Vertical Flame Propagation (VFP)

Presented to: International Aircraft Material Fire Test Forum Webinar

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Date: June 9th, 2020

Federal Aviation Administration

Ground Rules for Webinars and Zoom Meetings

Webinar:

Please use the Q & A button to ask questions. We will try to address them as they come in, but may answer at the end

Task Group Zoom:

Everyone PLEASE go on mute

Use raised hand feature (under participants button) to ask a question

A panelist will call on participant to ask their question, as time permits

Once question has been answered, click raised hand to “un-raise”

Vertical Flame Propagation (VFP)

Objective

- Proposed new test method for non-metallic, extensively used materials located in ***inaccessible areas***, i.e.:
- Composite skin, structure, and sub-components
- Wires (insulations/jackets/sleeving)
- Duct materials
- Other, tbd

What is it?

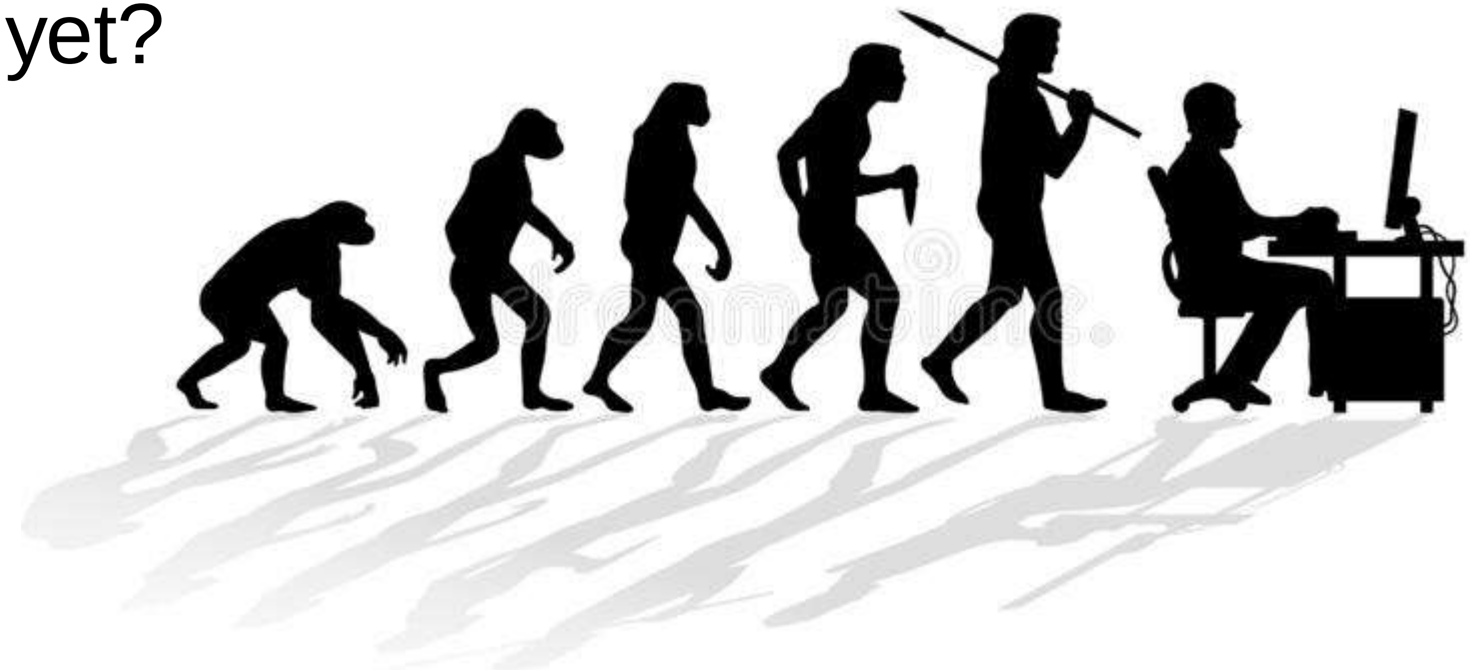
- A way of evaluating the performance of a material against a realistic fire threat using a line burner and radiant heat source.

Topics

Where were we?

Where are we?

Are we there yet?



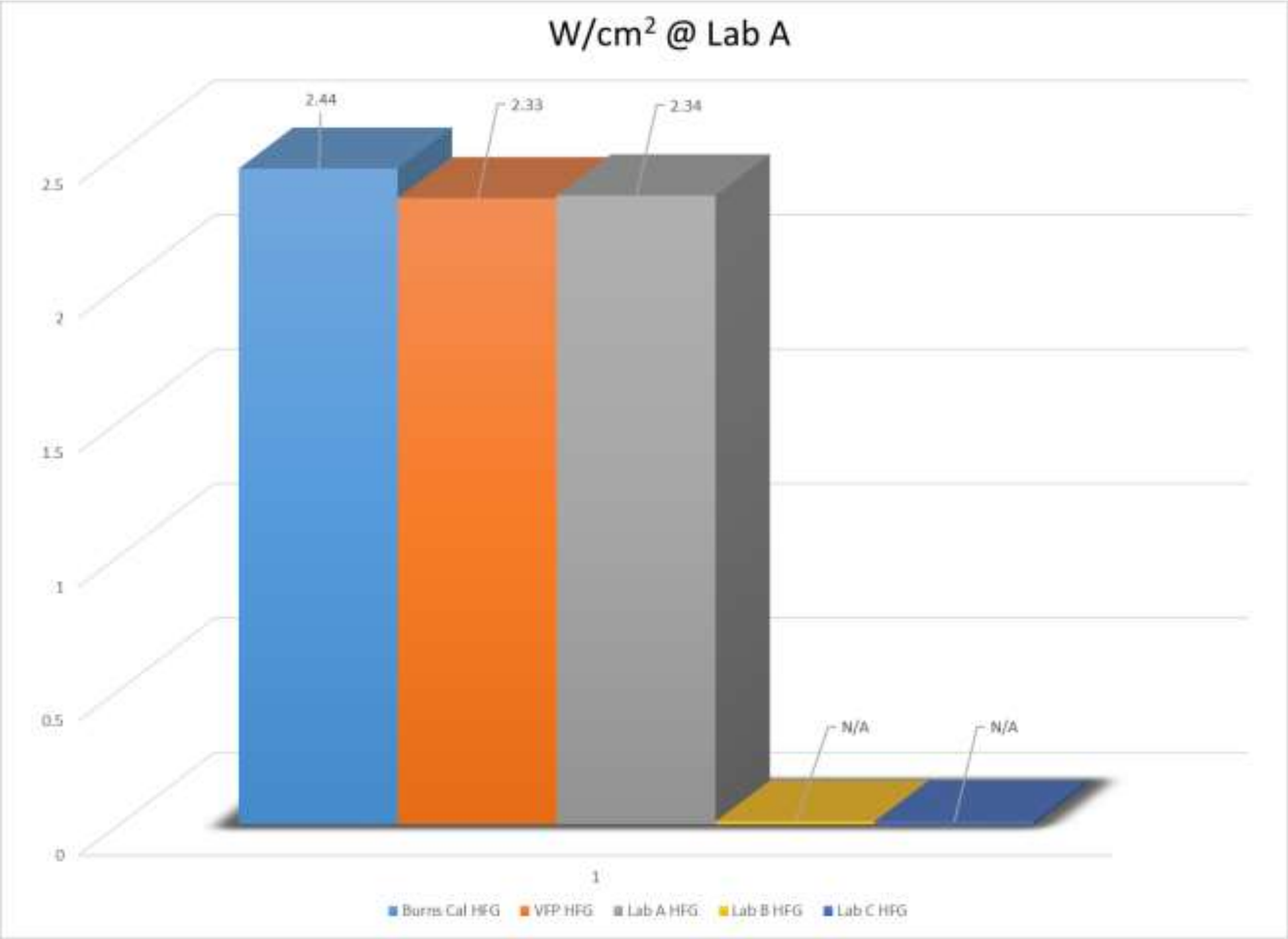
Where were we?

- **Varying diameters of ducts and their results**
  - Flat vs round
  - Varying thicknesses
- **Wire background**
- **Heater uniformity**
  - Different manufacturers = varying heat output per watt
  - Supply voltage
- **Heat flux**
  - Could HFG's resolve design and power differences

Where are we?

- **Interlab study of HFG’s**
  - 4 labs, 5 gauges
  - Set power to host gauge (reference)
  - Compared all other gauges (working)
- **Goals**
  - Determine the variability among HFG’s
  - Use this deviation to evaluate HFG reliability

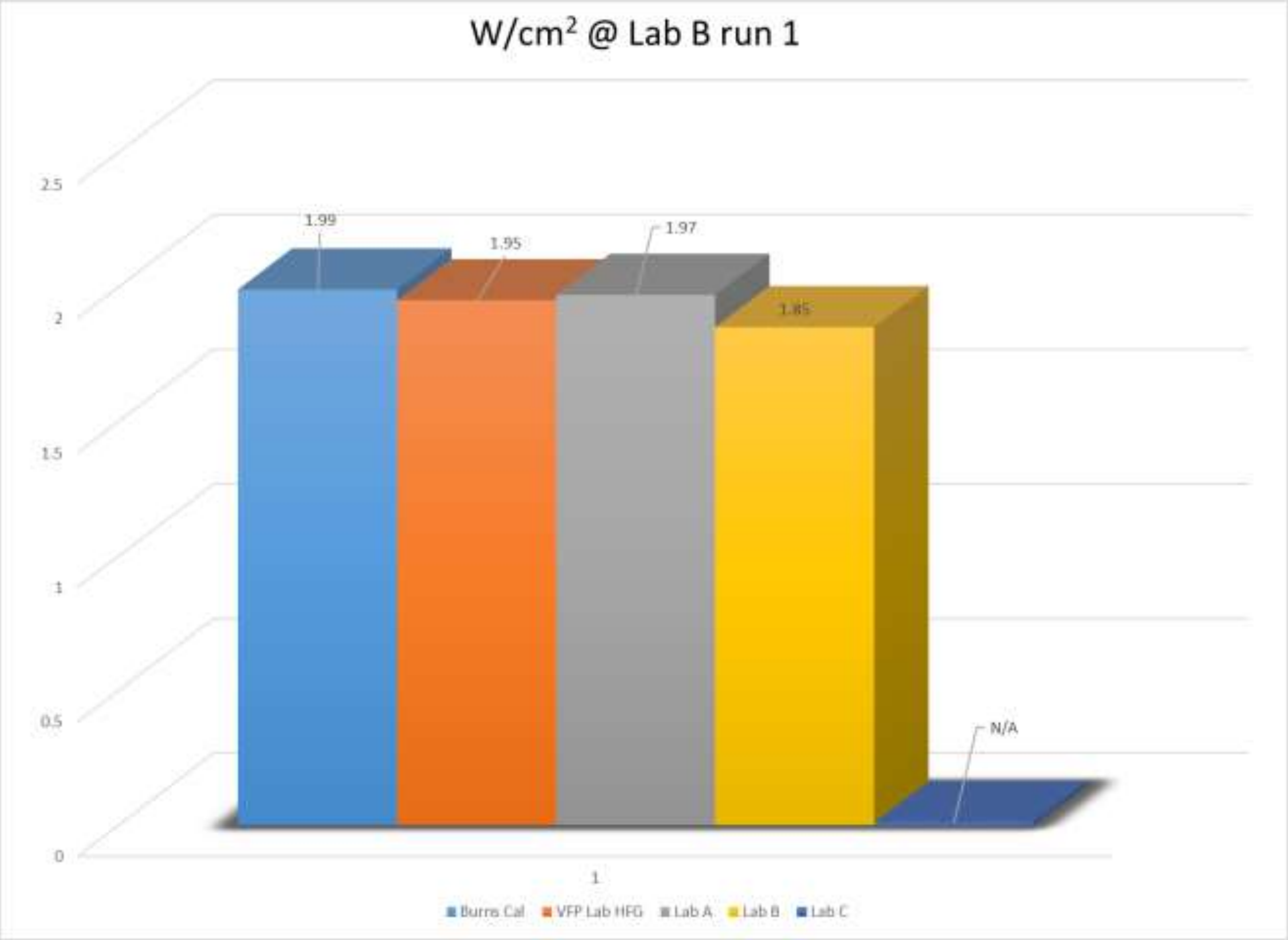
HFG Comparison



HFG Comparisons	Δ w/cm^2	max Δ w/cm^2
VFP Lab vs Burns Cal	-0.11	0.11
Lab A vs Burns Cal	-0.1	
Lab B vs Burns Cal		
Lab C vs Burns Cal		

- **St dev: 0.061**
- **% st dev: 2.57**
- **Set to power, not to heat flux. That update had not yet been installed to unit***

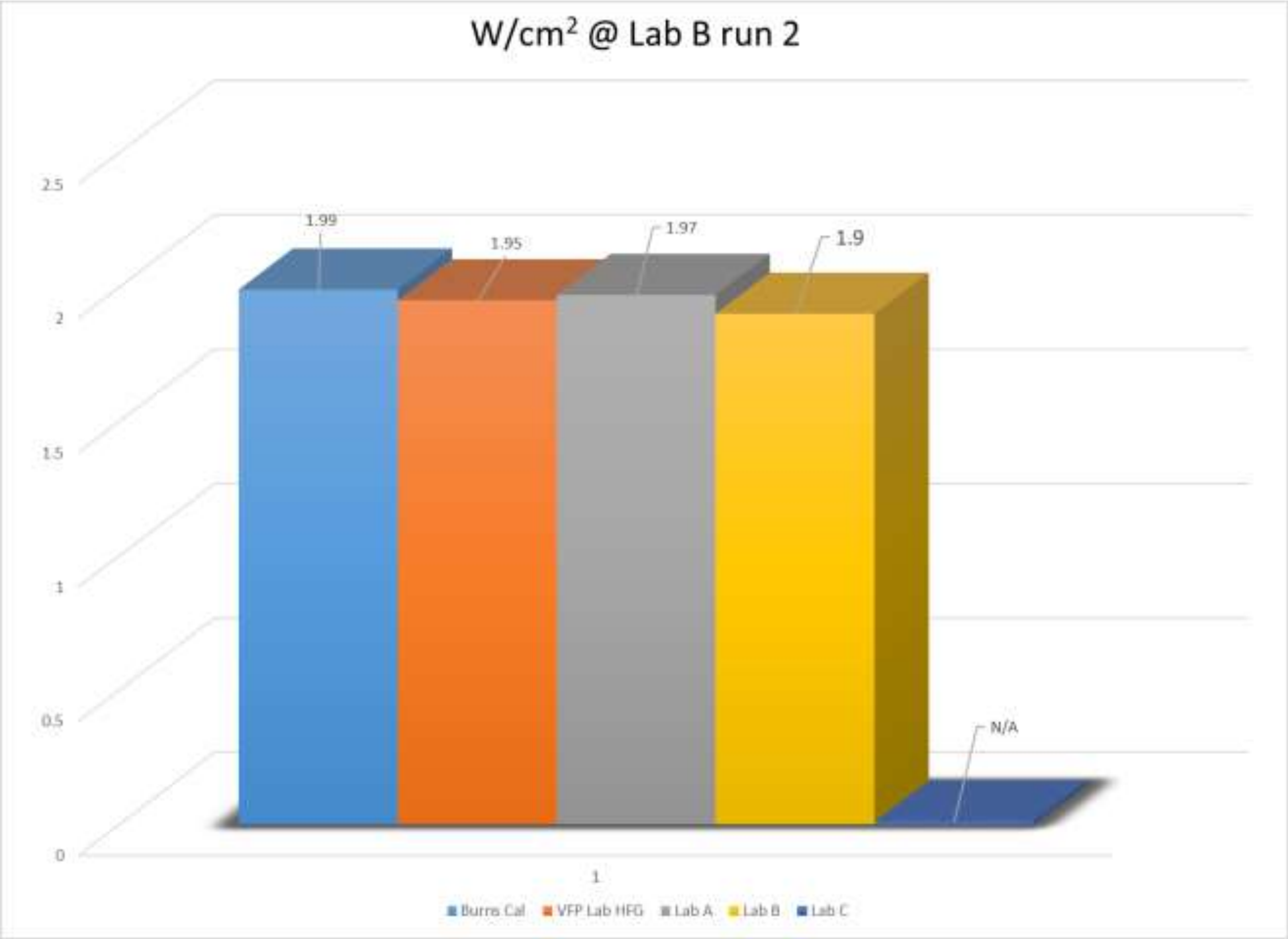
HFG Comparison



HFG Comparisons	Δ w/cm²		max Δ w/cm²
VFP Lab vs Burns Cal	-0.04		
Lab A vs Burns Cal	-0.02		
Lab B vs Burns Cal	-0.14		0.14
Lab C vs Burns Cal			

- **St dev: 0.057**
- **% st dev: 2.937**

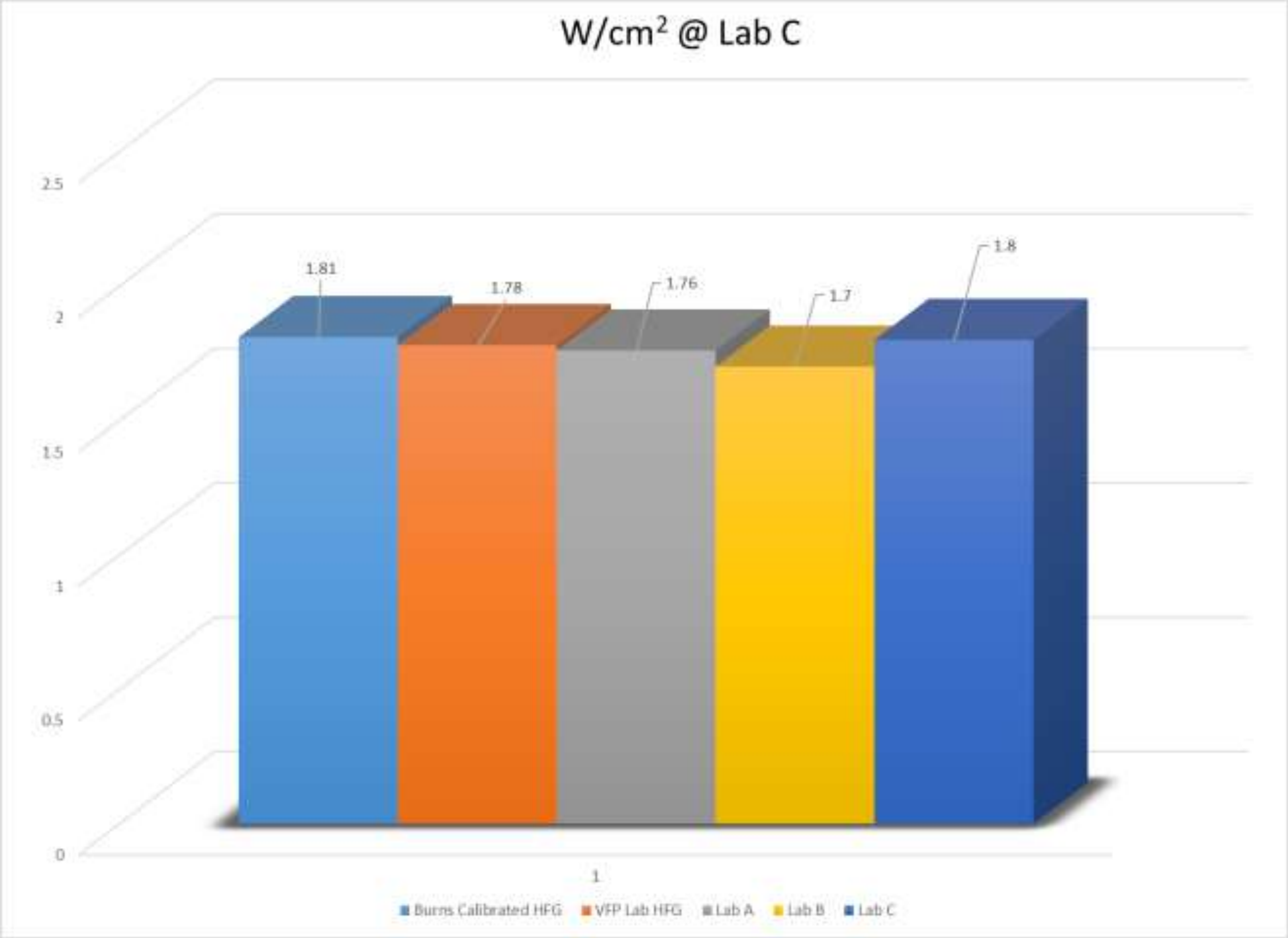
HFG Comparison



HFG Comparisons	Δ w/cm^2		max Δ w/cm^2
VFP Lab vs Burns Cal	-0.04		
Lab A vs Burns Cal	-0.02		
Lab B vs Burns Cal	-0.09		-0.09
Lab C vs Burns Cal			

- **St dev: 0.039**
- **% st dev: 1.98**

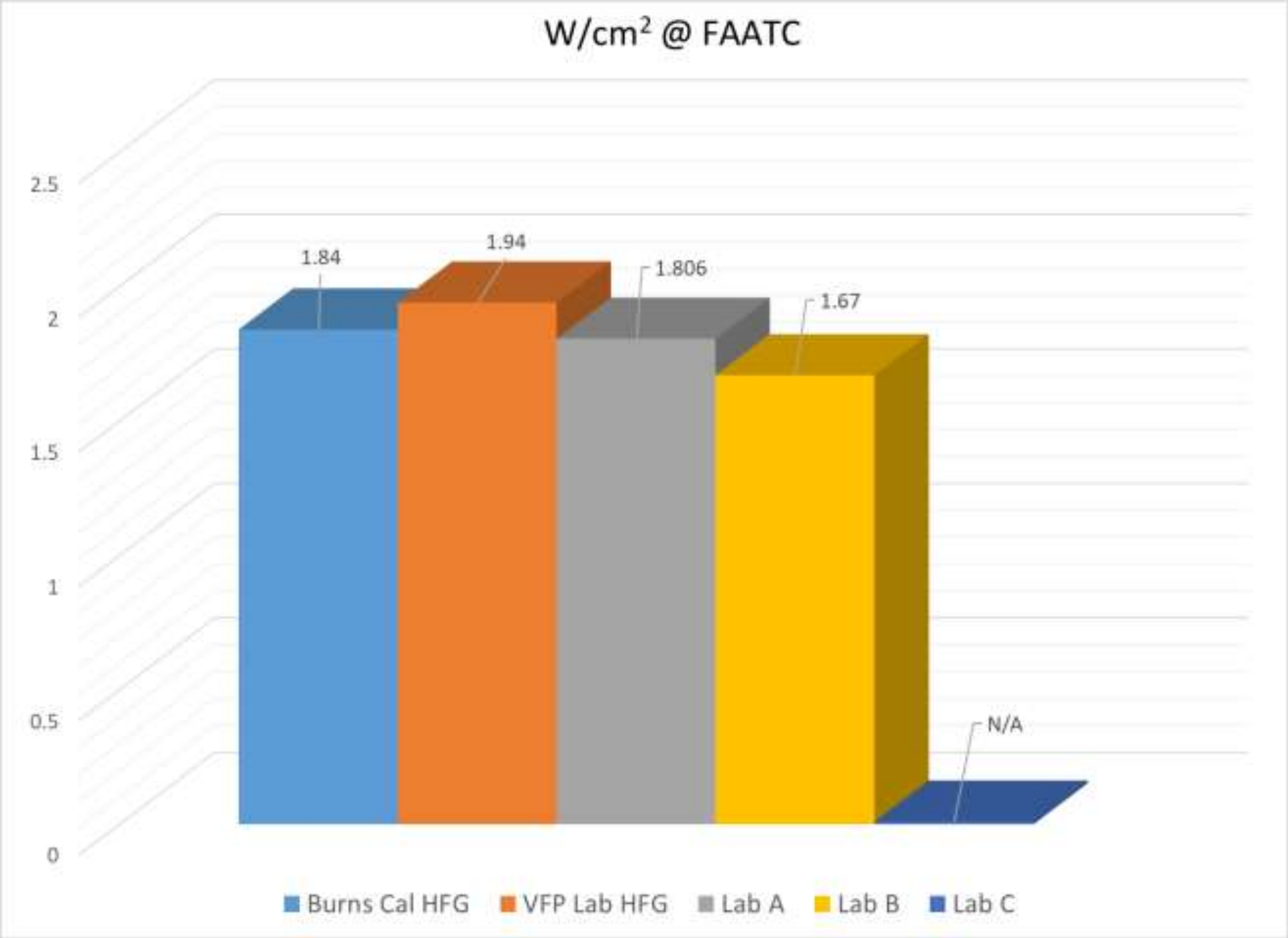
HFG Comparison



HFG Comparisons	Δ w/cm^2		max Δ w/cm^2
VFP Lab vs Burns Cal	-0.03		
Lab A vs Burns Cal	-0.05		
Lab B vs Burns Cal	-0.11		0.11
Lab C vs Burns Cal	-0.01		

- **St dev: 0.044**
- **% st dev: 2.463**

HFG Comparison



HFG Comparisons	Δ w/cm^2		max Δ w/cm^2
VFP Lab vs Burns Cal	0.1		
Lab A vs Burns Cal	-0.034		
Lab B vs Burns Cal	-0.17		0.17
Lab C vs Burns Cal			

- **St dev: 0.112**
- **% st dev: 2.566**

Conclusions

1. **Did we determine the variability of HFG's?**
   - Most gauges varied 0.03-0.1 w/cm^2
   - One gauge varied .11-.17 w/cm^2
2. **Will HFG be reliable going forward?**
   - Determine effect on burn length of these variances
   - Visit HFG manufacturer to discuss calibrations

Baseline Material Assessment

Avg Burn Length	Std Dev.	% Std Dev.
2.28”	0.23”	10.12

- **Series of tests conducted on an aircraft grade CFRP, 1/8” thick**
- **10 tests**
- **Strict 1.8 watts/cm^2**
- **Room temp 71^{o}F**

Experiment Set up

Factor	(-) Low Level	(+) High Level
Heat Flux (Watts/cm2)	1.7	1.9
Room Temp (F)	65	75

Experiment

Standard Order	Heat Flux	Room Temp	Randomize	Actual Heat Flux	Burn Length	After Flame	Room Temp	% RH	Back Wall Thermocouple Pre Test	Watts Before Test	Watts After Test
3	1.7	75	0.010730819								
9	1.7	65	0.161017441								
8	1.9	65	0.244162765								
11	1.7	75	0.363605551								
6	1.9	75	0.533051687								
4	1.9	65	0.545988063								
5	1.7	65	0.659694949								
1	1.7	65	0.663592607								
12	1.9	65	0.734122903								
10	1.9	75	0.804076379								
2	1.9	75	0.812019225								
7	1.7	75	0.866090654								

Effect on Burn Length

Experiment #1: Heat Flux (±0.2), Chamber Temp

Variable	Low	High	Avg. Effect on BL
Heat Flux (w/cm^2)	1.6	2.0	0.96”
Chamber Temp (^oC)	50	70	0.07”

Baseline St Dev
0.23”

Effect on Burn Length

Experiment #2: Heat Flux (±0.1), Room Temp

Variable	Low	High	Avg. Effect on BL
Heat Flux (w/cm2)	1.7	1.9	0.32”
Room Temp (^{o}C)	18.3	23.9	0.42”

Baseline St Dev
0.23”

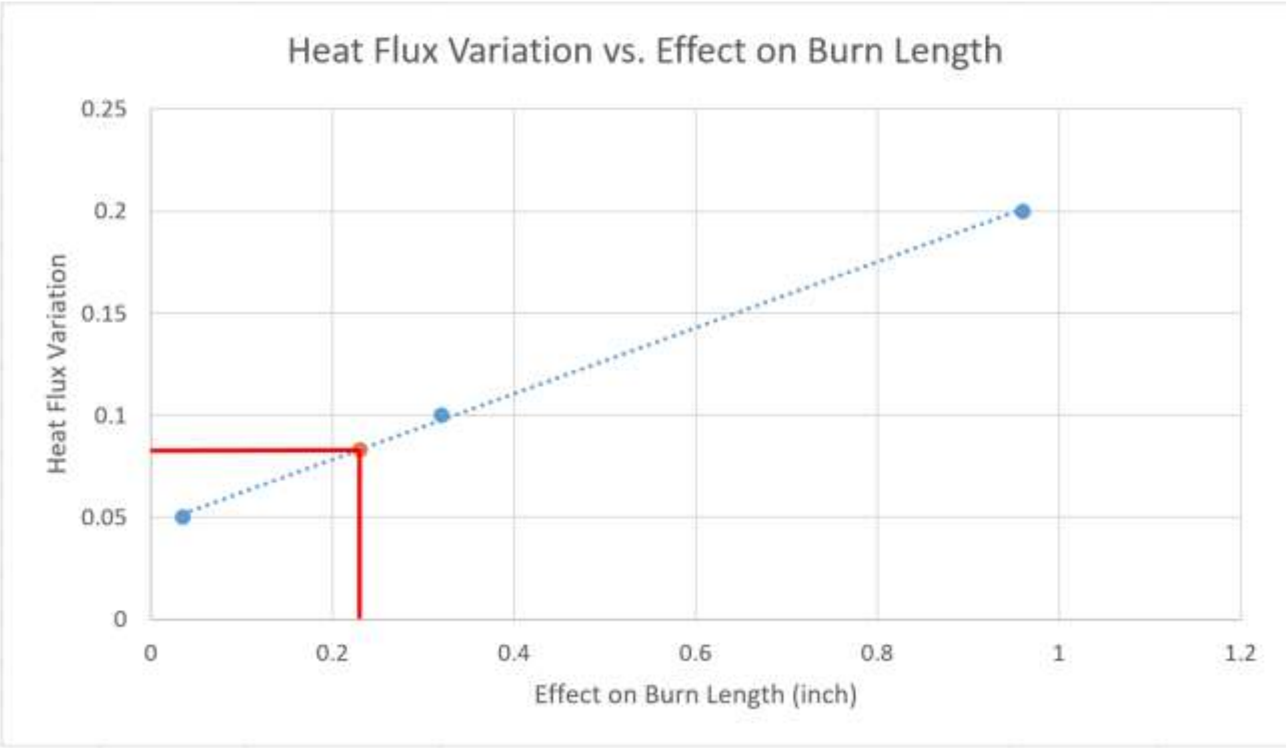
Effect on Burn Length

Experiment #3: Heat Flux (±0.05), Room Temp

Variable	Low	High	Avg. Effect on BL
Heat Flux (w/cm2)	1.75	1.85	0.04”
Room Temp (^{o}C)	19.4	22.8	0.002”

Baseline St Dev
0.23”

Conclusion



- Relationship between heat flux variation and the effect on burnlength
- 3 ranges shown
- Max heat flux variation < stdv of this material

Are we there yet?

Not. Quite. Yet.

- **The task group in March discussed and agreed upon a heat flux calibration tolerance of +/-0.05 w/cm2**
- **Also agreed to install a t/c to monitor inlet air**
- **Establish new air flow measurement using hood adapters**
- **Still need to open a dialog with HFG manufacturers to discuss calibrations**
- **Start Interlab Composite Testing**
- **Simultaneously continue ducting materials & wires**

Interlab Study (Round Robin I)

Please perform this Pre-Test Procedure before continuing onto the next sections.

Pre -Test Procedure

1. Place refractory board in sample holder to retain heat in the VFP chamber.

2. Confirm the distance from the heater coil to the inner vertical edge of the sample frame is 3 inches. Confirm the distance of the ribbon burner face to the inner vertical edge of the sample frame is 1/2 inch.

3. Check your mass flow controller's calibration sheet. To what pressure and temperature are your mass flow controllers calibrated to? Please note these values in the box to the right. If they are calibrated to 14.7 PSIA and 25°C (298 K) please use values 3.6 slpm air to 0.66 slpm methane for your air/fuel values. If they are not calibrated to 14.7 PSIA and 25°C use the calculated values shown to the right. (Please enter the units in Kelvin and PSIA to calculate properly).
   a. Refer to MFC calculation sheet in this Excel file for the full calculation if you're curious. This was taken from the VFP presentation in October of 2018.

4. Turn on radiant heater. Set wattage to an approximate value that will acheive 1.8 W/cm^2. No heat flux gauge is used at this point, just an estimated wattage.

5. Wait 1 hour for the chamber to stabilize.

6. Record air intake temperature. This value should be 70±3 degrees F. The temperature should be taken with a thermocouple placed XX inches below the VFP's air intake grate, centered. This image is shown in Figure 1 to the right.

7. Place refractory board holding the heat flux gauge in the sample holder. The heat flux gauge is to be placed so that it is centered with the radiant heater. Record heat flux data until the value stabilizes to 1.8 Watts/cm2 +/- 0.05 for an average of 5 minutes. Save this calibration and lock in the correlating wattage.

8. Remove heat flux gauge and replace with refractory board in the sample holder.

9. Ignite the ribbon burner and move it into the test position.

10. Place the anemometer cone on top of the VFP's exhaust. Attach the vane anemometer to this cone and measure the air speed exiting the VFP (OR ITS AIR FLOW VOLUME NOW?). Do this with your lab's exhaust fan off and again with the lab's fan on. Record these values in the table shown to the right. Return the ribbon burner to standby position.

11. You may now continue to Test Procedure.

Pre-Test Information

Mass Flow Controllers	
To what Pressure and Temperature are your MFC's calibrated to?	
Pressure (PSIA)	
Temperature (K)	
If your MFC ARE calibrated to 14.7 PSI and 298 K, use these values:	
Air (slpm)	3.6
Methane (slpm)	0.66
If your MFC are NOT calibrated to 14.7 PSI and 298 K, use these values:	
Air (slpm)	#DIV/0!
Methane (slpm)	#DIV/0!

Heat Flux
Final Heat Flux on a 5 minute Average

Exhaust Air Speed	
Lab Fan Exhaust Off	Lab Fan Exhaust On
Ignitor and Furnace On	Ignitor and Furnace On

Interlab Study

Test Procedure

1. Perform a new heat flux calibration as described in the Pre-Test Procedure for each batch of 10 samples. Print and submit this data for each sample set.

2. Initiate flow of premixed methane to air mixture to ribbon burner.

3. Ignite ribbon burner.

4. Go to the sheet of the material you're working on. Record in the given cells the current power output (Watts) of the unit and the internal chamber temperature (C), and your calibrated heat flux.

5. Open outer door.

6. Open sample door.

7. Secure test sample in sample holder with the face to be tested toward the radiant heater. The sample door is still open and away from the radiant heater now.

8. Push ribbon burner into test position.

9. Reset stopwatch to zero and prepare to start timing upon sample door closing.

10. Close sample door, begin stopwatch count.

11. Close outer door to protect user.

12. Pull the ribbon burner away from the sample and back into the standby position at a 30 second impingement time. Do not stop the timer yet.

13. Monitor sample flame propagation via viewing windows or video monitor.

14. Stop timer when all flaming on sample surface ceases.

15. Record after flame time as the time at extinguishment minus the flame impingement time (30 seconds).

16. Open door, remove sample and place under fume hood until off-gassing ceases.

17. Return refractory board into test sample holder.

18. Measure and record burn length (inch).

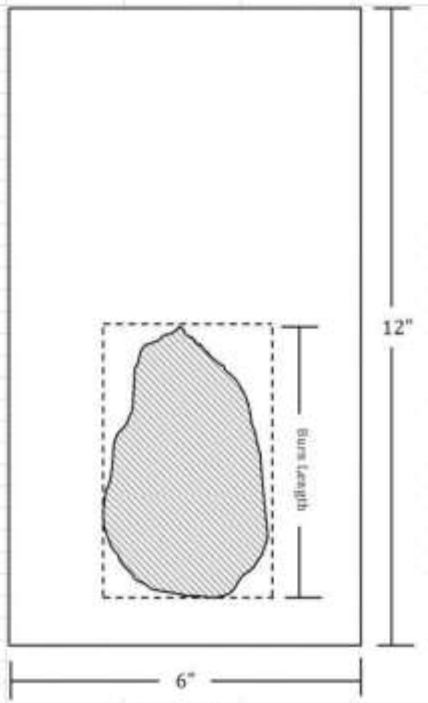


Figure 2

Interlab Study

1	Material A - 1/4 inch Thick				
2	Before Testing the First Sample, Record:				
3		**Internal Chamber Temperature**			
4		**Power of Heater**			
5		**Heat Flux**			
6	Is the distance of the ribbon burner face to the inner vertical edge of the sample frame 1/2 inch?				
7	Is the distance of the heater coil to the inner vertical edge of the sample frame 3 inches?				
8	**Sample**	**After Flame (sec)**	**Burn Length (inch)**	**Power of Heater Before Test (Watts)**	**Internal Chamber Temperature Before Test (C)**
9	A1				
10	A2				
11	A3				
12	A4				
13	A5				
14	A6				
15	A7				
16	A8				
17	A9				
18	A10				
19					

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Questions