Radiant Panel Update

Presented to: International Aircraft Materials Fire Test Forum
By: Steve Rehn
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Introduction

- **Handbook update**
  - Updated December 2017
- **Testing heat flux calibration at ±5%**
- **Electric Panel aging testing**
  - Panel runs hotter as it ages, can affect test results
- **Future Work**

Handbook changes

- **Removed air-propane panel**
- **Replaced Kaowool M with Superwool 607**
- **Removed voltage requirement**
  - Previously said you must use 208V 3-phase or 240V single phase, replaced with 7574 Watt requirement
- **Reduced ±5% error on heat flux to ±1% on Zero Position (P1 and P2 remain ±5%)**
- **5 minute average on heat flux measurement**

Handbook Changes

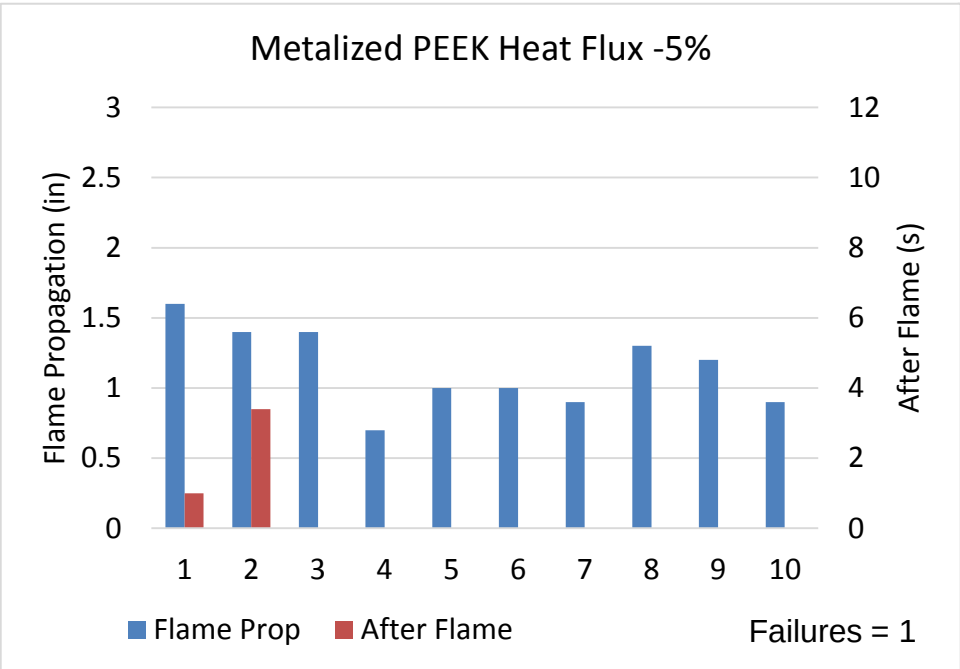
- **Heat Flux Transducer: Vatell TG 1000-1B**
- **Range: 0-5 W/cm^2**
- **Accuracy: ±3% of Full Scale (.15 W/cm^2)**
  - ±8.8% at 1.7 W/cm^2
- **Repeatability: 1%**
- **Is accuracy better if only operating at 1.7 W/cm^2 and all labs use the same gauge?**
- **Changing gauges in FAA radiant panel doesn't change panel set point**

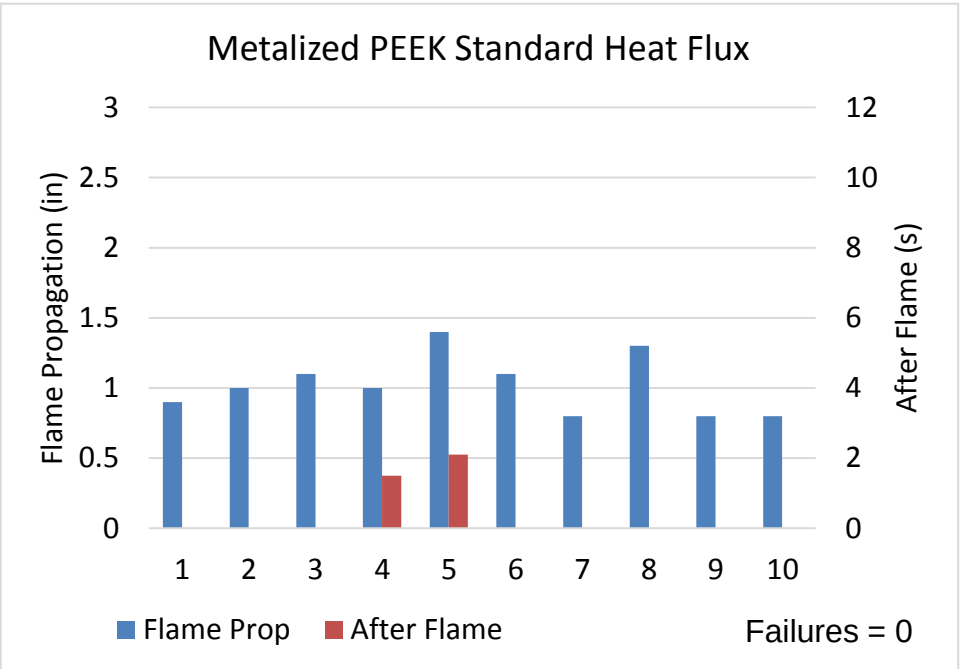
±5% Heat Flux Testing

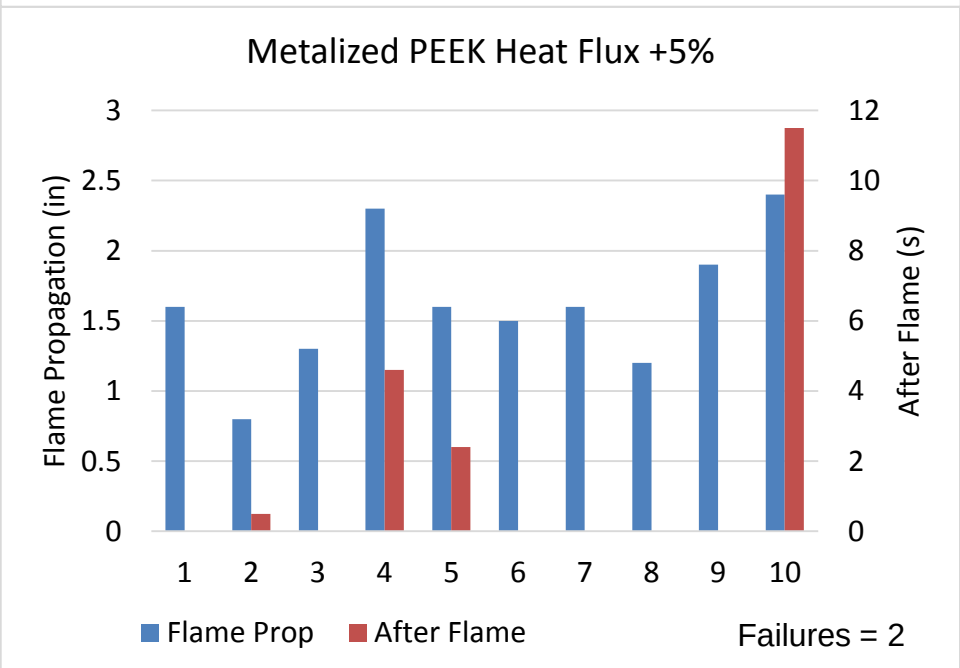
- **Test insulation samples at standard heat flux compared to +5% and -5%**

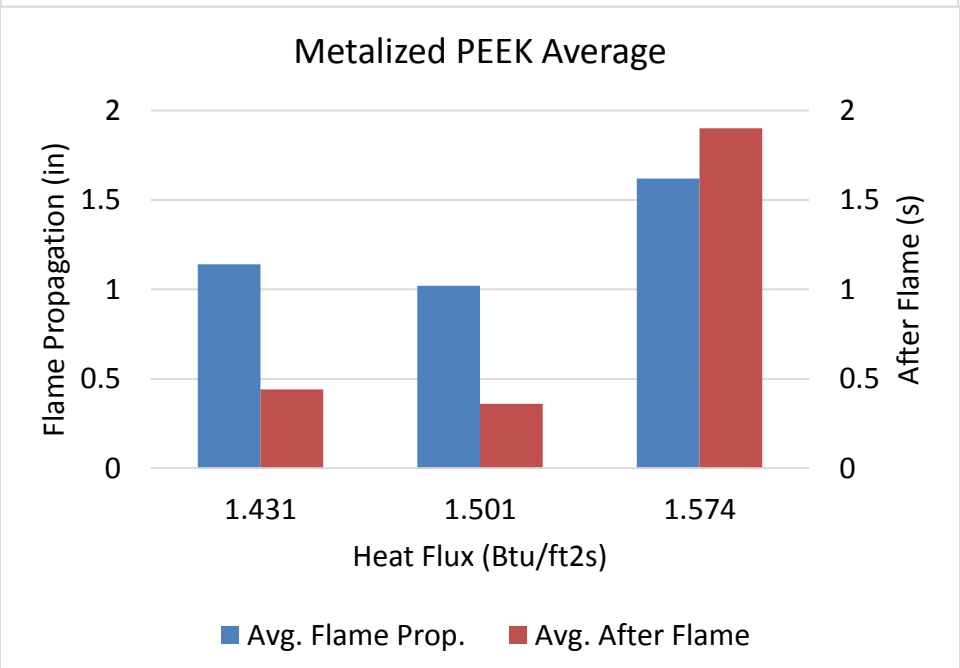
Heat Flux	US	Metric
Standard	1.500 Btu/ft^{2}s	1.700 W/cm^2
+5%	1.575 Btu/ft^{2}s	1.785 W/cm^2
-5%	1.425 Btu/ft^{2}s	1.615 W/cm^2

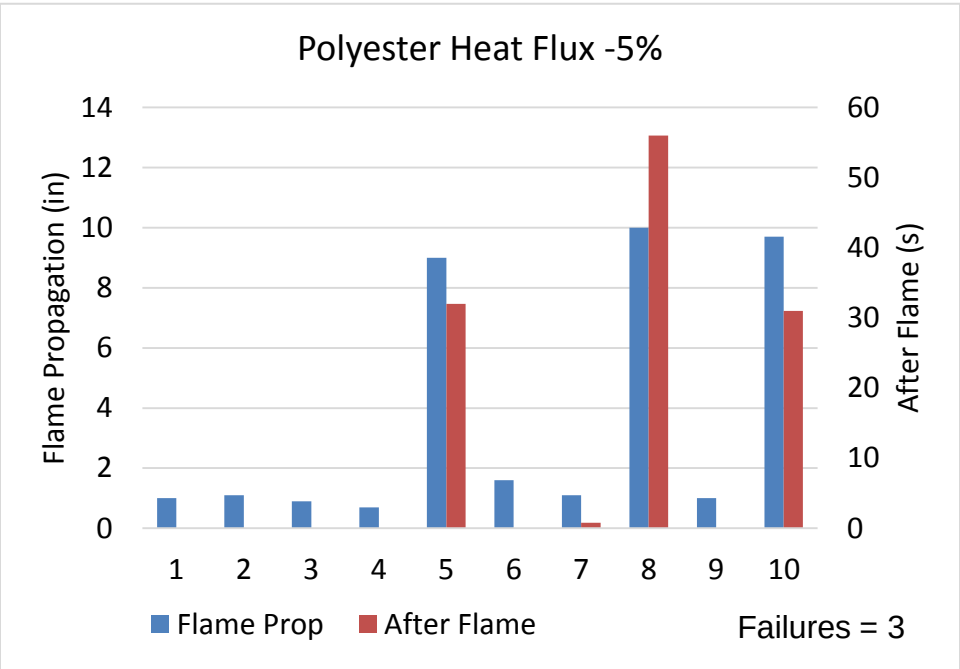
- **Is ±5% too wide of a tolerance to ensure repeatable test results?**

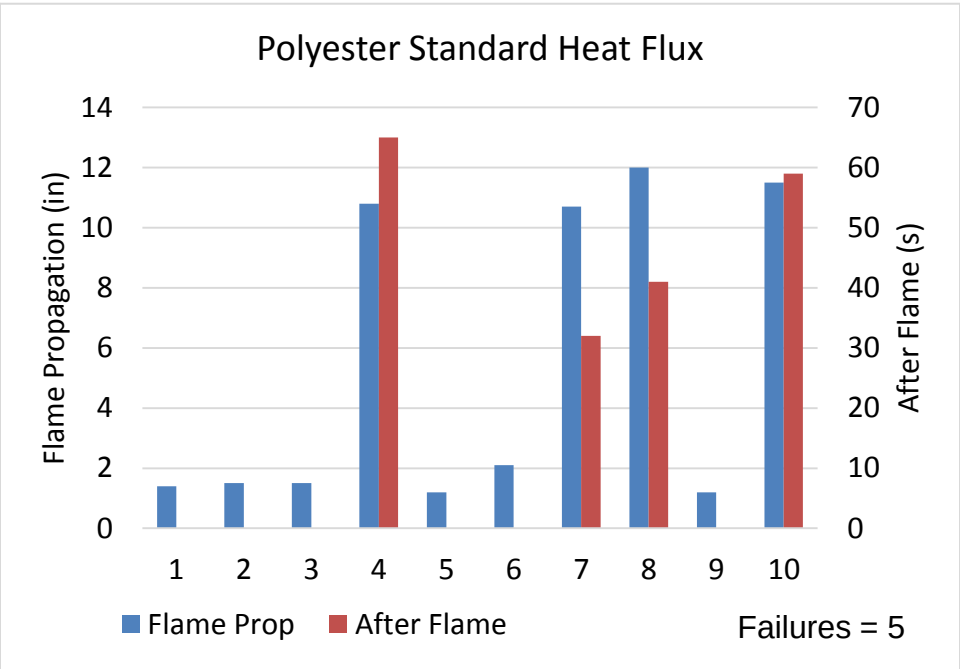

Metalized PEEK Heat Flux -5%
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 1

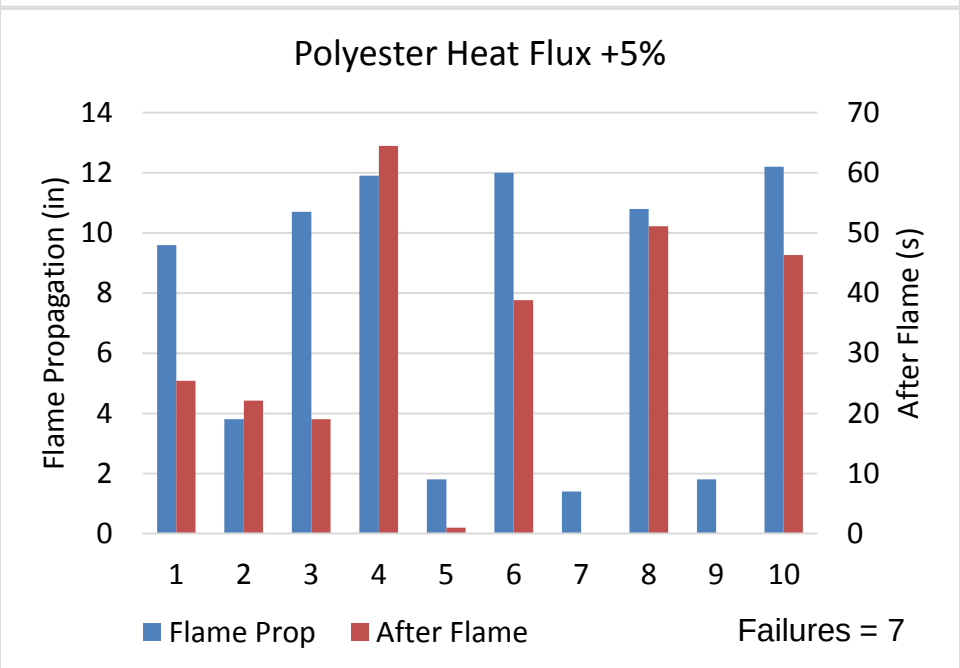

Metalized PEEK Standard Heat Flux
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 0

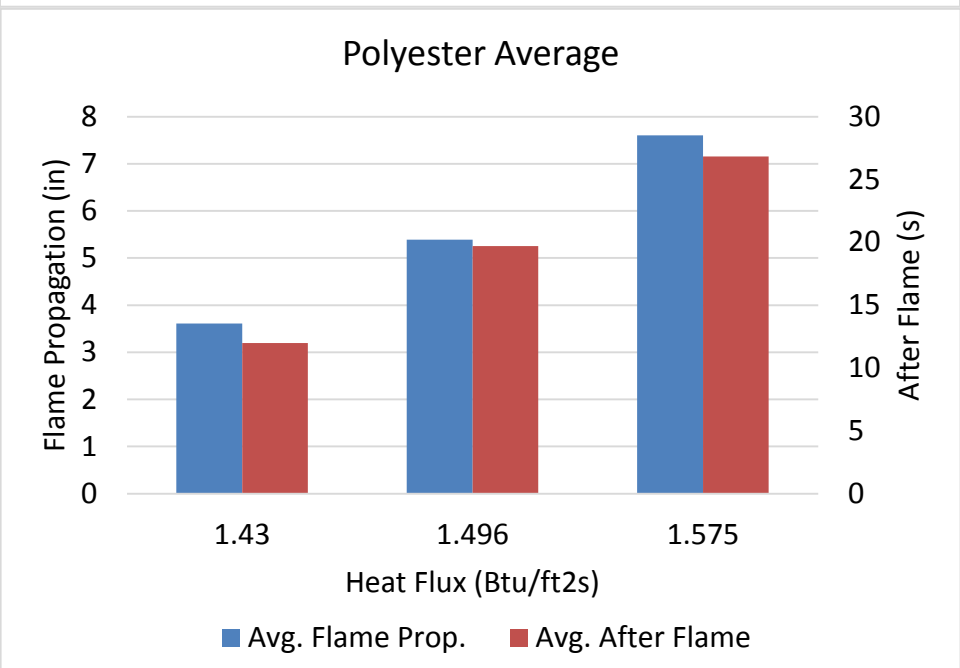

Metalized PEEK Heat Flux +5%
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 2


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)
Flame Prop
After Flame
Failures = 3


Polyester Standard Heat Flux
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 5

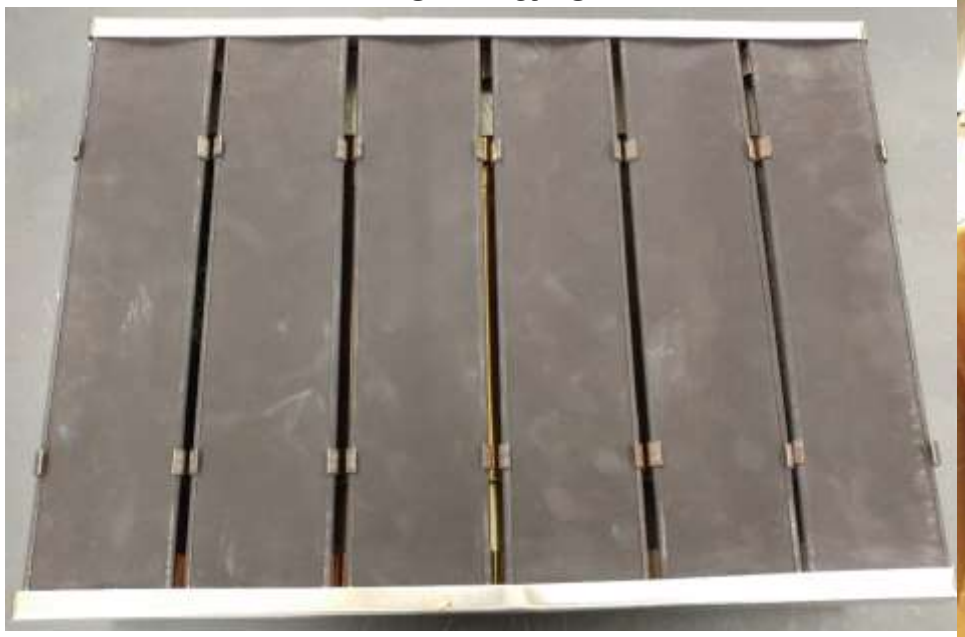

Polyester Heat Flux +5%
Flame Propagation (in)
After Flame (s)
Flame Prop
After Flame
Failures = 7


Polyester Average
Flame Propagation (in)
After Flame (s)
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 add guidance about when to replace electric panel**

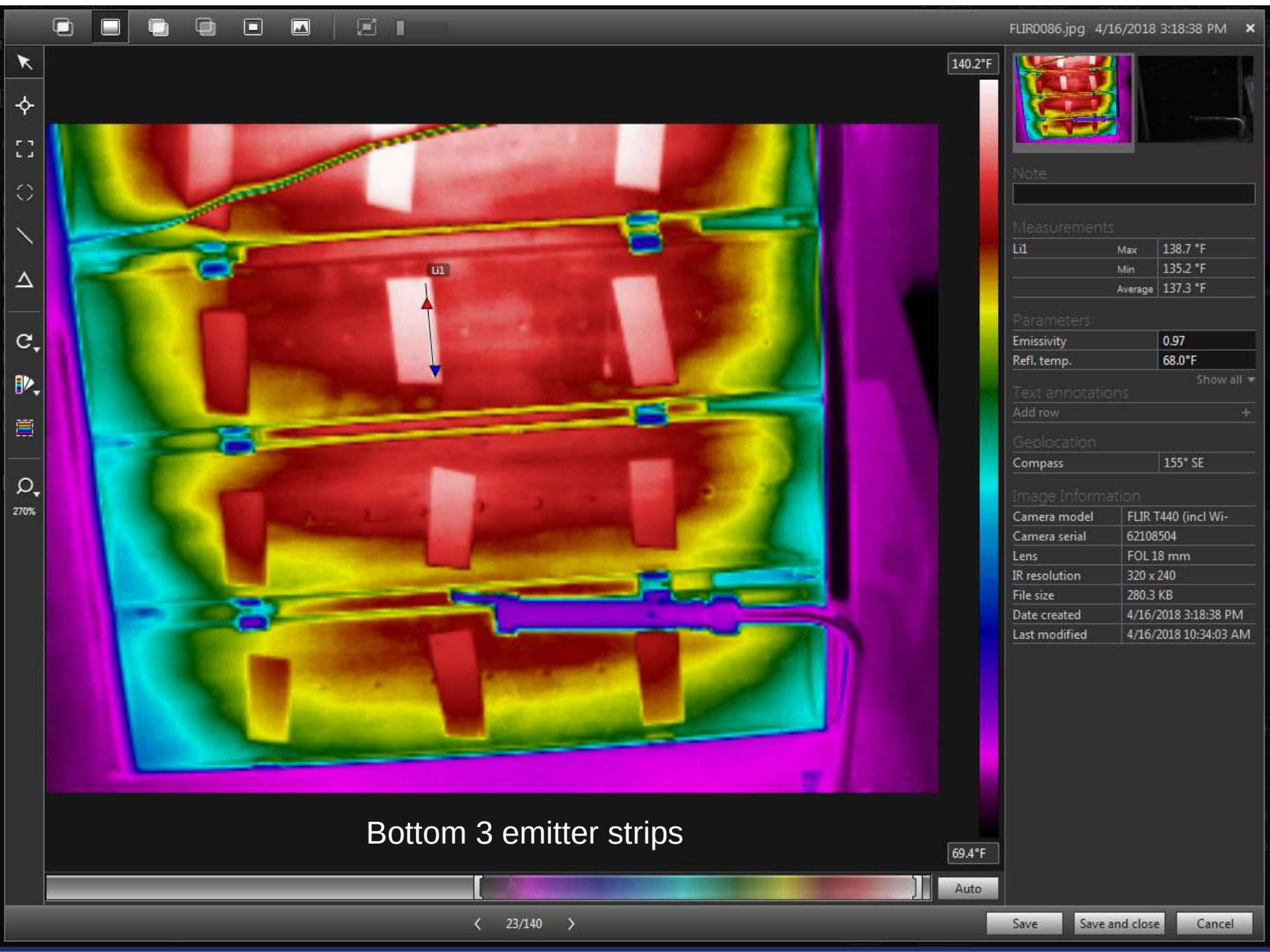
New Panel



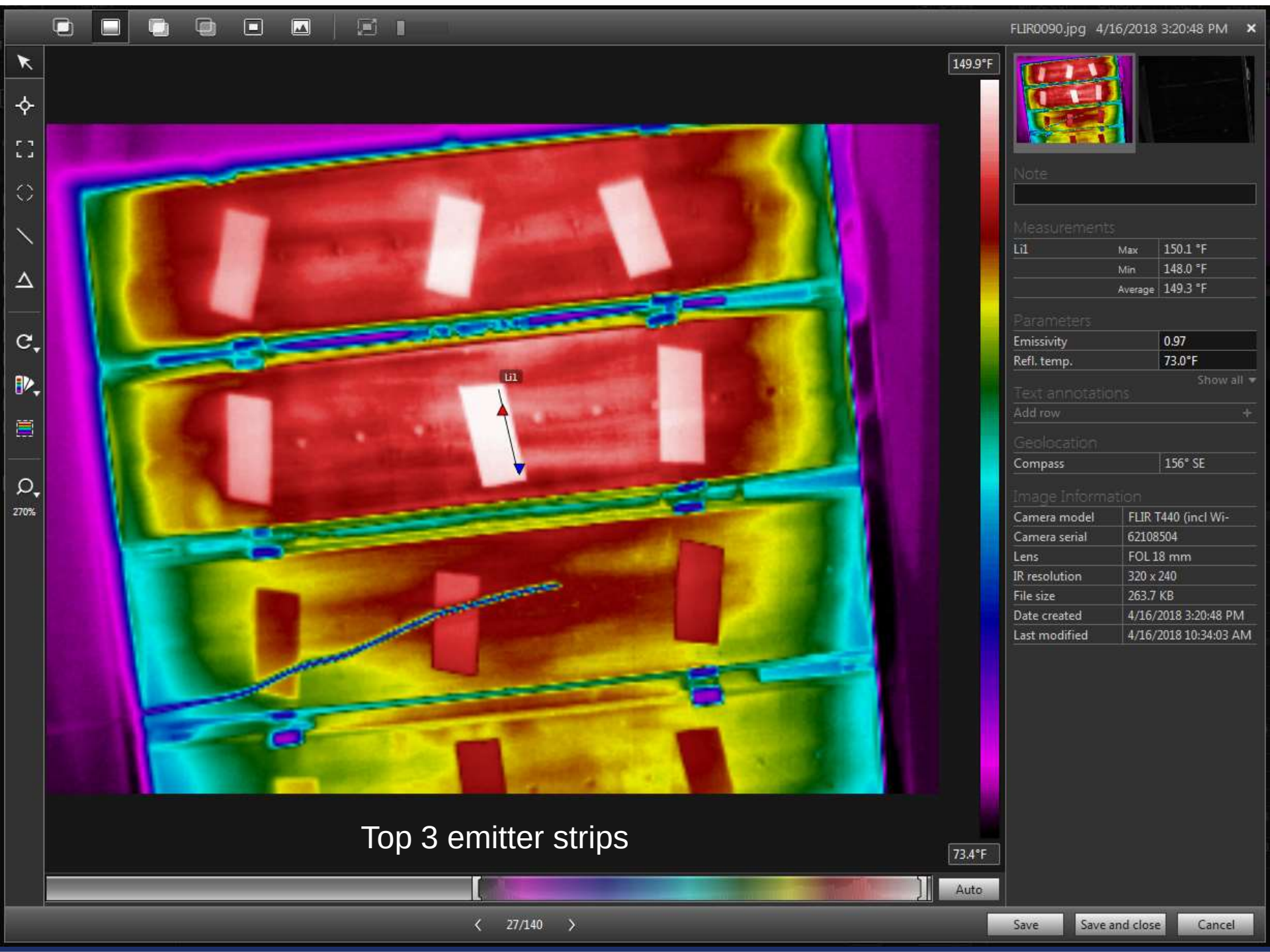
Old Panel

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

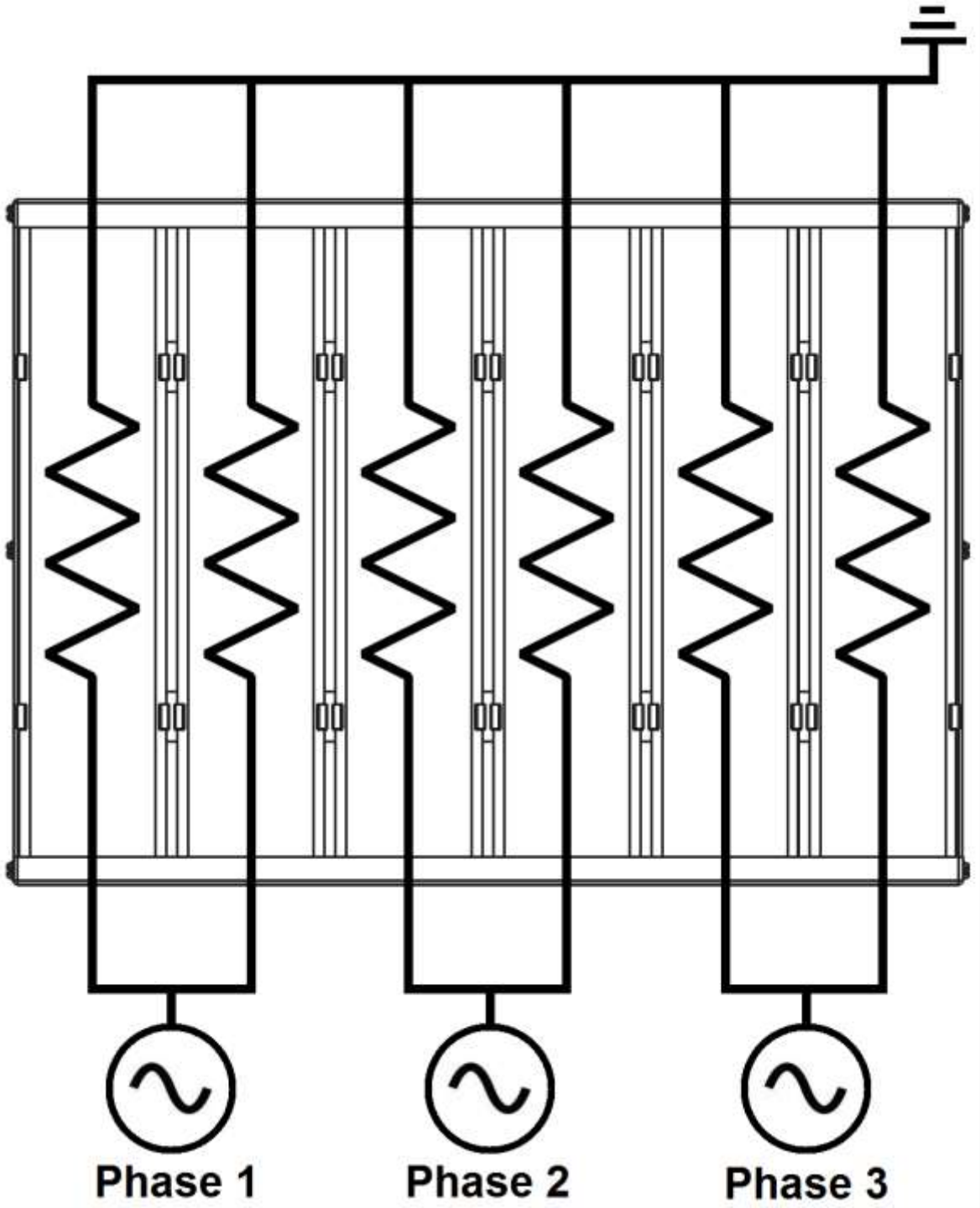
- **Have not measured other panels yet**
- **Did not have suitable material to test at same time**
- **Perfect mirror has emissivity of 0**
- **Perfect “black body” has emissivity of 1**
- **Color has little effect on emissivity, biggest effect is reflexivity**

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?**

Phase 1 ~ Emitter strips 1 & 2
Phase 2 ~ Emitter strips 3 & 4
Phase 3 ~ Emitter strips 5 & 6

- Tried to measure resistance from each terminal to ground but read open circuit
- Was able to measure resistance between each phase terminal

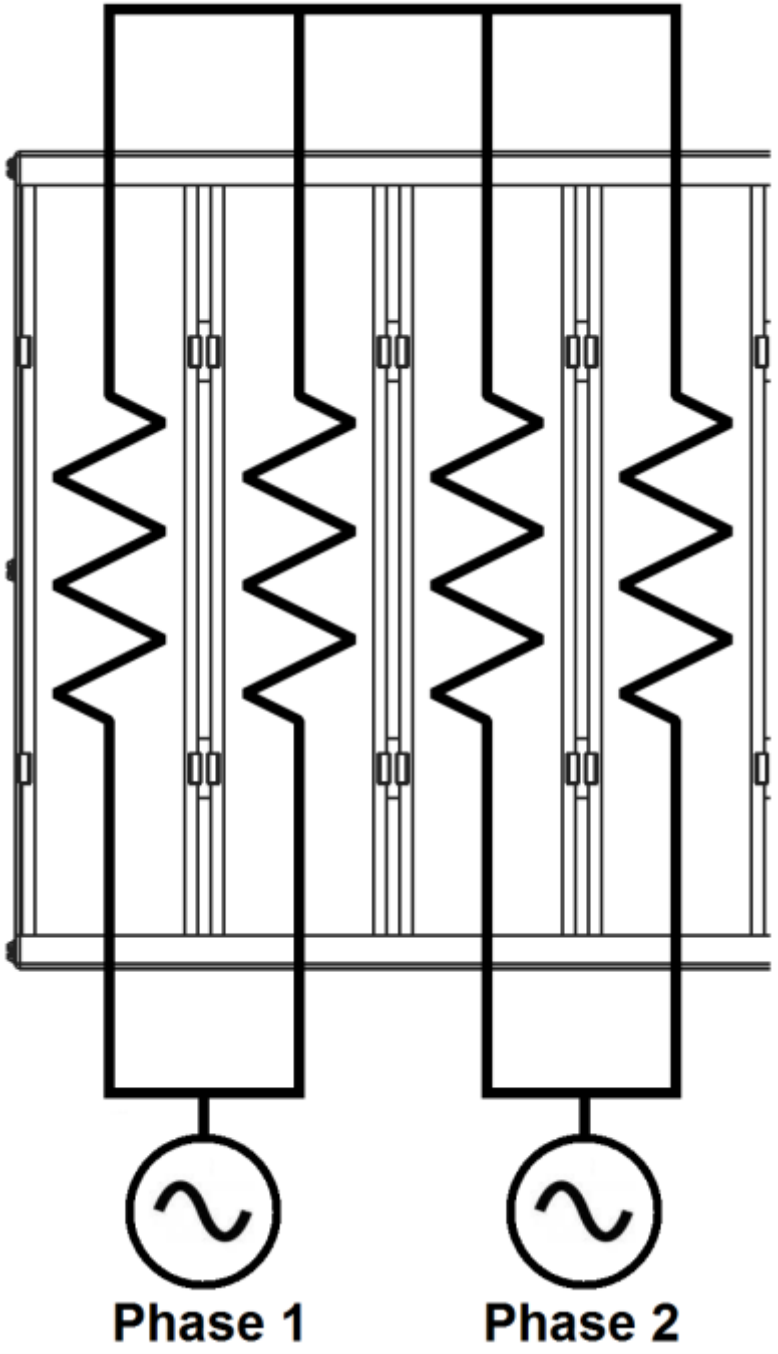


- Measured resistance between Phases 1 & 2, 1 & 3, and 2 & 3

$$\frac{1}{R_{P1}} = \frac{1}{R_1} + \frac{1}{R_2} \qquad \frac{1}{R_{P2}} = \frac{1}{R_3} + \frac{1}{R_4}$$

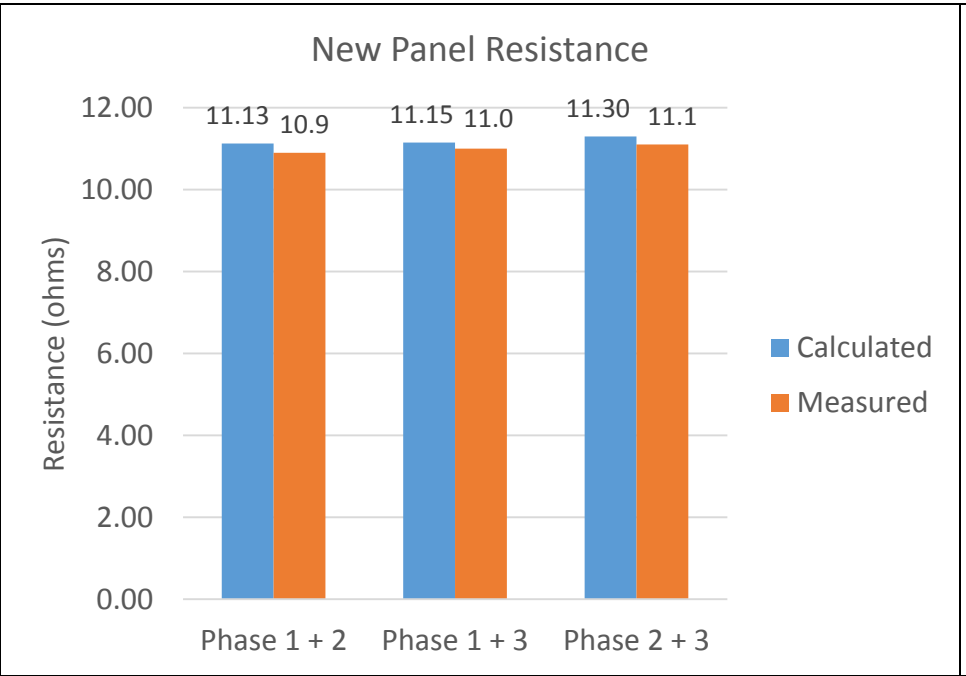
$$R_{P1+P2} = R_{P1} + R_{P2}$$

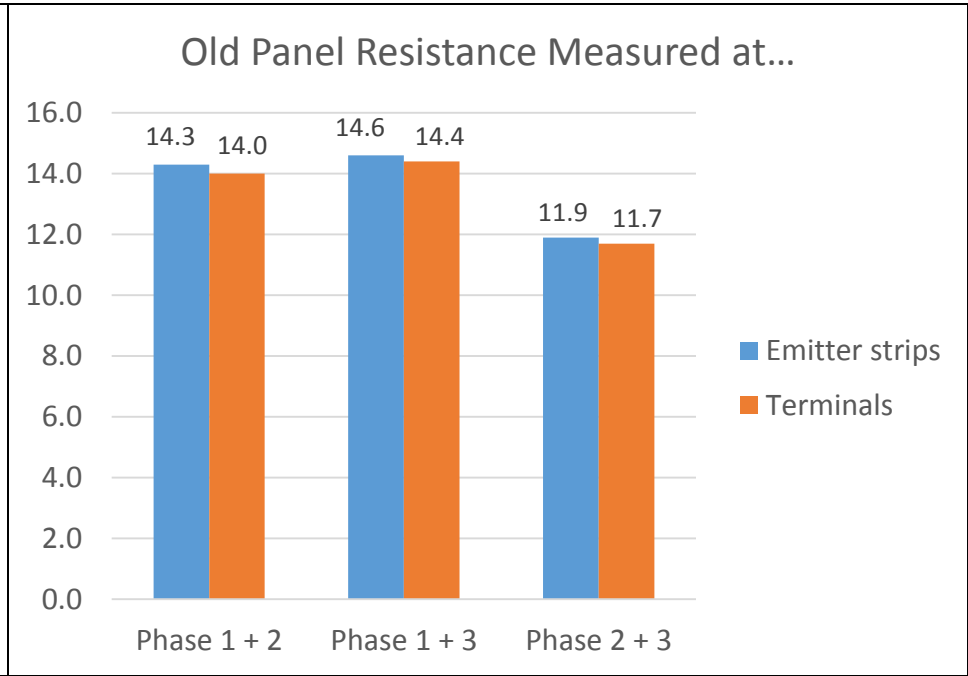
- New Panels come with paper stating the measured resistance of each emitter strip
- Manufactured such that lowest resistance is on the bottom and highest at the top

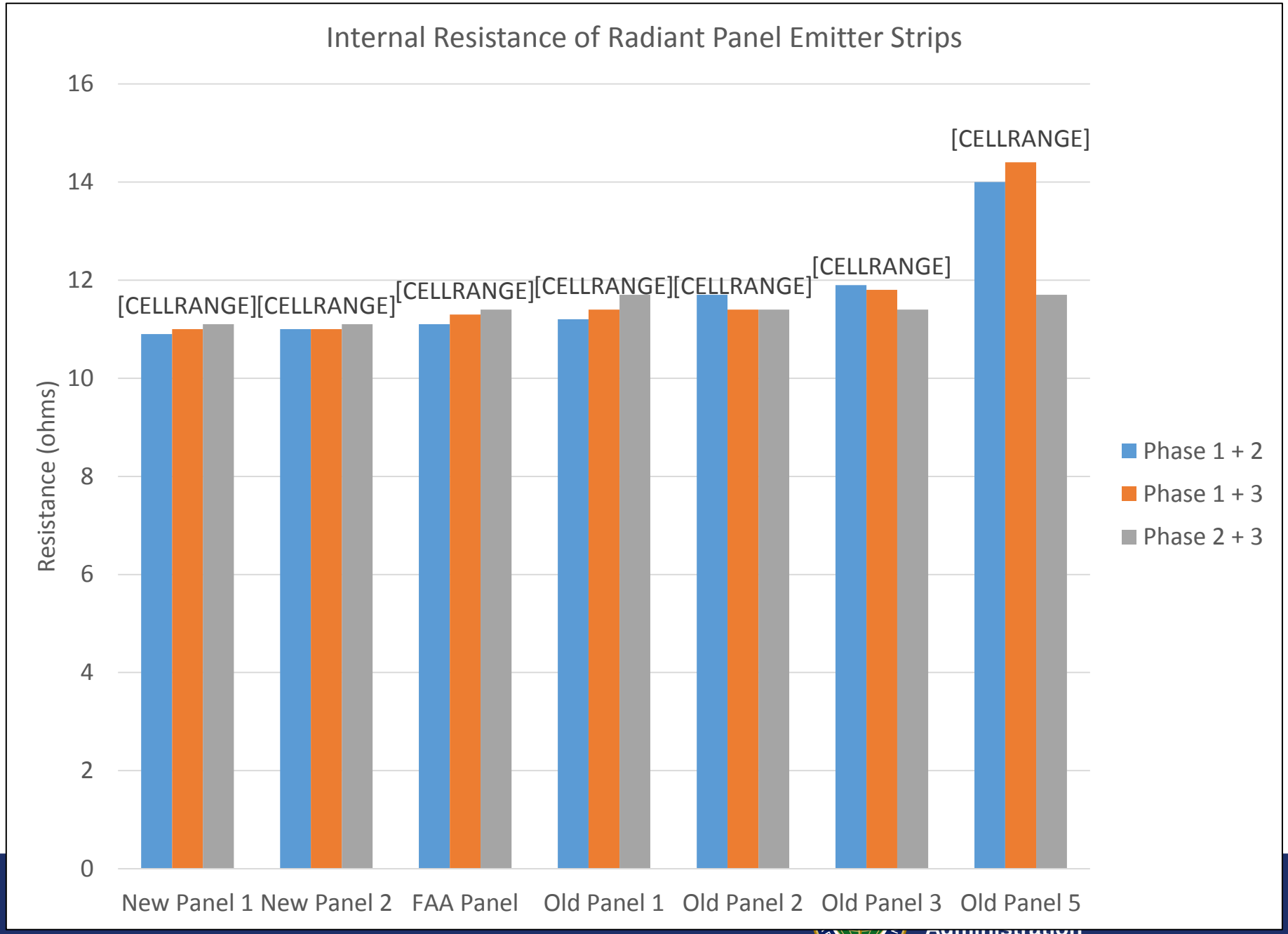


Radiant Panel Resistance

- **On new panel, measured resistance was on average 1.72% lower than value calculated from given values**
- **On old broken panel, measured resistance at emitter strips and terminals. Measured value at terminals was also on average 1.72% lower**






Internal Resistance of Radiant Panel Emitter Strips
Resistance (ohms)
16
14
12
10
8
6
4
2
0
[CELLRANGE][CELLRANGE]
[CELLRANGE]
[CELLRANGE][CELLRANGE]
[CELLRANGE]
[CELLRANGE]
New Panel 1
New Panel 2
FAA Panel
Old Panel 1
Old Panel 2
Old Panel 3
Old Panel 5
Phase 1 + 2
Phase 1 + 3
Phase 2 + 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

Future Work

- **Measure all panel's emissivity**
- **Test all panels with a material sensitive enough to show small changes**
- **Discuss test plans in task group**
- **Refurbishing panel is secondary goal**

Questions?

Contact:
Steven Rehn
Federal Aviation Administration
William J. Hughes Technical Center
Fire Safety Branch, Bldg. 203
Atlantic City Int'l Airport, NJ 08405
(609) 485-5587
steven.rehn@faa.gov