Radiant Panel Insulation Test Update

Presented to: International Aircraft Materials Fire Test Forum
By: Steve Rehn
Date: 10/29/2018

Introduction

- **Handbook update**
  - Updated June 2018
- **Electric Panel aging testing**
  - Panel runs hotter as it ages, can affect test results
  - Need “borderline” material to test
- **Future Work**

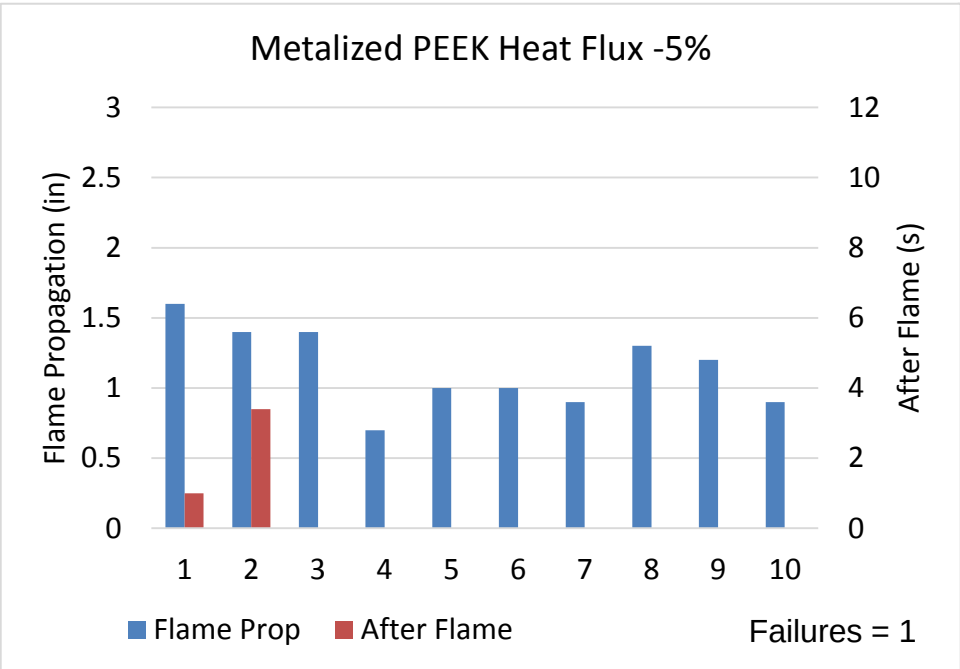
Handbook changes

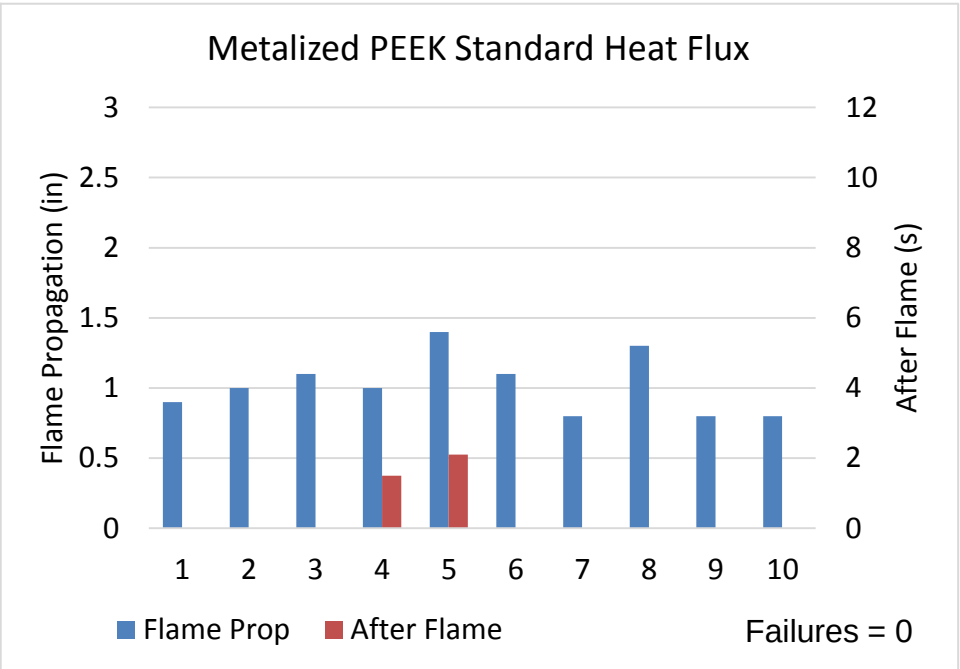
- **Replaced Superwool 607 with Superwool Plus**
  - All references say “refractory board” with a recommendation of Superwool Plus at the beginning
- **Reduced ±5% error on heat flux to ±1% on Zero Position (P1 and P2 remain ±5%)**
  - Previous results showed more failures with certain materials at 5% higher heat flux
  - Asked task group in June to check with their lab to see if this would be a problem

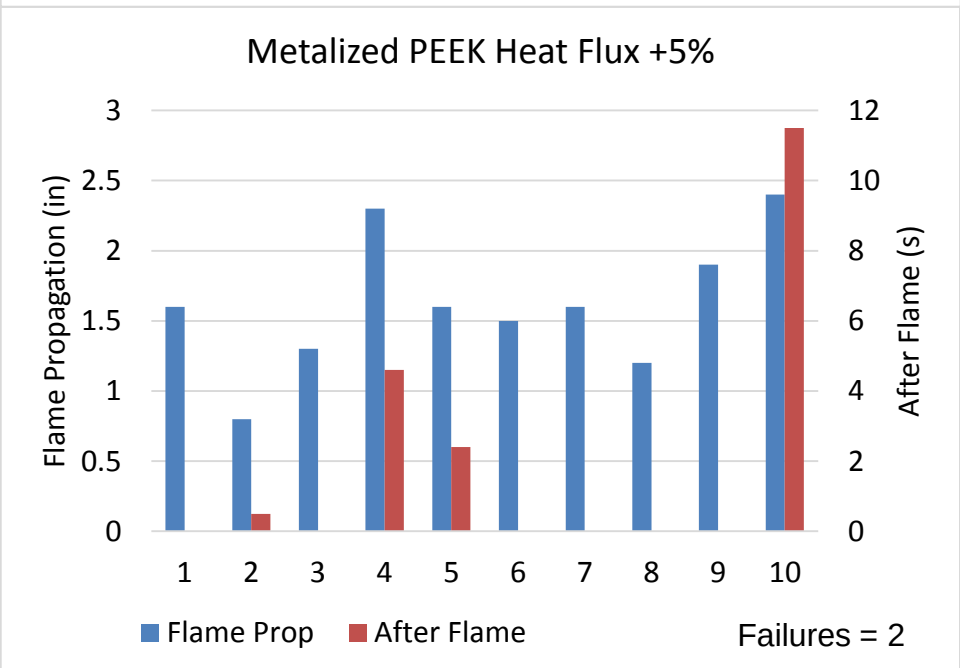
±5% Heat Flux Testing

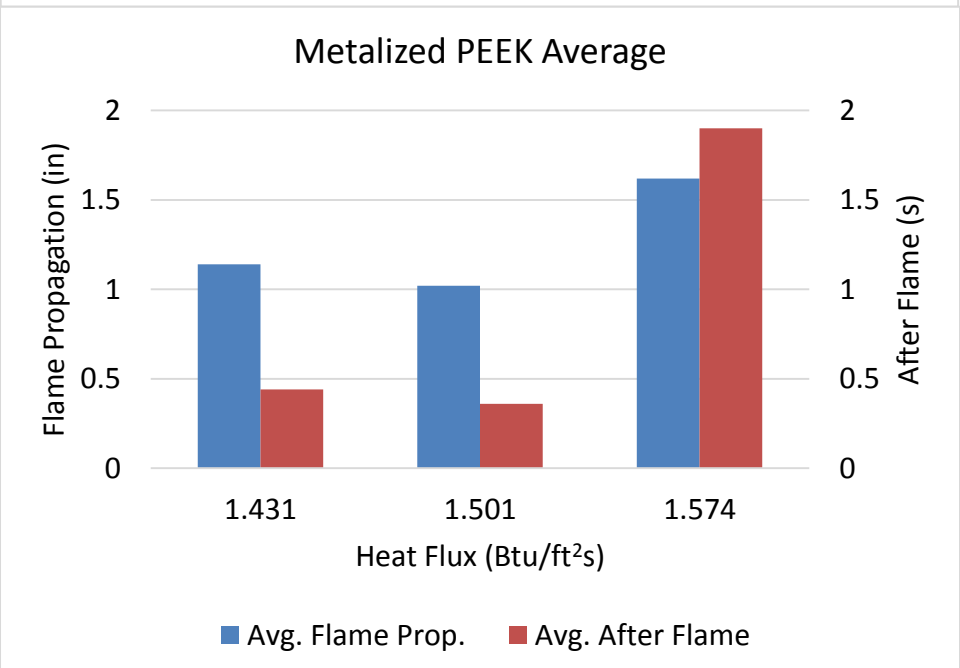
- **Test insulation samples at standard heat flux compared to +5% and -5%**

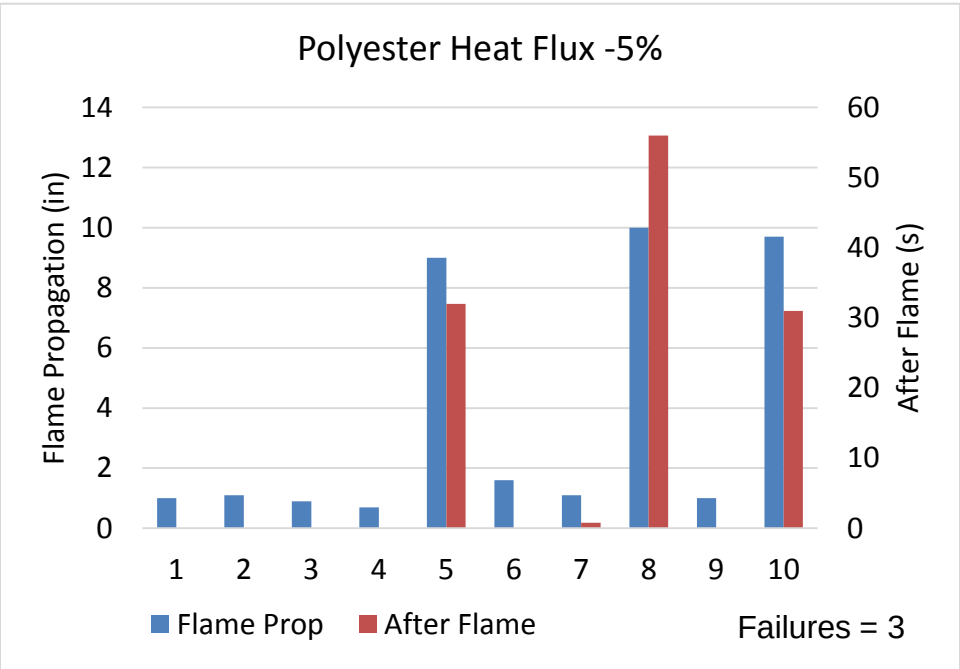
Heat Flux	US	Metric
Standard	1.500 Btu/ft^{2}s	1.700 W/cm^2
+5%	1.575 Btu/ft^{2}s	1.785 W/cm^2
-5%	1.425 Btu/ft^{2}s	1.615 W/cm^2

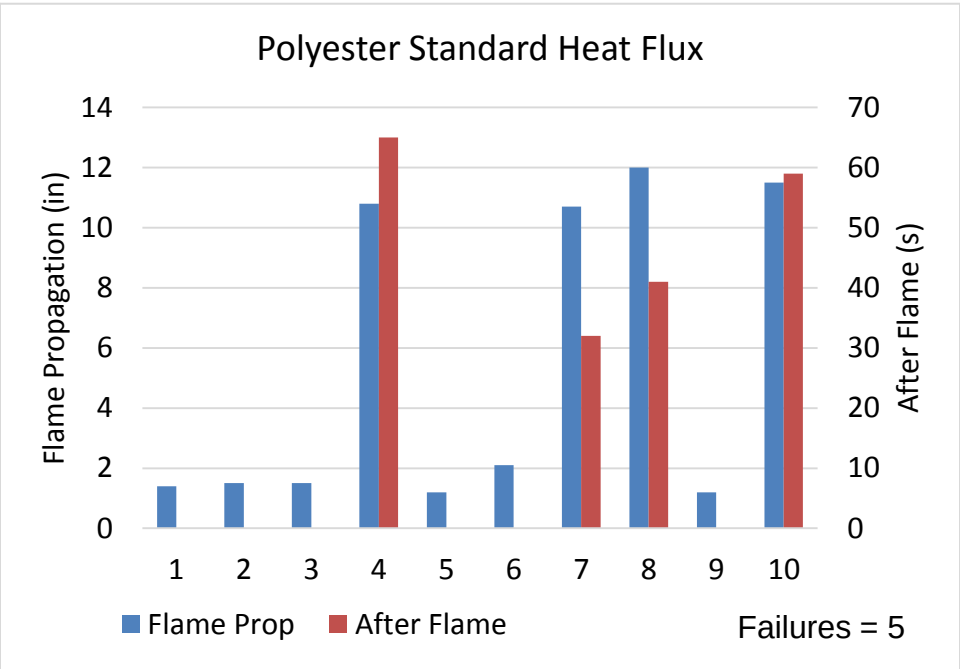

Metalized PEEK Heat Flux -5%
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 1

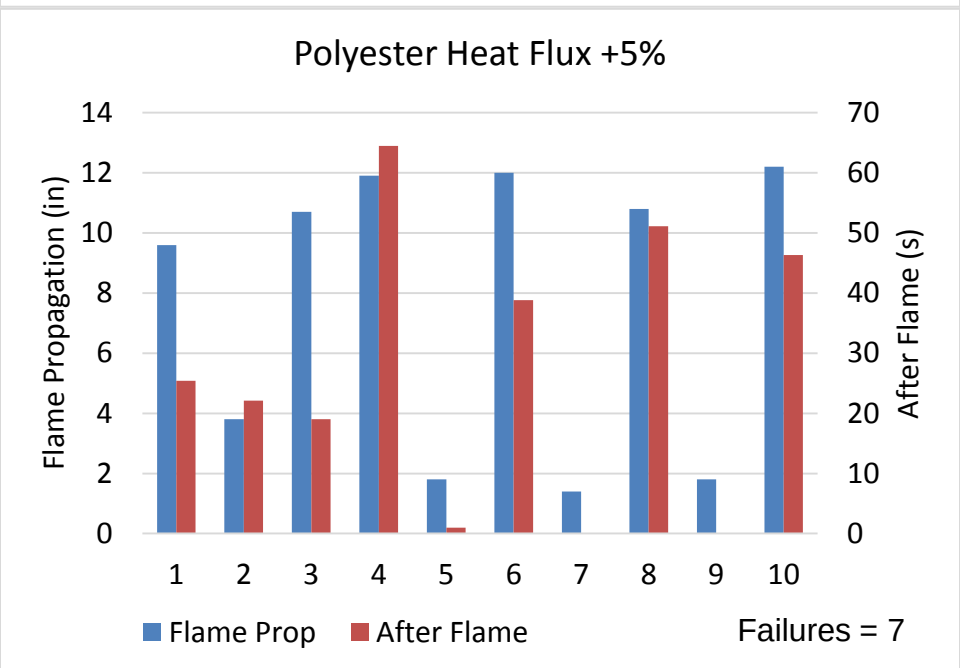

Metalized PEEK Standard Heat Flux
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 0

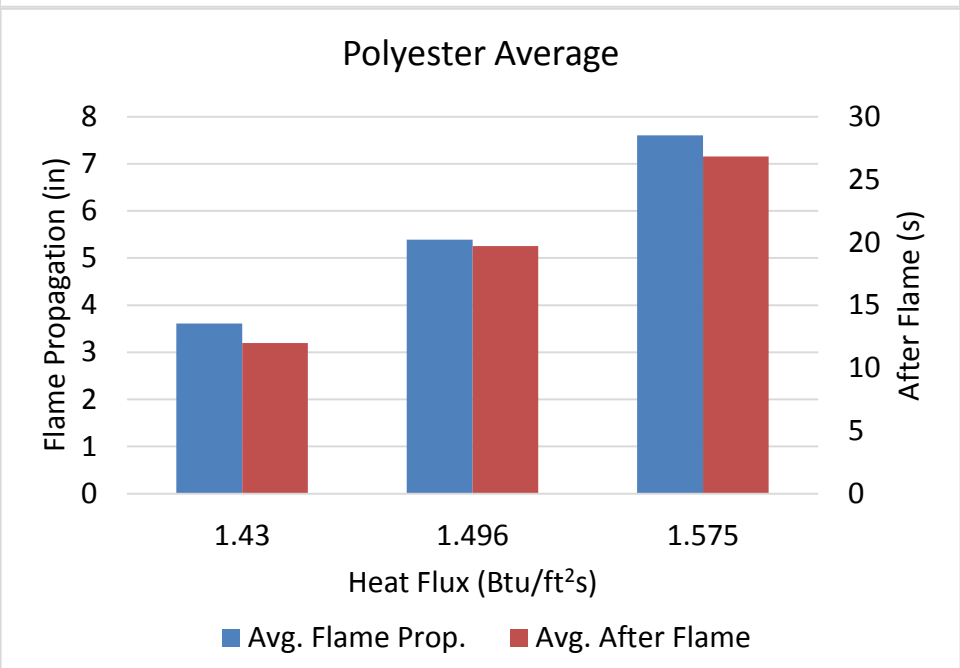

Metalized PEEK Heat Flux +5%
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 2


Metalized PEEK Average
Flame Propagation (in)
After Flame (s)
1.431
1.501
1.574
Heat Flux (Btu/ft²s)
Avg. Flame Prop.
Avg. After Flame


Polyester Heat Flux -5%
Flame Propagation (in)
After Flame (s)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
1
2
3
4
5
6
7
8
9
10
Flame Prop
After Flame
Failures = 3


Polyester Standard Heat Flux
Flame Propagation (in)
After Flame (s)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
Flame Prop
After Flame
Failures = 5

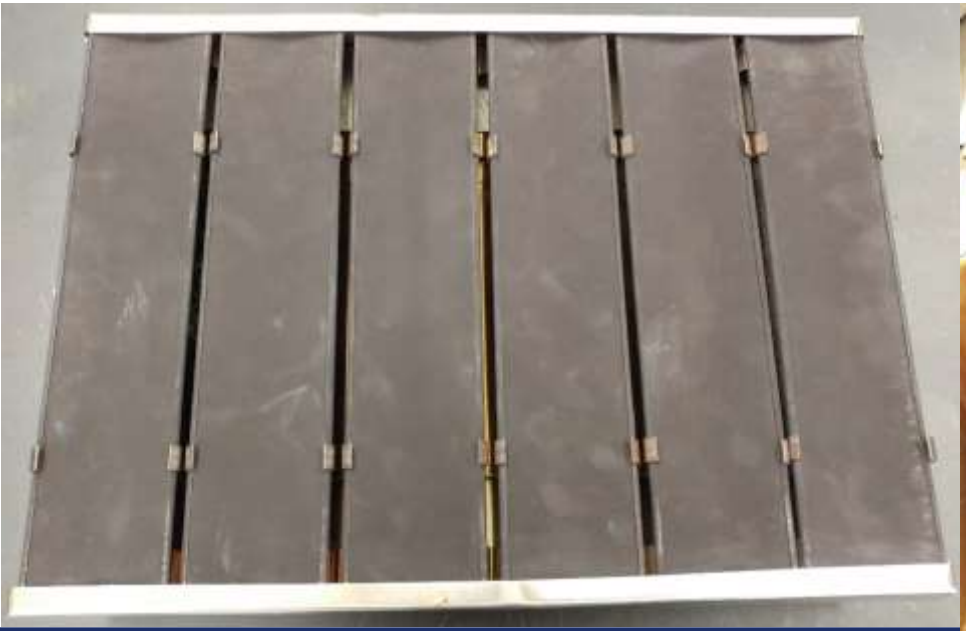

Polyester Heat Flux +5%
Flame Propagation (in)
After Flame (s)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
Flame Prop
After Flame
Failures = 7


Polyester Average
Flame Propagation (in)
After Flame (s)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
30
1.43
1.496
1.575
Heat Flux (Btu/ft²s)
Avg. Flame Prop.
Avg. After Flame

Radiant Panel Aging

- **Temperature set point steadily increases to obtain same heat flux as panel ages – eventually leads to more material failures**
- **Biggest difference seems to be black paint on surface**
- **Need to find out what changes in the panel to make it run hotter**
- **Need to add guidance about when to replace electric panel**

New Panel



Old Panel

Radiant Panel Aging

- Condition likely depends on amount of use and types of materials tested

Radiant Panel Aging

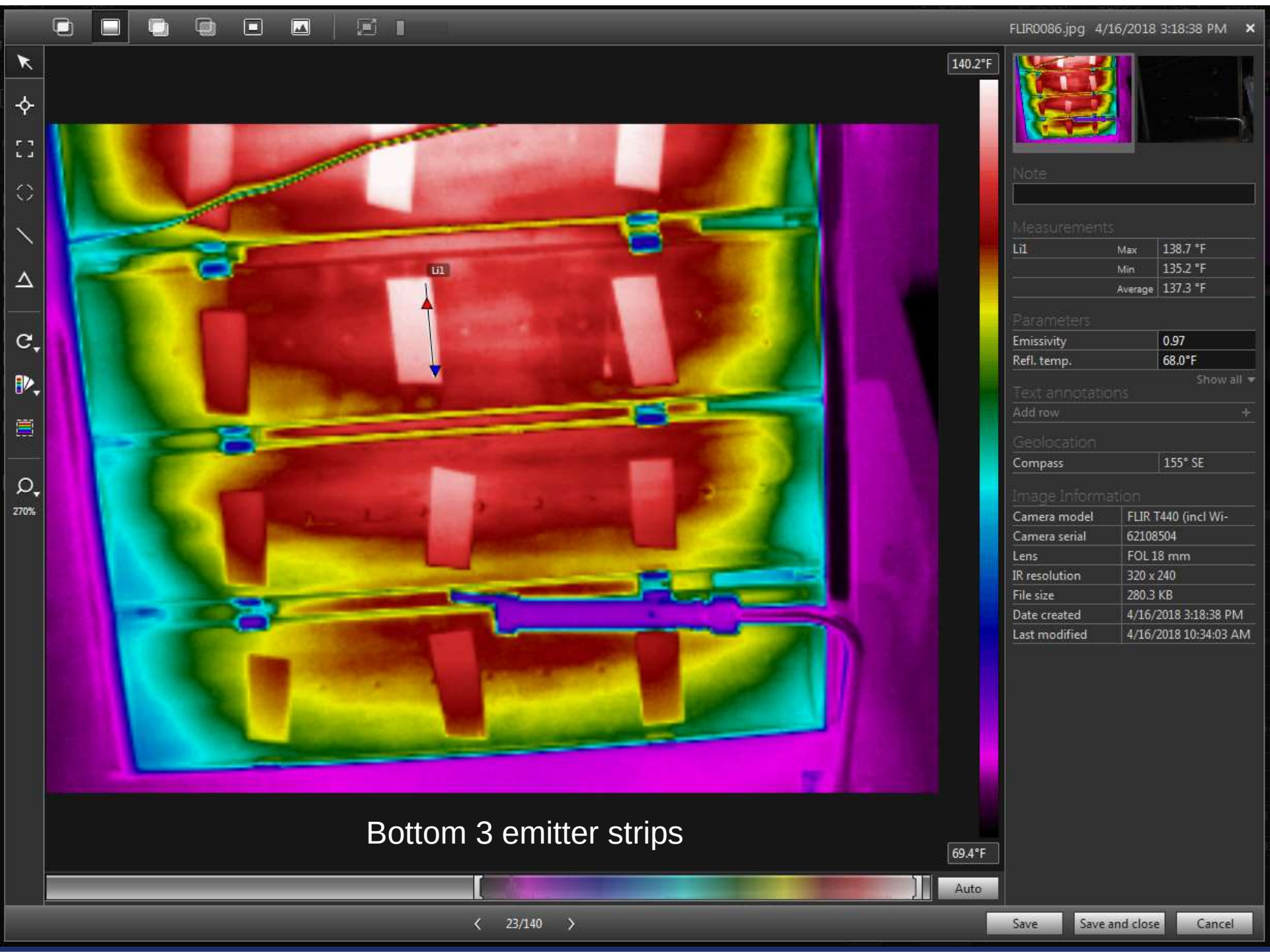
- **Test 7 electric panels**
  - 2 brand new, 1 in use, 4 old out of use
- **Panel set point**
- **3-position calibration check**
- **Measure emissivity of panel surface**
- **Measure internal resistance**
- **Measure power**
- **Measure temperature at sample surface**
- **Material testing**

Material Problems

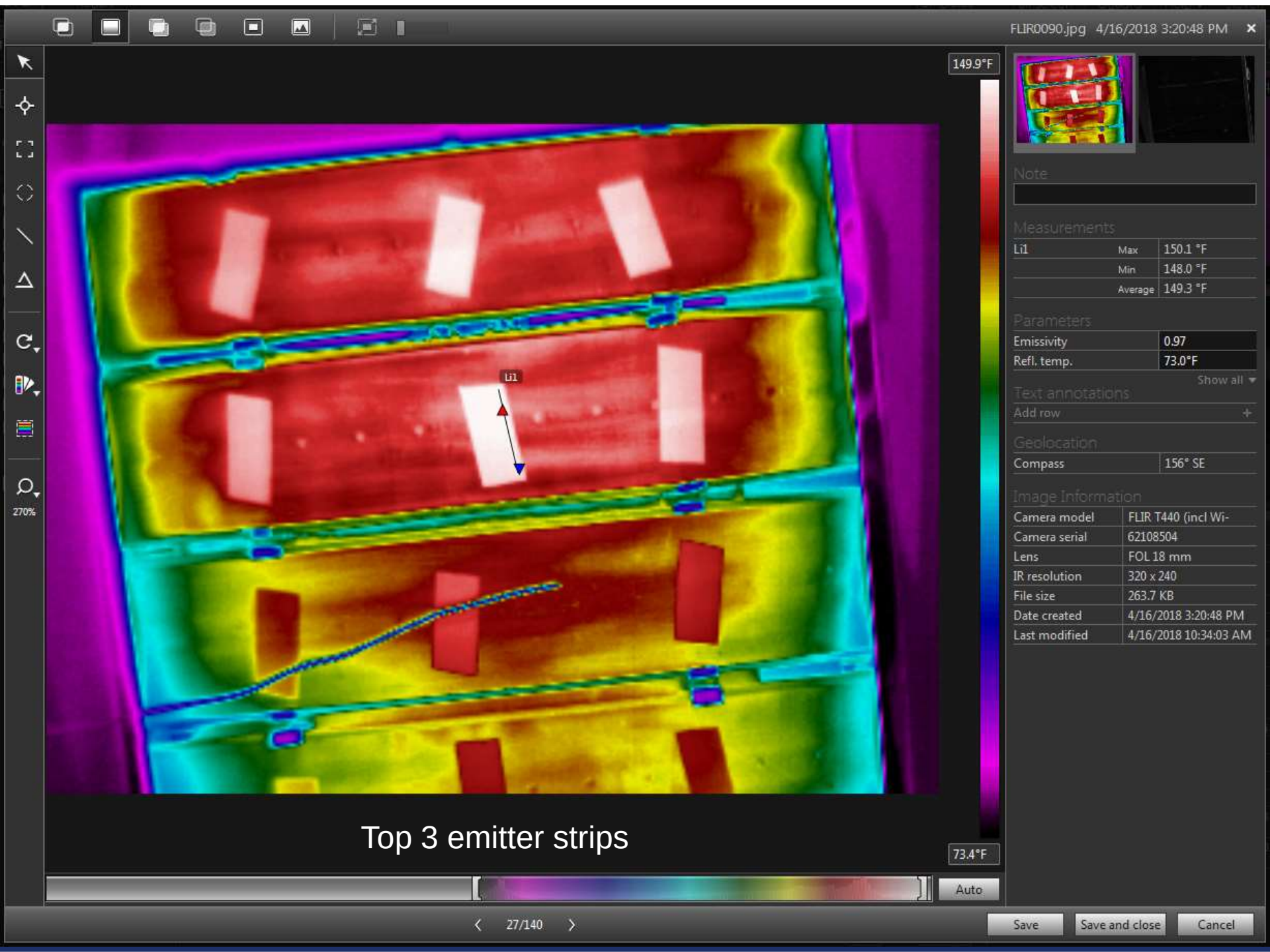
- **Received two new metalized PEEK materials**
- **From manufacturer:**
  - 50% Top Coat: 1 out of 6 failed
  - 0% Top Coat: 4 out of 6 failed
  - All failures had >10 after flame and >4 in. flame prop.
- **FAA passed all samples**
  - Increased heat flux, replaced panel, ignitor, and calorimeter and everything still passed
- **Third party lab**
  - Passed all but one sample with 50% top coat
- **Doesn't help with aging study, but potentially gives us something else to study to determine what is causing the difference**

Radiant Panel Emissivity

- **Infrared camera: FLIR T440**
- **320 × 240 Infrared resolution**
- **Place electrical tape (18 pieces) on panel and assume temperature of electrical tape equals temperature of panel surface**
- **Assume electrical tape emissivity (ε) = 0.97**
- **Maximum safe electrical tape temperature = 176°F**
- **Set Panel set point to 120°F**
  - Very low compared to testing conditions (normally ~1080°F)
- **Compare measured temperature of panel surface and tape to calculate emissivity of panel surface**
- **18 points of measurement**



Bottom 3 emitter strips



Top 3 emitter strips

Radiant Panel Emissivity

- **Q**$= \varepsilon\sigma(T_m^4 - T_s^4)$
  - Q = Radiative Flux (W/m^2)
  - ε = Emissivity
  - σ = Stefan-Boltzmann Constant (5.67×10^{-8} W/m^{2}K^4)
  - T_m = Measured Temperature (K)
  - T_s = Surrounding Temperature (K)
- **Q at set emissivity (0.97) and measured temperature = Q at actual temperature (tape temperature) and actual emissivity**
- $\varepsilon_m\left(T_m^4 - T_s^4\right) = \varepsilon_{actual}\left(T_a^4 - T_s^4\right)$
- $$\boxed{\varepsilon_a = \frac{\varepsilon_m\left(T_m^4 - T_s^4\right)}{\left(T_a^4 - T_s^4\right)}}$$

Radiant Panel Emissivity

	Left	Center	Right
Emitter Strip 1 (bottom)	0.880	0.876	0.858
Emitter Strip 2	0.899	0.891	0.900
Emitter Strip 3	0.882	0.887	0.872
Emitter Strip 4	0.893	0.883	0.878
Emitter Strip 5	0.885	0.859	0.871
Emitter Strip 6 (top)	0.896	0.873	0.864

Average Emissivity = 0.880
Standard Deviation = 0.012 (1.36%)

Radiant Panel Emissivity

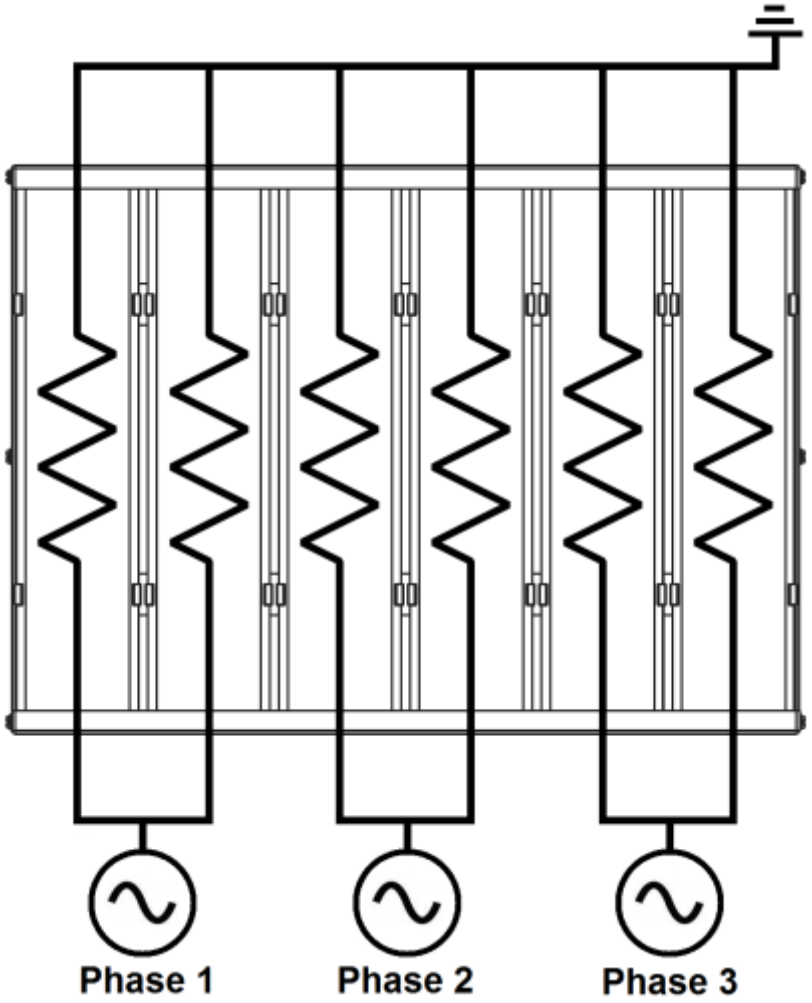
- **Have not measured other panels yet**
- **Did not have suitable material to test at same time**
- **Perfect mirror has emissivity of 0**
- **Perfect “black body” has emissivity of 1**
- **Color has little effect on emissivity, biggest effect is reflexivity**

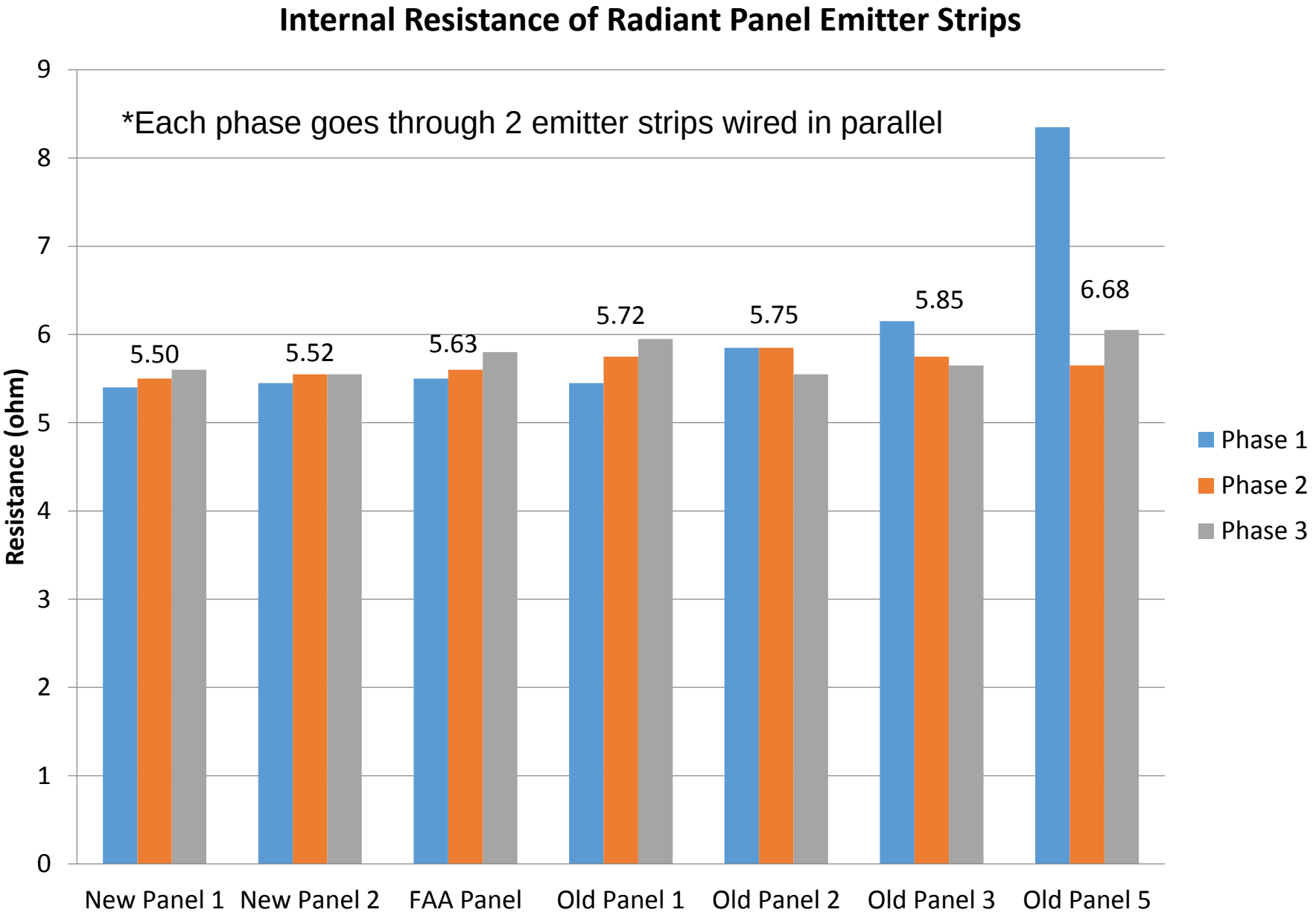
Radiant Panel Resistance

- **Electric radiant panel consists of 6 emitter strips**
- **Runs on 208V 3-Phase power**
- **Rated at 7574 Watts**
- **Does the internal resistance of the emitter strips change over time and does that affect test results?**

Radiant Panel Resistance

- Each electrical phase feeds two emitter strips wired in parallel
- Must measure resistance through both, can't do each separately without complete disassembly
- Calculating resistance with V=IR can only be done with two emitter strips in parallel as well




Internal Resistance of Radiant Panel Emitter Strips
*Each phase goes through 2 emitter strips wired in parallel
Resistance (ohm)
0
1
2
3
4
5
6
7
8
9
5.50
5.52
5.63
5.72
5.75
5.85
6.68
New Panel 1
New Panel 2
FAA Panel
Old Panel 1
Old Panel 2
Old Panel 3
Old Panel 5
Phase 1
Phase 2
Phase 3

Radiant Panel Resistance

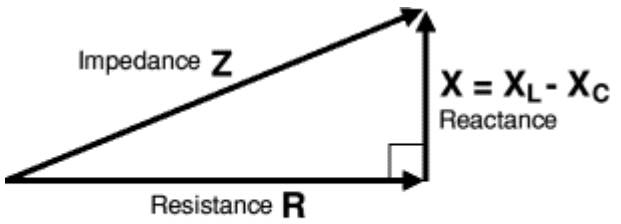
- **One panel tested at 53.9 Ω for Phase 1 + 3 and open circuits for the other two**
- **Internal resistance of old panels was higher than new panels**
- **Higher resistance should weaken panel because $Power = \frac{V^2}{R}$**
- **However the panel doesn't need full power when it reaches steady state temperature**
- **Do not know if this affects test results**

Power Measurement

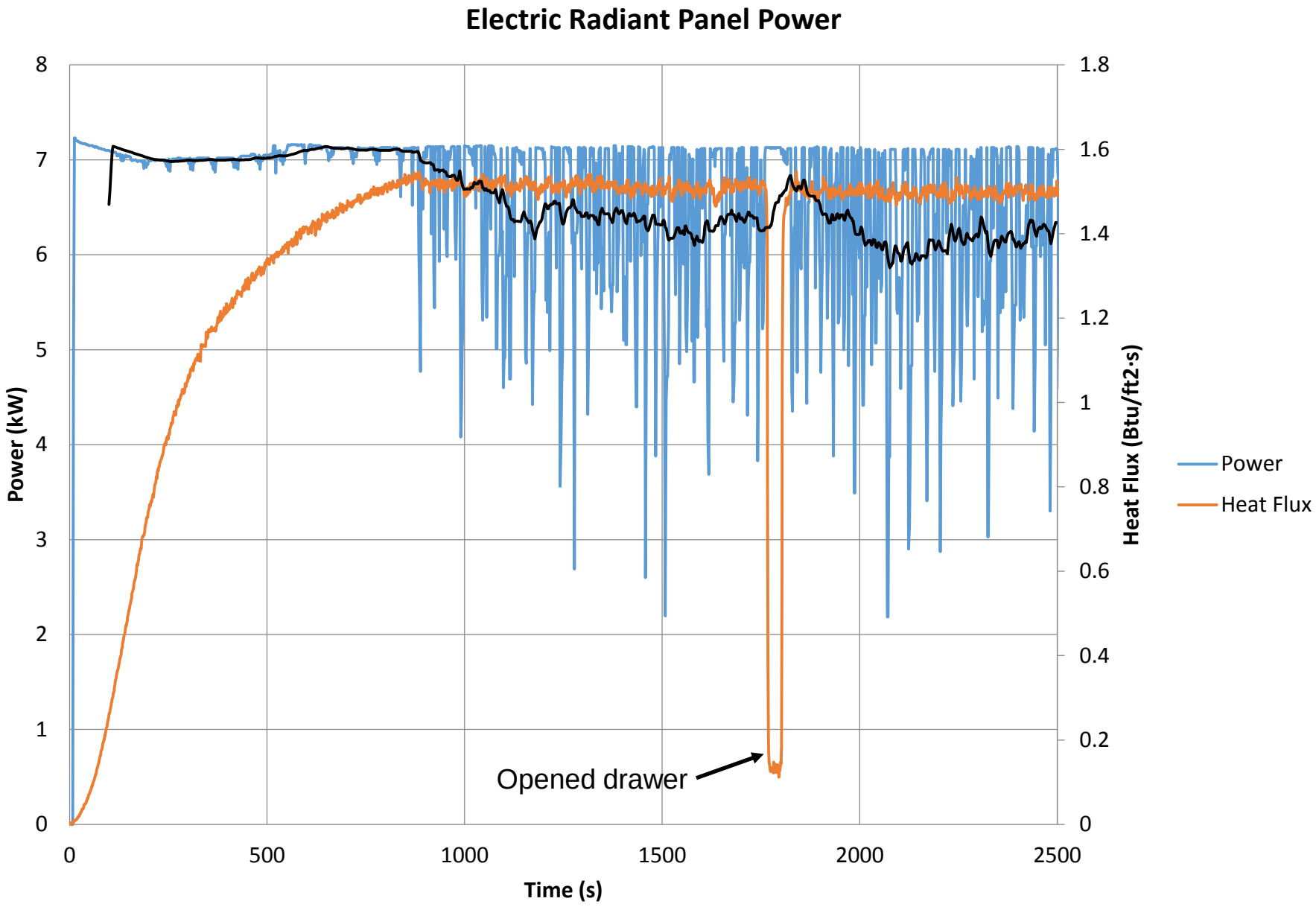
- **Bought new 3-phase power meter**
- **PCE-PA 8000**
- **Measures:**
  - Voltage
  - Current
  - Power
  - Phase angle
  - Frequency
  - Power Factor

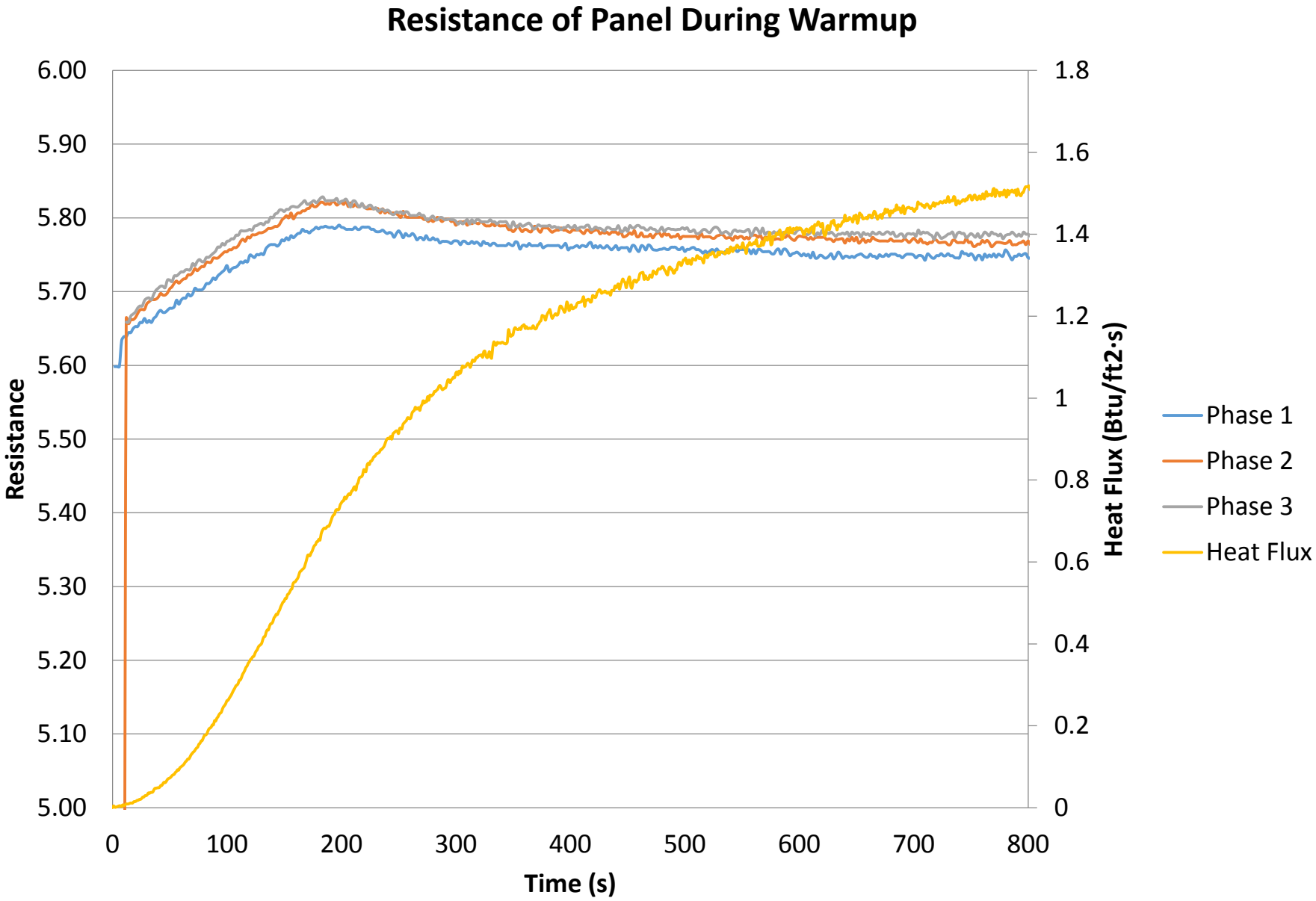
Measuring AC Power

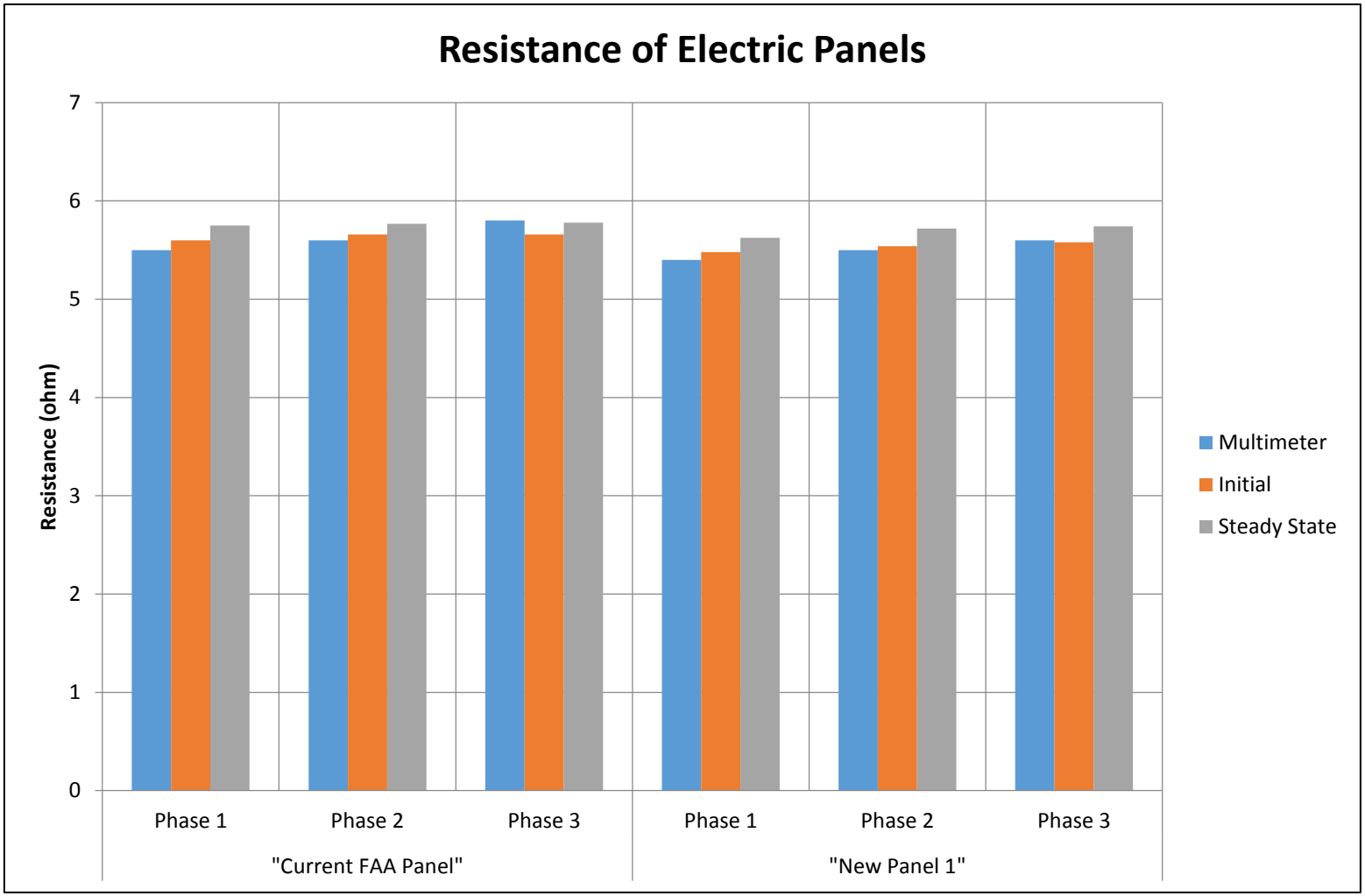
- **Temperature controller on radiant panel affects resistance, inductance, and capacitance to control the power**
- **Must measure phase angle between voltage and current**
- **Perfect resistor: phase angle = 0°**
- **Perfect inductor: phase angle = 90°**
  - Voltage leads current
- **Perfect capacitor: phase angle = -90°**
  - Voltage lags current
- **Power meter does this for you**



Impedance, $Z = \sqrt{R^2 + X^2}$

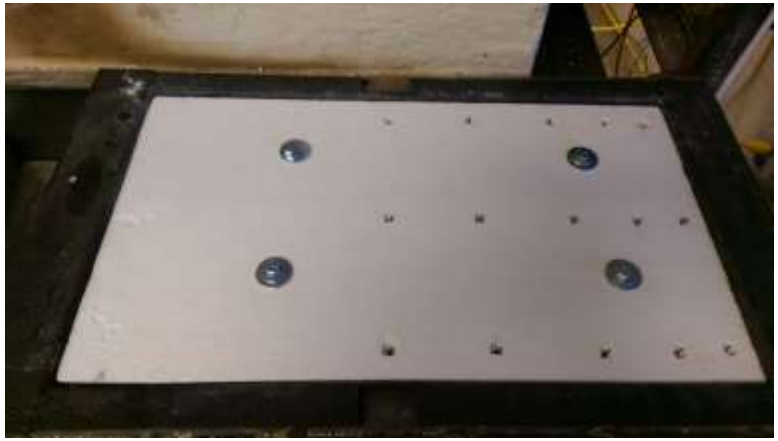

Electric Radiant Panel Power
Power (kW)
Heat Flux (Btu/ft2·s)
Time (s)
0
500
1000
1500
2000
2500
1
2
3
4
5
6
7
8
0.2
0.4
0.6
0.8
1.2
1.4
1.6
1.8
Opened drawer
Power
Heat Flux


Resistance of Panel During Warmup
Resistance
6.00
5.90
5.80
5.70
5.60
5.50
5.40
5.30
5.20
5.10
5.00
0
100
200
300
400
500
600
700
800
Time (s)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Heat Flux (Btu/ft2·s)
Phase 1
Phase 2
Phase 3
Heat Flux

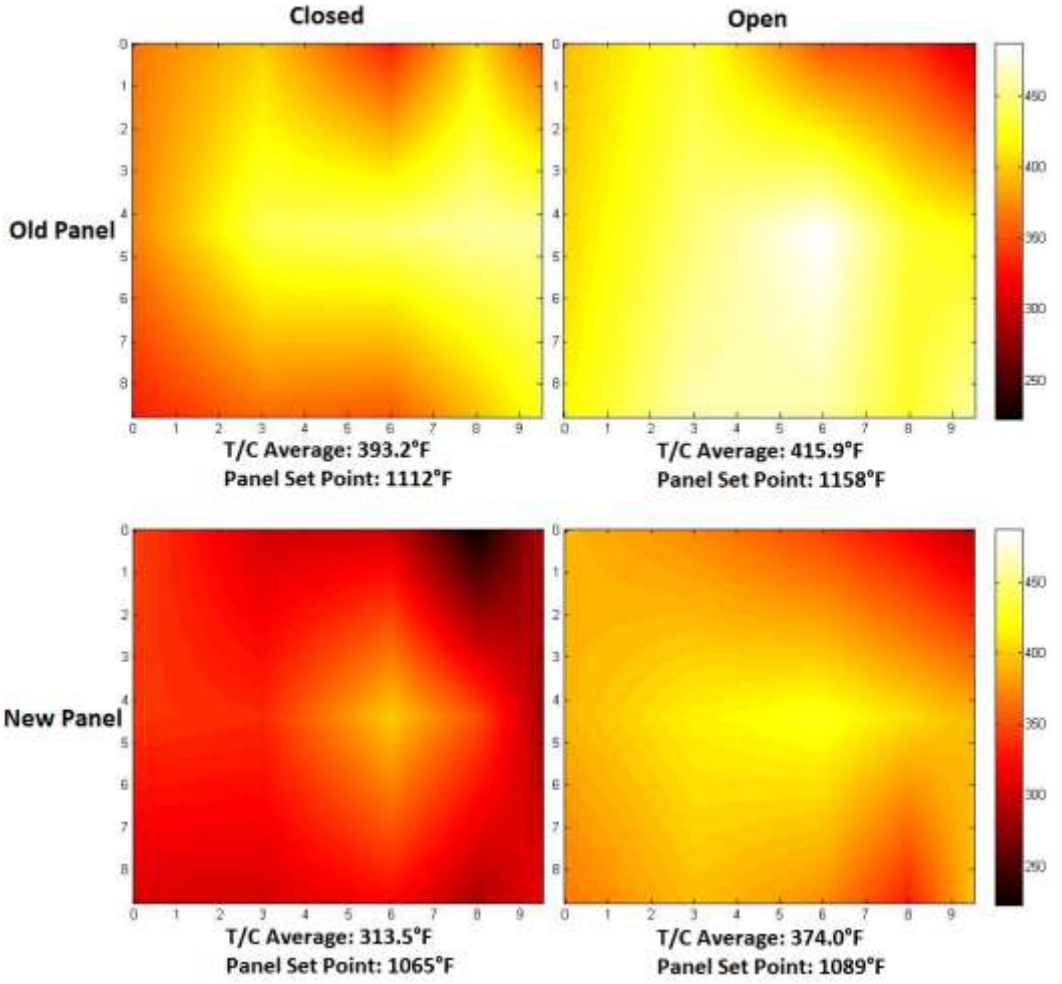


- Not much difference between measurement methods, calculating from voltage and current is probably more accurate
- Resistance only increased an average of 2.6% when heated

Temperature at Sample Surface



- From previous testing:
- 15 thermocouples at sample surface
- Old panel showed much higher temperatures
- “New panel” was installed 3/1/2017*



Conclusion

- **Need borderline material to test with**
- **Lots of testing to be done**
- **If we can find a material that can pass with good panels and fail with old ones, then we can determine the difference that caused it – emissivity, resistance, power, etc.**

Questions?

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