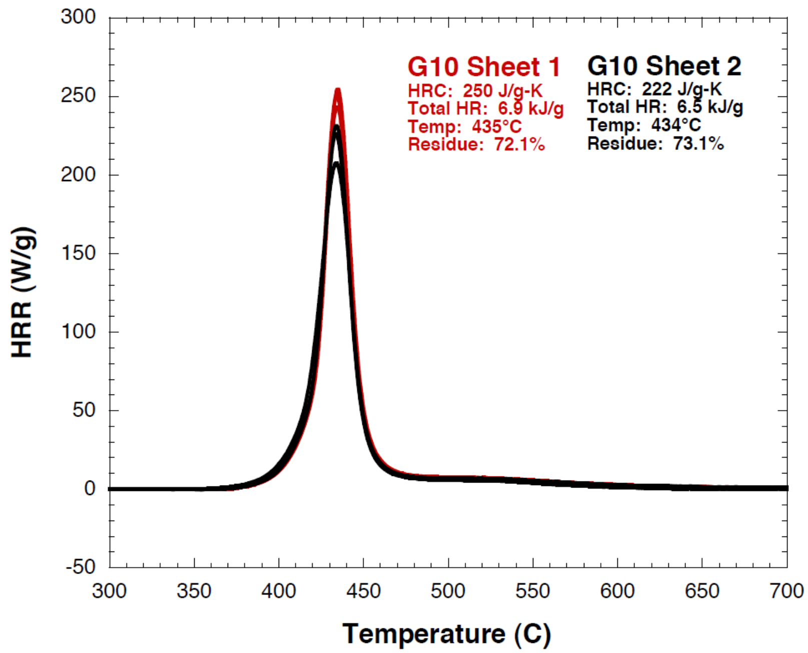


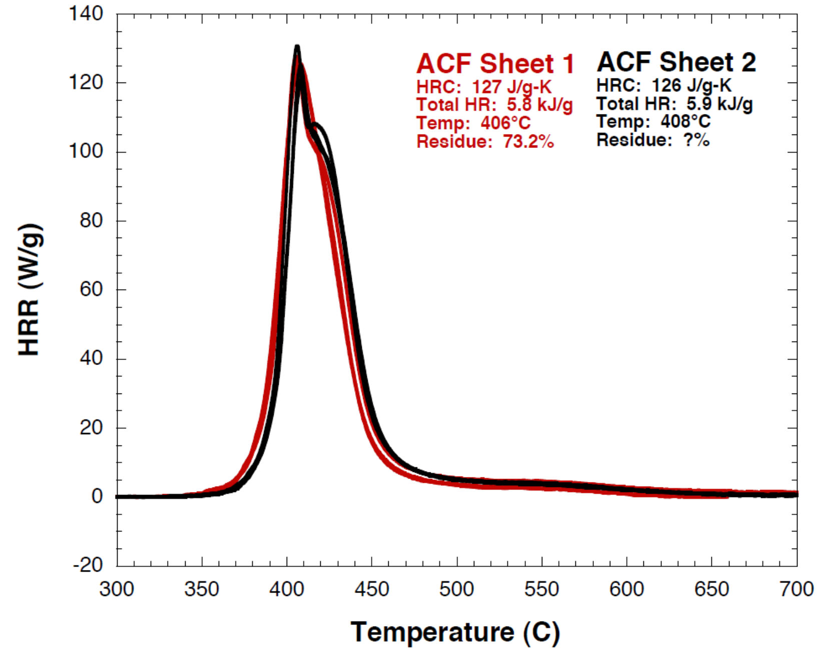


	Thermal Combustion Property	Repeatability COV (%)	Reproducibility COV (%)
Max Specific Heat Release Rate	Q'_{max}	2.7	8.5
Heat Release Capacity	η_c	3.2	7.9
Total Heat Release	Q_∞	1.4	5.6
Pyrolysis Temperature	T_p	<1	2.2
Char Residue	μ	3.8	6.8

*study performed with polymers PMMA, HIPS, PP, PC, PPSU

MCC Data





Thermal Combustion Properties:

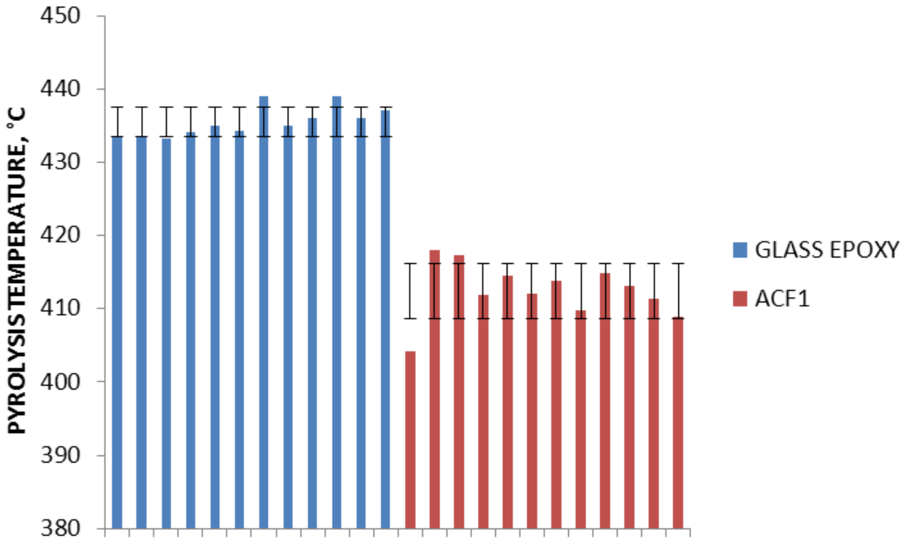
- Pyrolysis Temperature, °C
- Heat Release Capacity, J/g-K
- Peak Heat Release Rate, W/g
- Total Heat Release, kJ/g

Two different materials tested:

- ACF1 and Glass-Epoxy
- 12 MCC tests for each material
- Samples cut from different sections of 6” x 12” panels

MCC Data

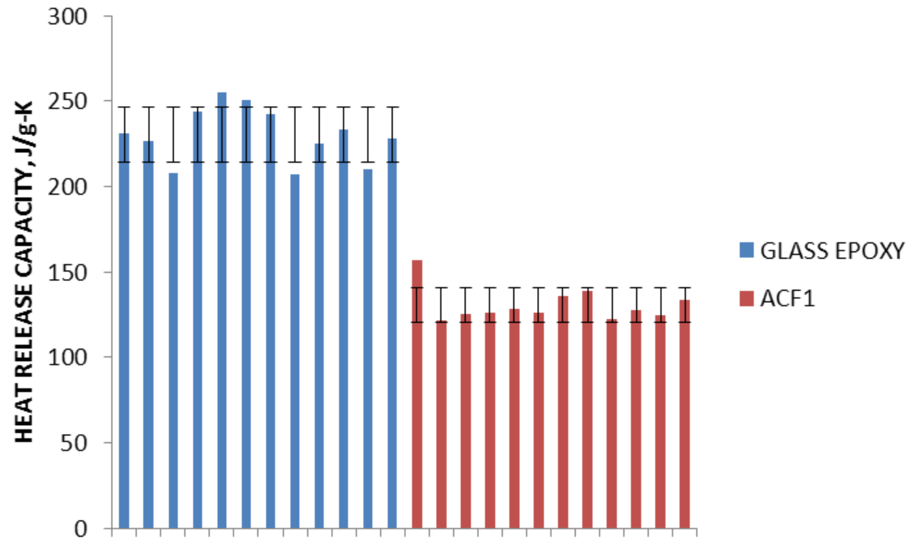
Pyrolysis Temperature
<1%



Glass Epoxy
Avg: 435.48
SD: 2.00
%SD: 0.46%

ACF1
Avg: 412.47
SD: 3.78
%SD: 0.92%

Heat Release Capacity
3.2%

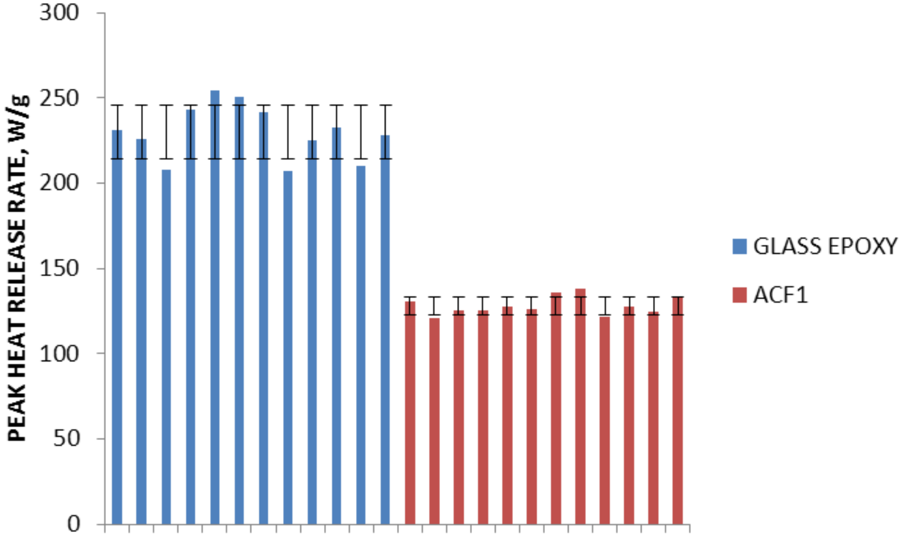


Glass Epoxy
Avg: 230.04
SD: 16.09
%SD: 6.99%

ACF1
Avg: 130.65
SD: 9.90
%SD: 7.58%

MCC Data

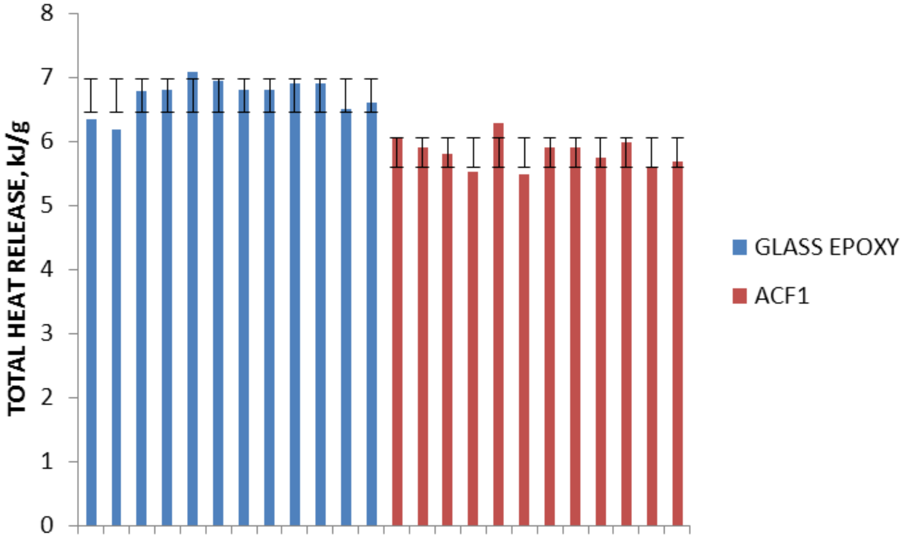
Peak Heat Release Rate
2.7%



Glass Epoxy
Avg: 229.87
SD: 15.98
%SD: 6.95%

ACF1
Avg: 128.11
SD: 5.37
%SD: 4.19%

Total Heat Release
1.4%



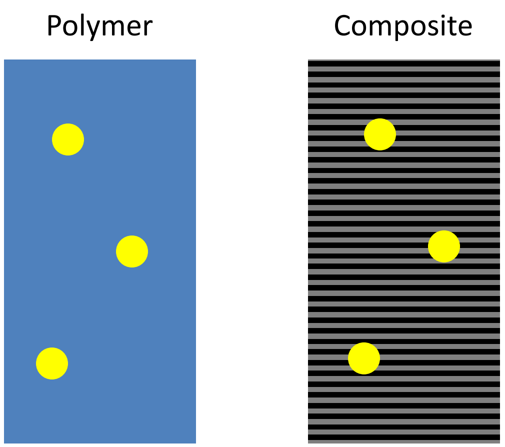
Glass Epoxy
Avg: 6.72
SD: 0.26
%SD: 3.91%

ACF1
Avg: 5.82
SD: 0.23
%SD: 3.98%

MCC Data - Summary

- Materials show good repeatability for MCC measurable parameters
- MCC repeatability study performed with single component polymers
- Composites can have spatially non-uniform composition

Property	% Standard Deviation		
	Glass Epoxy	ACF1	MCC
HRC (J/g-K)	6.99	7.58	3.2
PEAK HRR (W/g)	6.95	4.19	2.7
TOTAL HR (kJ/g)	3.91	3.98	1.4
T_P (°C)	0.46	0.92	<1



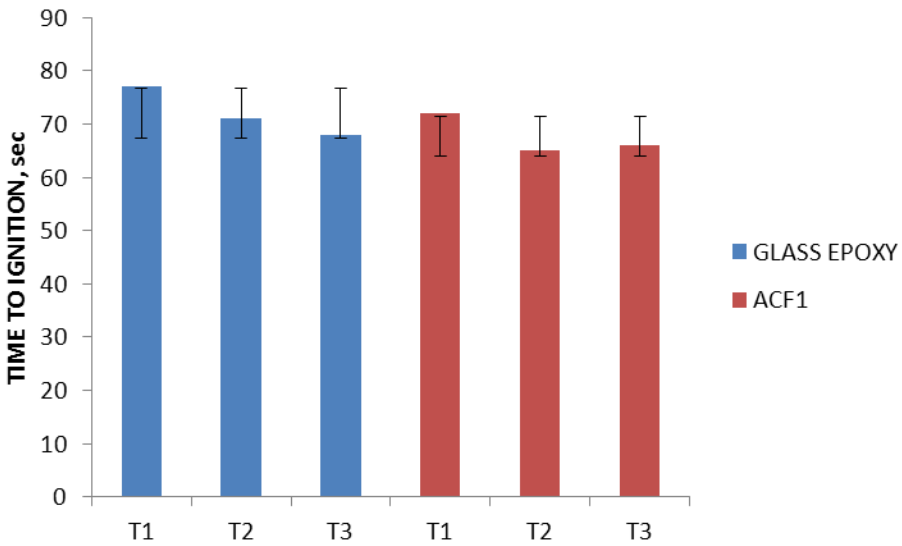
Cone Calorimeter Data

- 2 different materials tested
  - ACF1 and Glass Epoxy
  - 3 samples of each material tested

	GLASS EPOXY			ACF1		
	T1	T2	T3	T1	T2	T3
TIME TO IGNITION (sec)	77	71	68	72	65	66
TIME TO FLAMEOUT (sec)	256	421	321	206	244	218
FUEL LOAD (MJ/kg)	5.55	4.56	3.75	3.25	4.63	5.08
MASS LOSS (g)	16.3	13.7	11.5	9.6	13	14.3
PEAK HRR (kW/m^2)	320.02	237.95	185.37	245.29	293.56	500.81
PEAK HRR TIME (sec)	152	80	84	86	153	76
MEAN HRR (kW/m^2)	187.75	91.37	102.1	129.65	144.11	161.47
TOTAL HEAT RELEASE (MJ/m^2)	36.2	33.3	27.3	19.3	27.8	27

Cone Calorimeter Data

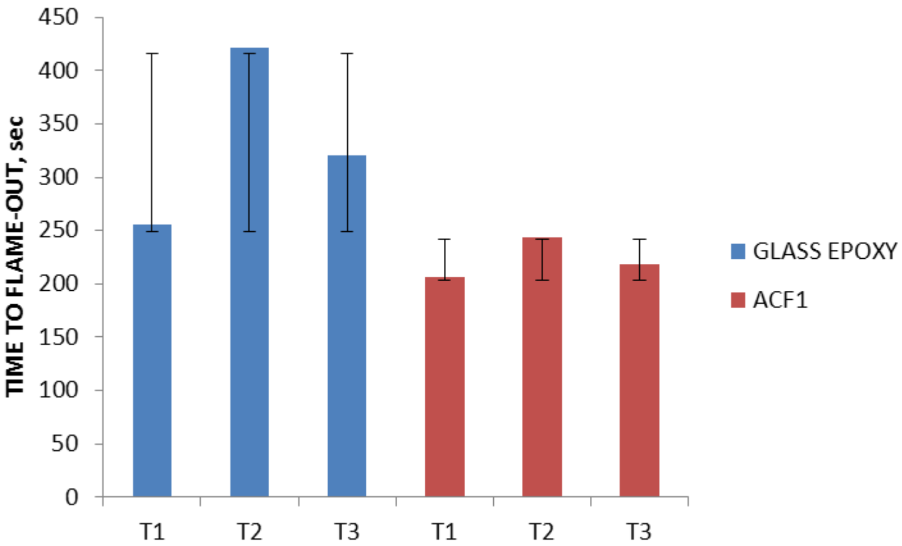
Time to Ignition



Glass Epoxy
Avg: 72
SD: 4.58
%SD: 6.36%

ACF1
Avg: 67.67
SD: 3.79
%SD: 5.59%

Time to Flame-Out

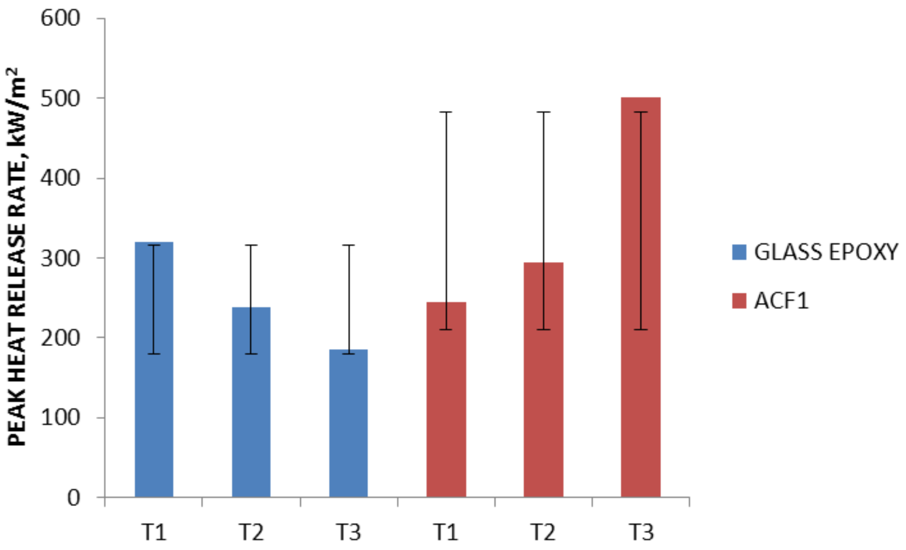


Glass Epoxy
Avg: 332.67
SD: 83.12
%SD: 24.98%

ACF1
Avg: 222.67
SD: 19.43
%SD: 8.72%

Cone Calorimeter Data

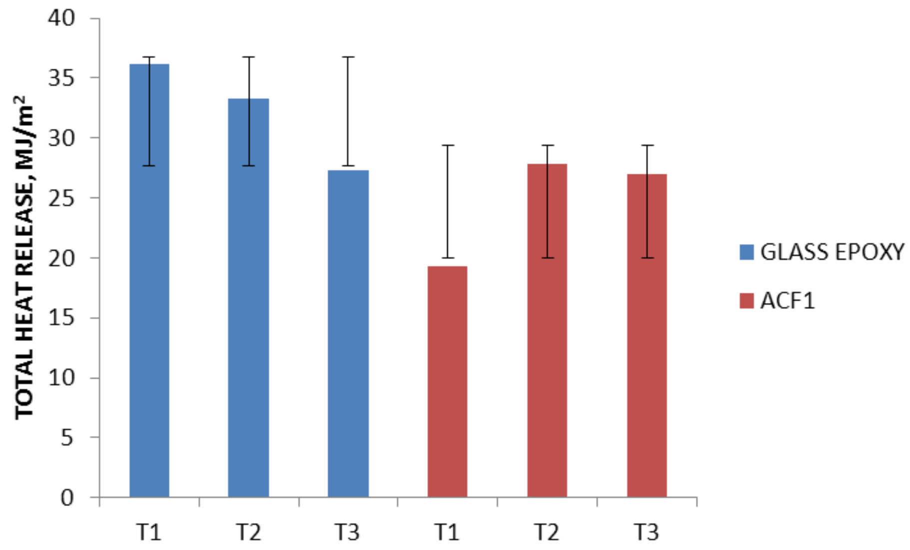
Peak HRR



Glass Epoxy
Avg: 247.78
SD: 67.86
%SD: 27.39%

ACF1
Avg: 346.55
SD: 135.75
%SD: 39.17%

Total HR



Glass Epoxy
Avg: 32.27
SD: 4.54
%SD: 14.07%

ACF1
Avg: 24.70
SD: 4.69
%SD: 19%

Cone Calorimeter Data – Summary

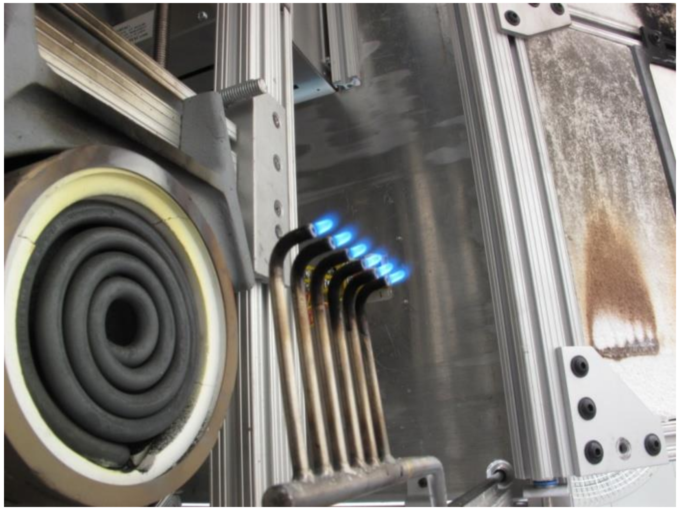
- Cone calorimeter has more variation than MCC
  - Surface combustion similar to real fires
- Composite materials found to have more variability than standard machine variability

Property	% Standard Deviation		
	Glass Epoxy	ACF1	CC
PEAK HRR (kW/m^2)	27.39	39.17	17
TOTAL HEAT RELEASE (MJ/m^2)	14.07	19.00	8

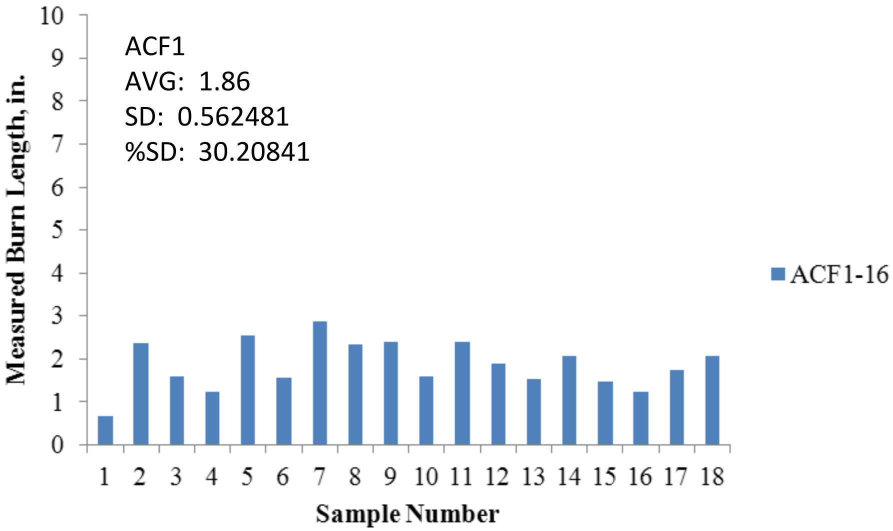
Summary: Microscale & Cone Calorimeters

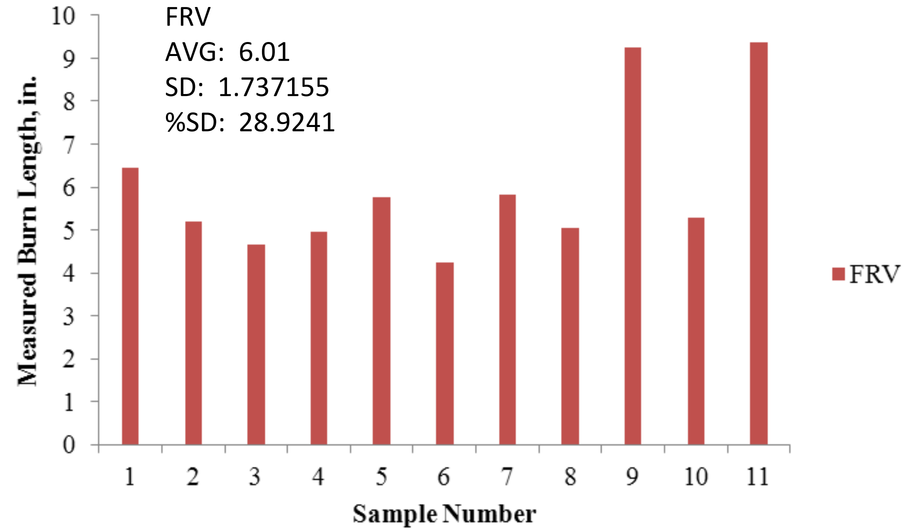
- Good repeatability was found in the MCC (<10%)
  - Composite materials less repeatable than single component polymer materials used in repeatability study
- Cone calorimeter data shows more deviation
  - Conditions more representative of real material combustion

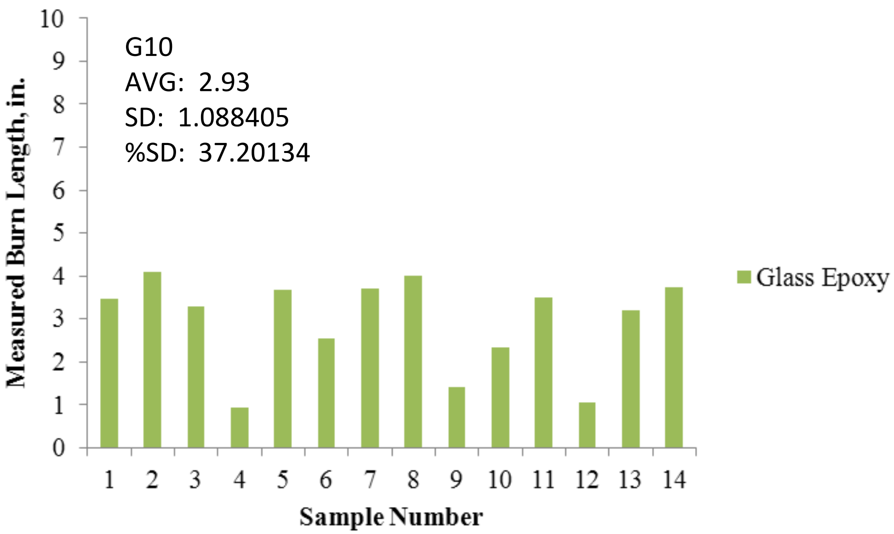
Premixed Pilot Ignition

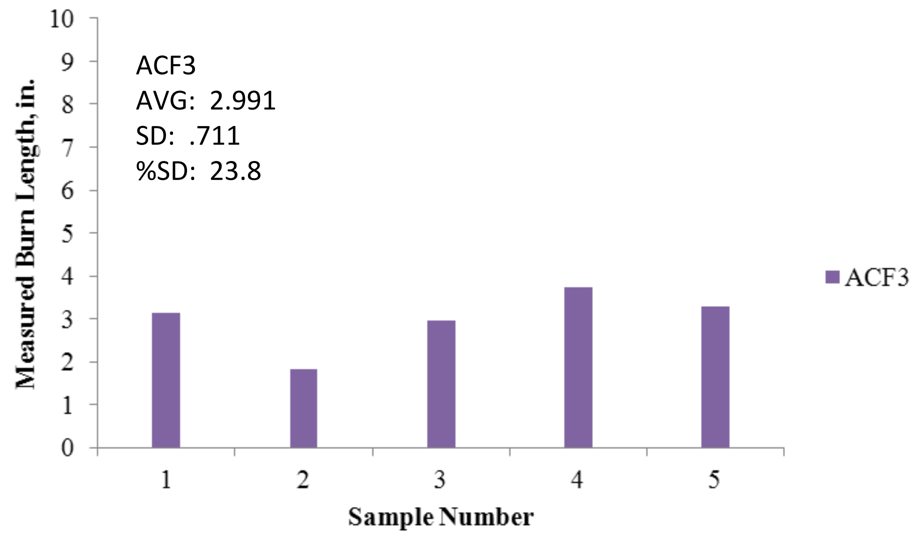


60 sec. Pilot Impingement

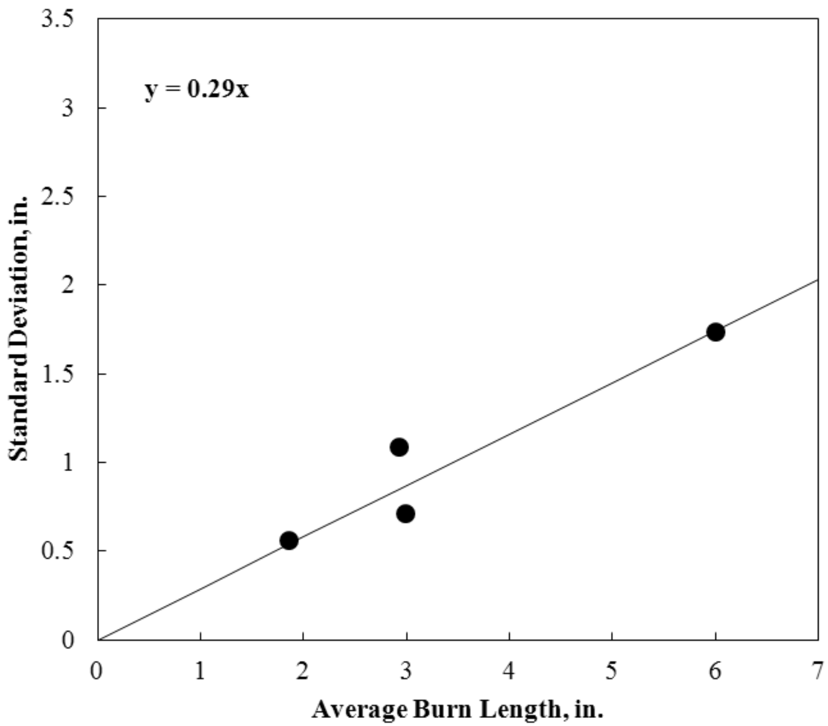




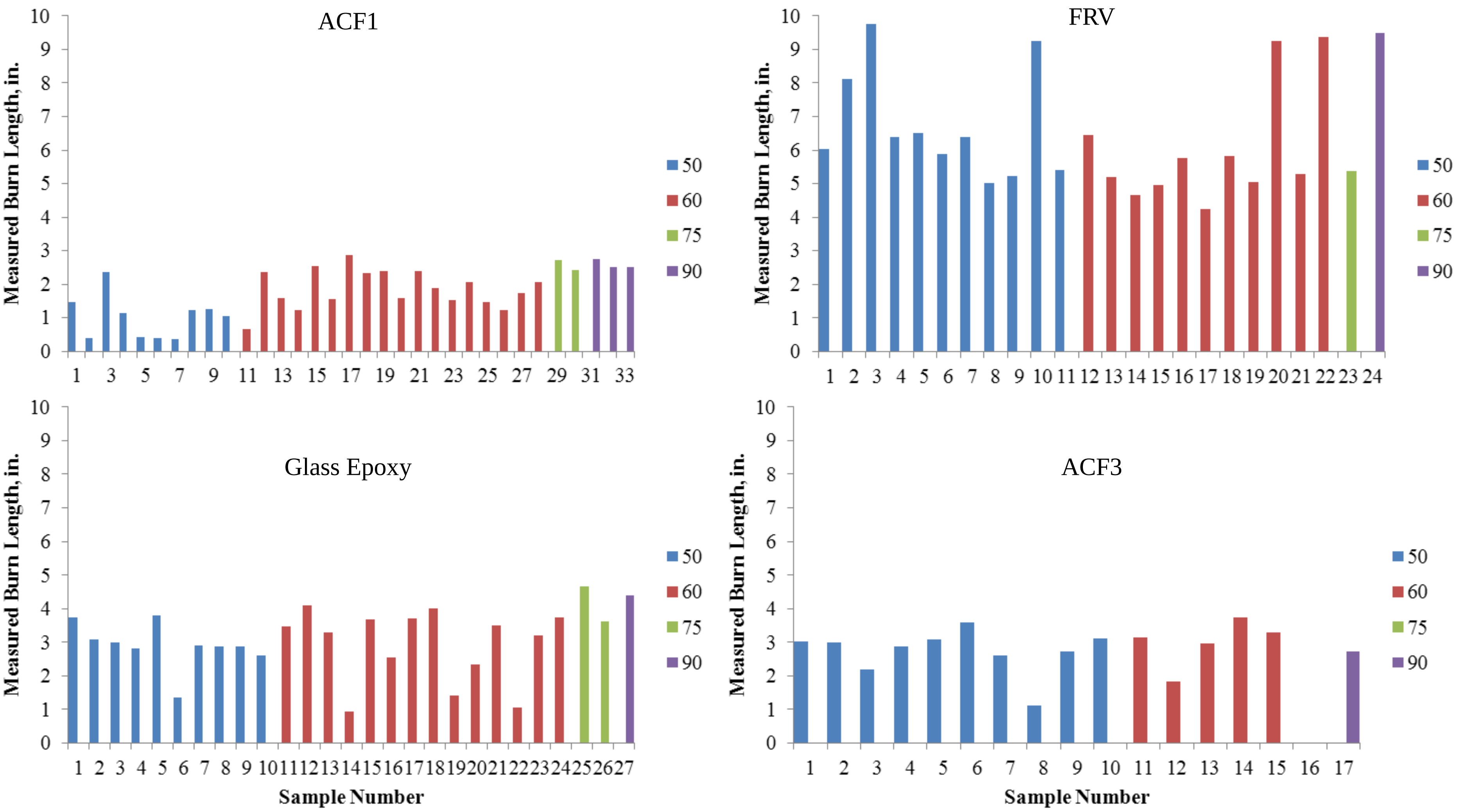




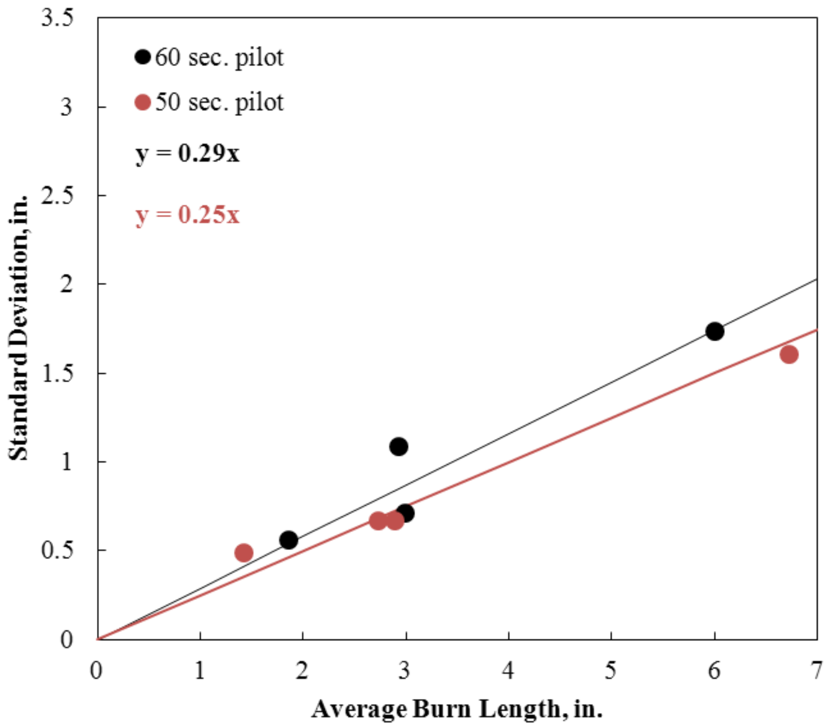
60 sec. Pilot - Repeatability



Vary Pilot Exposure Time



50 & 60 sec. Repeatability



50 s. Flame Impingement

ACF1

A.F.: 22 sec.
B.L.: 1.2”
B.W.: 1.6”

GLASS EPOXY

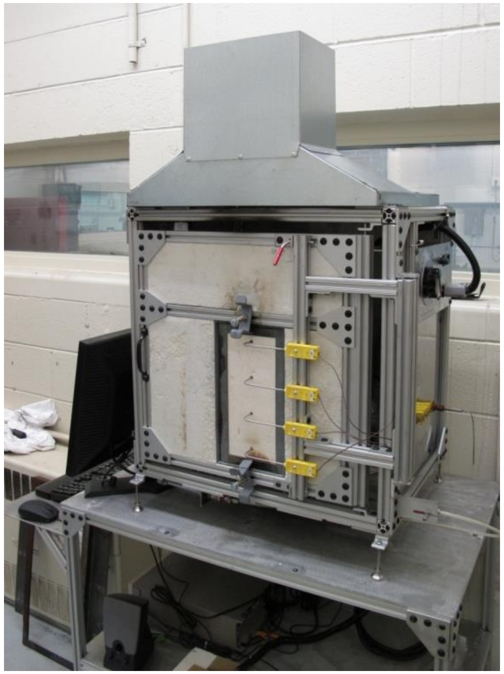
A.F.: 200 sec.
B.L.: 3.7”
B.W.: 3.2”

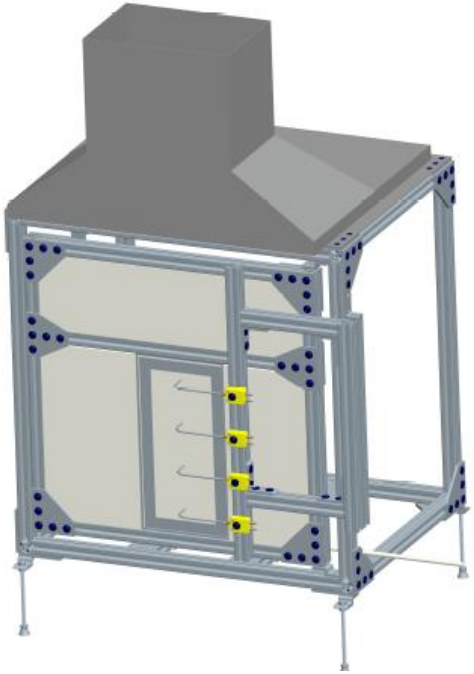
FRV

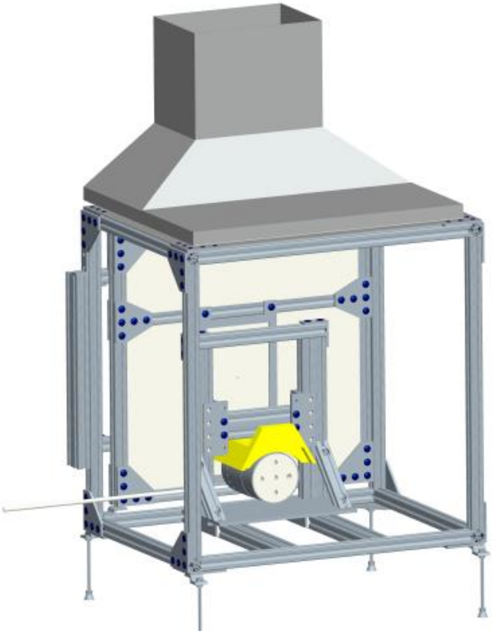
A.F.: 267 sec.
B.L.: 5.8”
B.W.: 4.9”

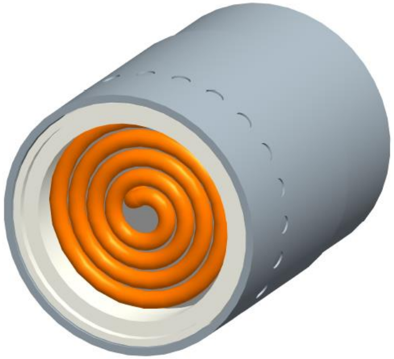
Burn Length Determination

Development of Detailed Drawings





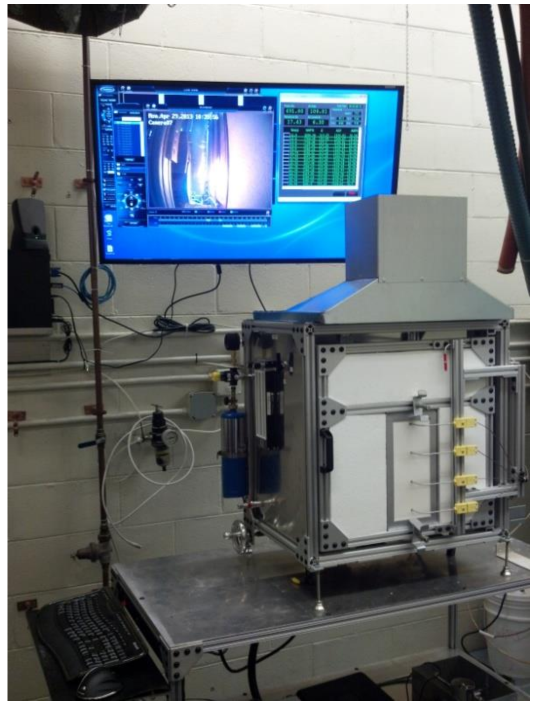




Apparatus Reproducibility

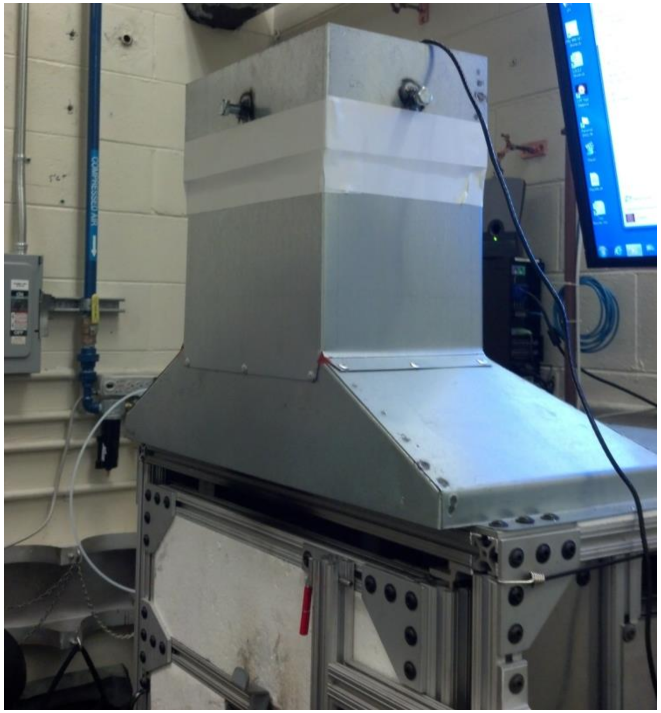
Unit #1

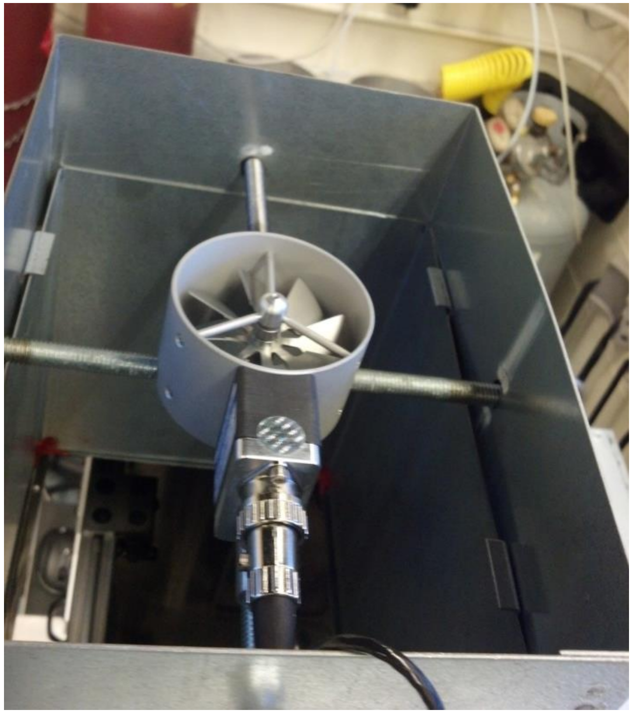
Unit #2



Unit #3

Hood Exit Flow Measurement





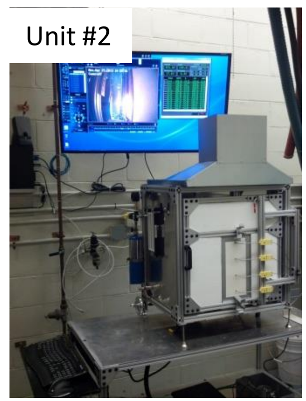
Unit	Cold	Cold w/fan	Hot w/ fan	Hot w/o fan
1	0	0	125	133
2	0	0	127	125
3	0	0	128	128

Apparatus Reproducibility

- A series of tests will be performed to determine the reproducibility of the test apparatus
- An array of materials will be tested on each machine:
  - Glass/epoxy: 10 tests
  - ACF1 8ply: 6 tests
  - FRV: 3 tests
  - 3KPW/TCR (woven CF)
    - 4, 8, 12, 16 ply: 3 tests each
  - T700/TC250 (uni tape CF, 250°F cure epoxy)
    - 4, 8, 12, 16 ply: 3 tests each
  - T700/TC350 (uni tape CF, 350°F cure epoxy)
    - 4, 8, 12, 16 ply: 3 tests each
  - 55 tests total
- Each machine will be tested in two laboratories
  - FAATC: B203
  - FAATC: B277
- Machines will also be shipped to outside labs to confirm reproducibility

Unit #1

Unit #2



Unit #3

203

277

Test Matrix

Apparatus	B203	B277	Away
1	Glass/Epoxy: 10 ACF1-8 ply: 6 FRV: 3 3KPW/TCR: 3x(4, 8, 12, 16 ply, 12 tests) T700/TC250: 3x(4, 8, 12, 16 ply, 12tests) T700/TC350: 3x(4, 8, 12, 16 ply, 12tests)	Glass/Epoxy: 10 ACF1-8 ply: 3 FRV: 3 3KPW/TCR: 3x(4, 8, 12, 16 ply, 12 tests) T700/TC250: 3x(4, 8, 12, 16 ply, 12tests) T700/TC350: 3x(4, 8, 12, 16 ply, 12tests)	Glass/Epoxy: 10 ACF1-8 ply: 3 FRV: 3 3KPW/TCR: 3x(4, 8, 12, 16 ply, 12 tests) T700/TC250: 3x(4, 8, 12, 16 ply, 12tests) T700/TC350: 3x(4, 8, 12, 16 ply, 12tests)
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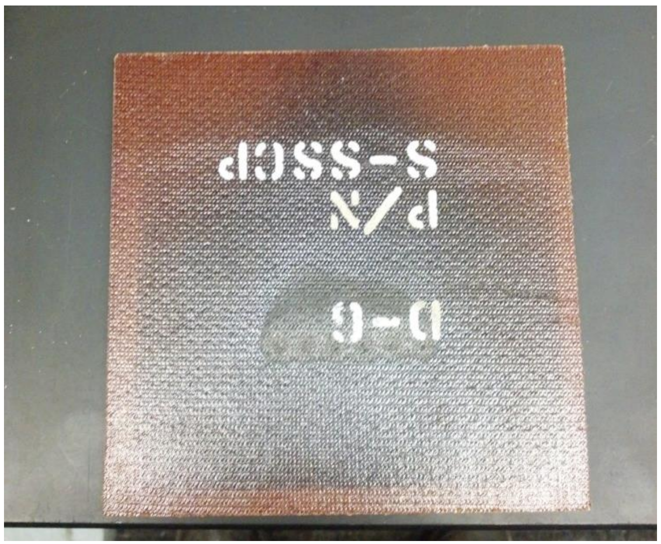
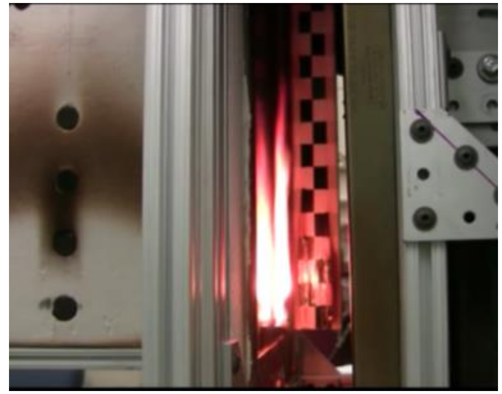
Repeatable Materials

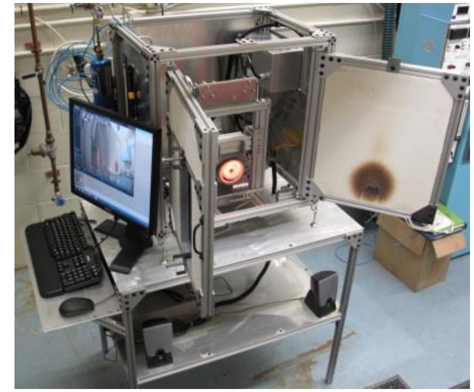


- Seeking materials with better repeatability of flame propagation from test to test
- Attempted Schneller panel from OSU, but no burning occurred
- Any materials manufacturers have ideas, let us know.

Summary

- MCC and CC used to determine repeatability of current materials
  - Composites show more variability compared to pure polymers
- Premixed pilot flame provides uniform line ignition, less buoyant and more precise compared to propane diffusion flame
- 50 second flame impingement provides good repeatability, more distinction between ACF1 and other materials
- Hood exit flow measurements were made, indicate that the only flow through the chamber results from the natural convection, not the overhead exhaust system
- 3 units were constructed and are currently being tested with a variety of materials, thicknesses to show repeatability. All three units will be tested in two different laboratories to show reproducibility
- Apparatus drawings are about 75% complete, will be available on website
- Repeatable composite materials are sought for refinement of test parameters





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