HEAT FLUX SENSITIVITY STUDY IN NBS/OSU/RP/SEAT TEST

2009 October Materials Meeting

Materials Working Group

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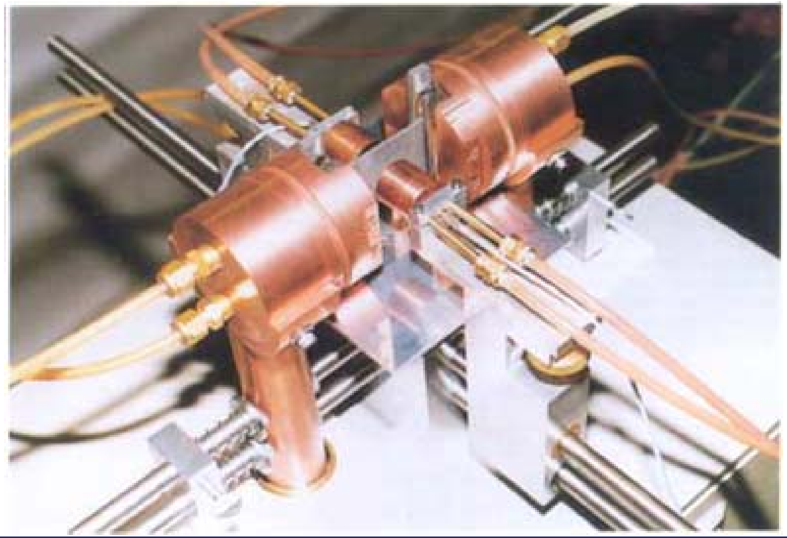
Heat Flux Sensitivity Study – OSU/NBS/RP

- 4 Gages Were Selected For Study In OSU/NBS & RP
  - » 1.) MEDTHERM (GARDON) 0-5 BTU
  - » 2.) MEDTHERM (SCHMIDT-BOELTER) 0-5 BTU
  - » 3.) VATELL (GARDON) 0-5 BTU
  - » 4.) HUKSEFLUX (GARDON) 0-5 BTU
- The Gages Were Calibrated By Comparison To A NIST Calibrated HFG
- The Transfer Method

Was Made Using A Heated

Graphite Plate



Heat Flux Sensitivity Study – OSU/NBS/RP

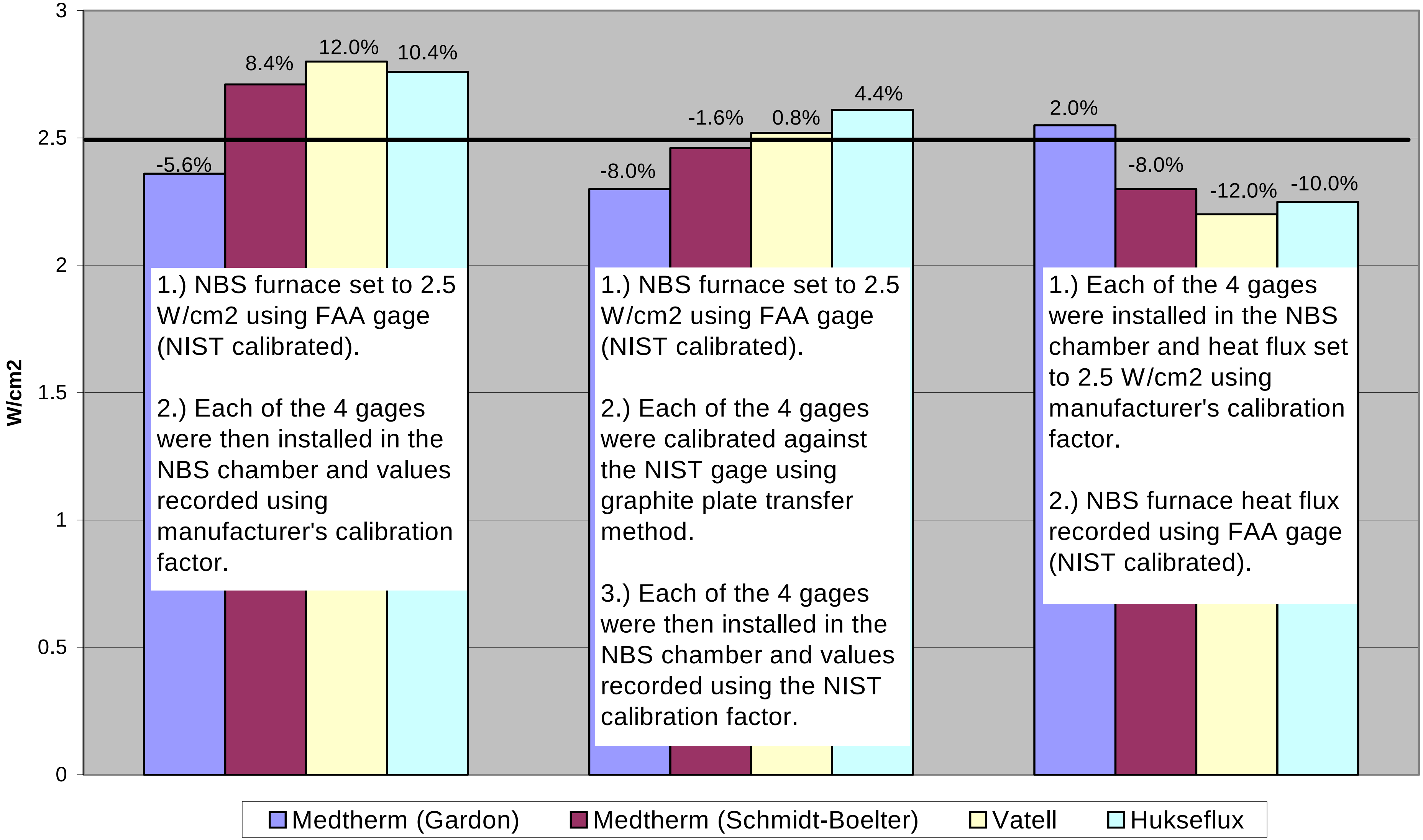
- Step #1
  - The FAA HFG (NIST Calibration Factor) Was Initially Used To Set Heat Flux
- Step #2
  - 4 HFG's Were Installed In Apparatus And Heat Flux Recorded Using Manufacturers Calibration Factor
- Step #3
  - 4 HFG's Were Installed In Apparatus And Heat Flux Recorded Using NIST Calibration Factor
- Step #4
  - 4 HFG's Were Installed And Heat Flux Set Using Manufacturers Calibration Factor
  - FAA HFG Was Installed After Each Gage And Heat Flux Recorded Using NIST Calibration Factor

Heat Flux Sensitivity Study – OSU/NBS/RP

- Calibration Factor (NIST vs. Manufacturer's)
  - ❖For Each Gage, The Manufacturer's Calibration Factor Was Found To Be Higher Than The NIST Calibration Factor.

HFG	Man. Cal. Factor	FAA (NIST) Cal. Factor	Delta
Medtherm (Gardon)	0.5889	0.5747	-2.4%
Medtherm (Schmidt-Boelter)	0.484	0.4397	-9.2%
Vatell	0.56	0.504	-10.0%
Hukseflux	0.2689	0.2537	-5.7%

NBS Heat Flux Sensitivity Study
Manufacturer's Calibration Factor vs. NIST Calibration Factor



NBS Heat Flux Gage Calibration / Sensitivity study

3 Materials Tested At The Highest And Lowest Heat Flux Found

- Material #1

  Schneller Panel (Adhesive Sample Face)

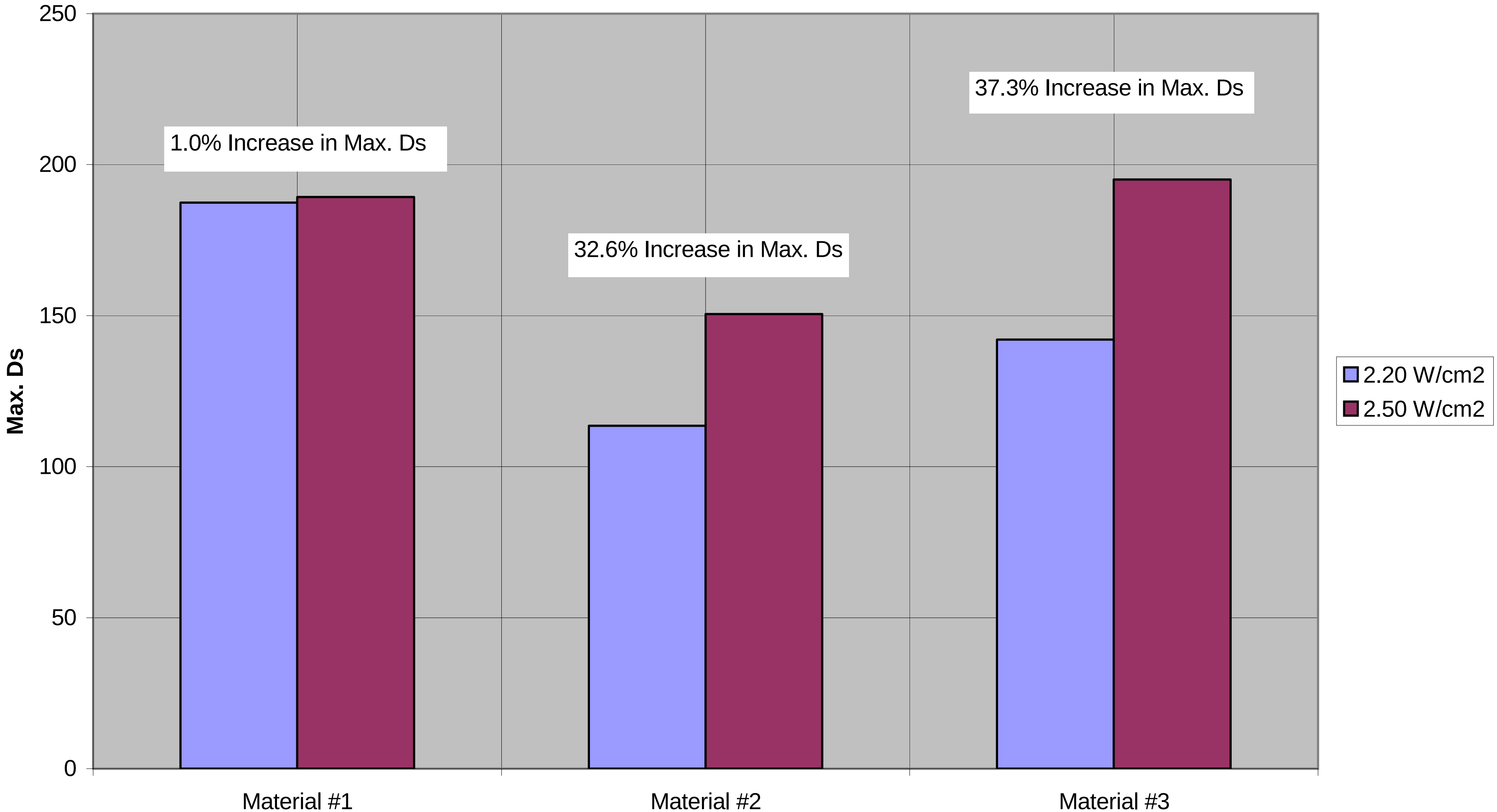
- Material #2

  1/8” Honeycomb Panel W/ Textured Face

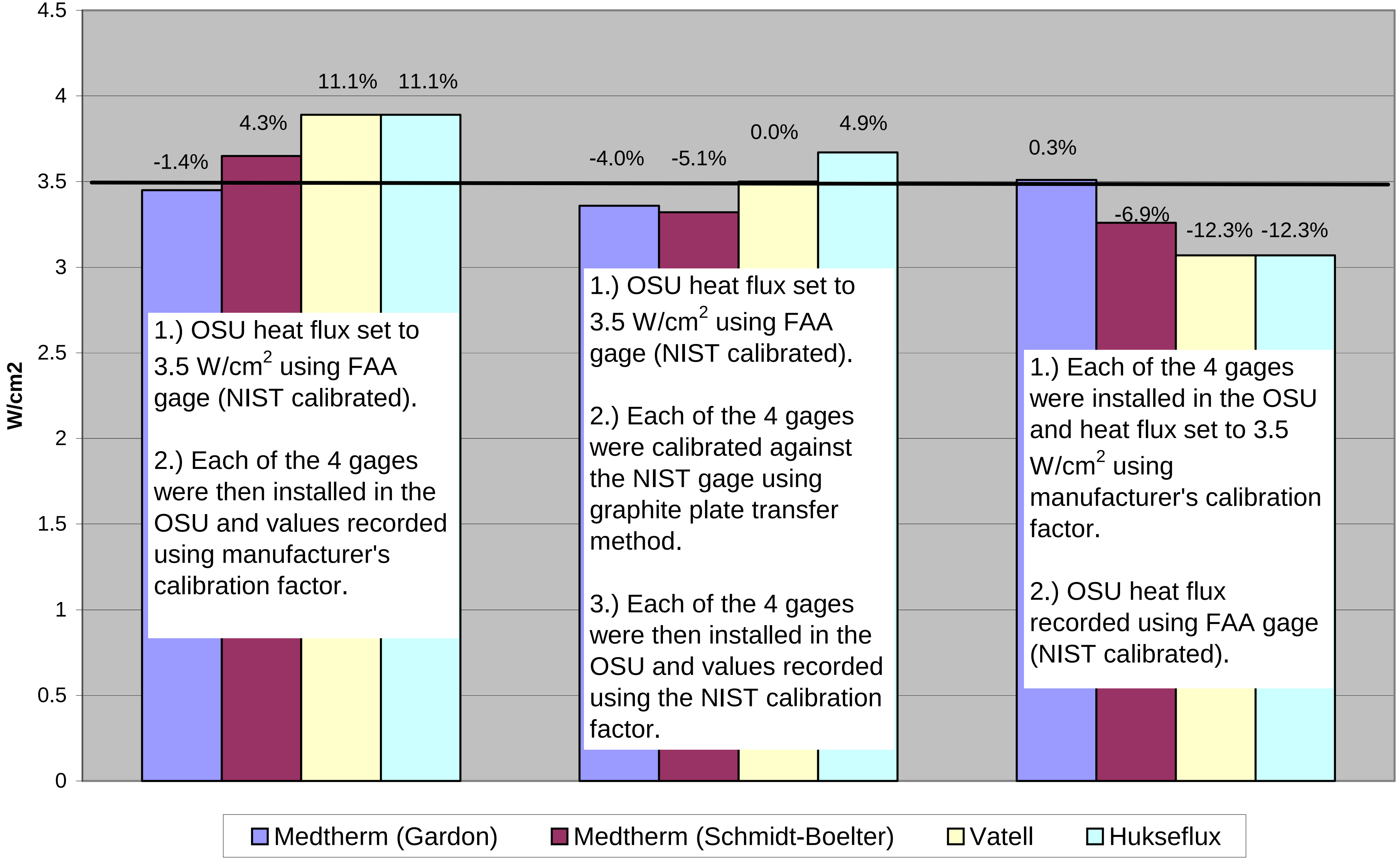
- Material #3

  3/8” Honeycomb Panel W/ Textured Face

NBS Heat Flux Sensitivity Study
2.2 W/cm^2 vs. 2.5 W/cm^2 (13.6% Delta)



OSU Heat Flux Sensitivity Study
Manufacturer's Calibration Factor vs. NIST Calibration Factor



OSU Heat Flux Gage Calibration / Sensitivity study

3 Materials Tested At The Highest And Lowest Heat Flux Found

- Material #1

  Schneller OSU Test Panel

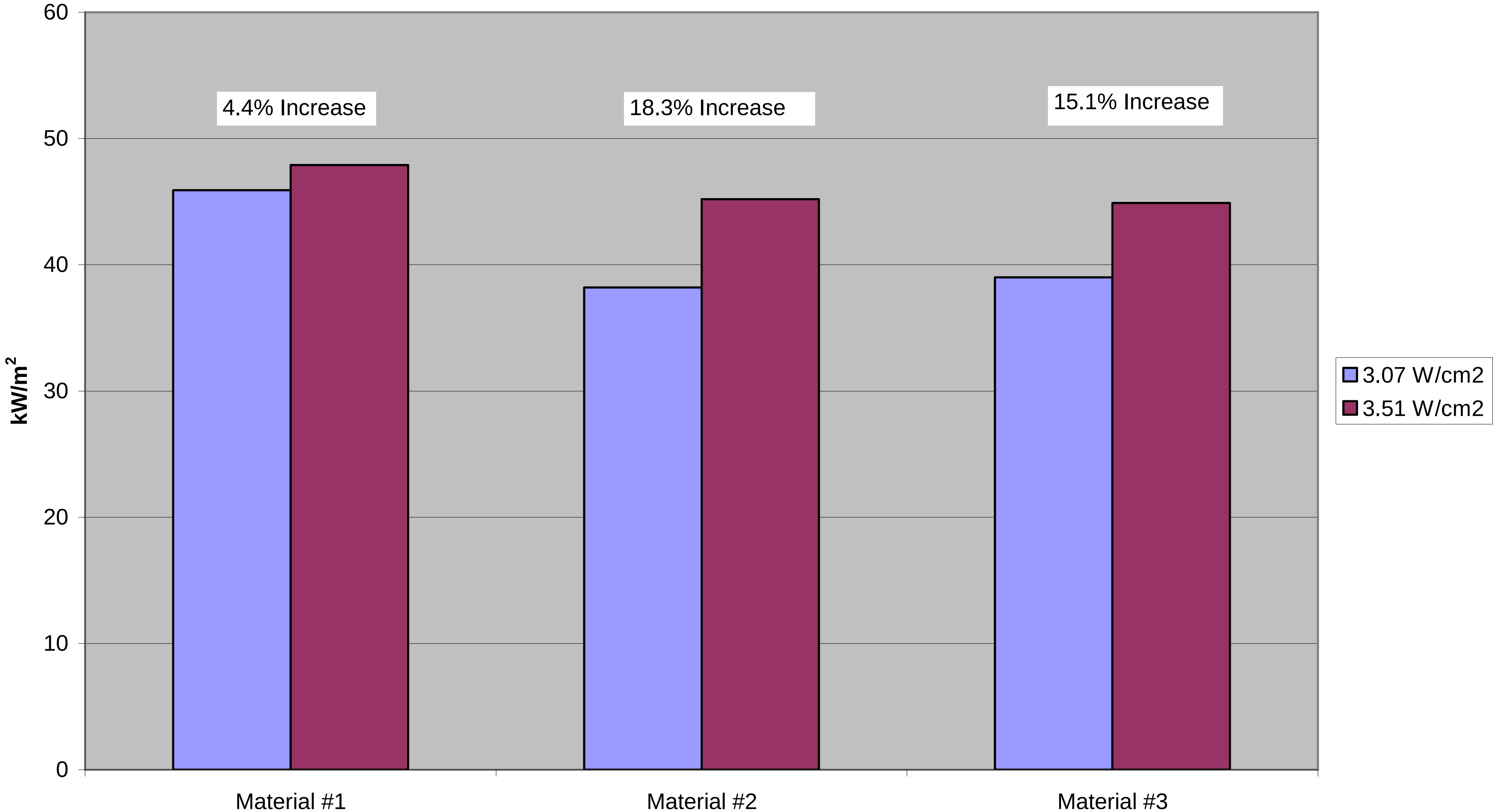
- Material #2

  1" Honeycomb Panel W/ Textured Face

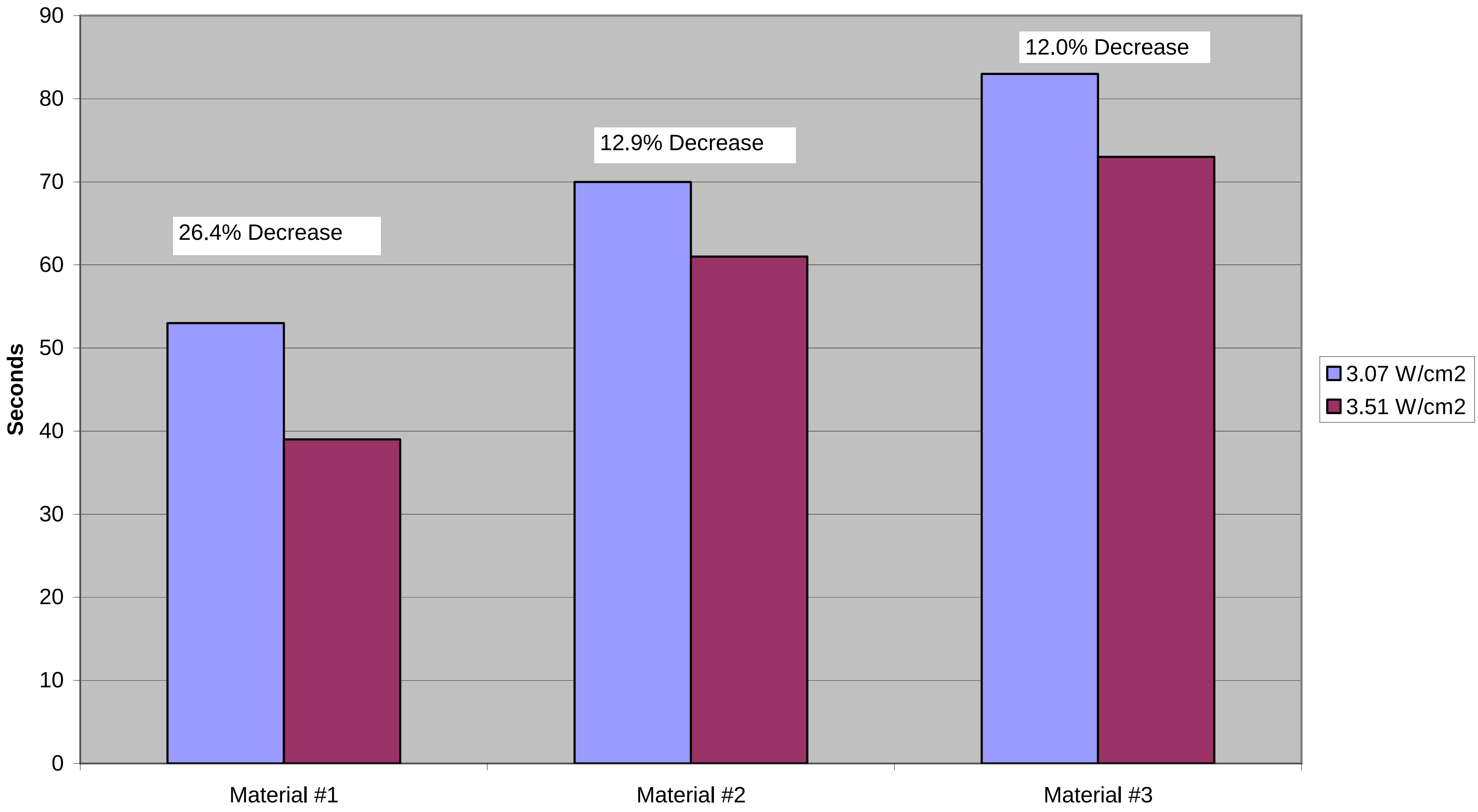
- Material #3

  11/16" Honeycomb Panel W/ Textured Face (Double Peak Material)

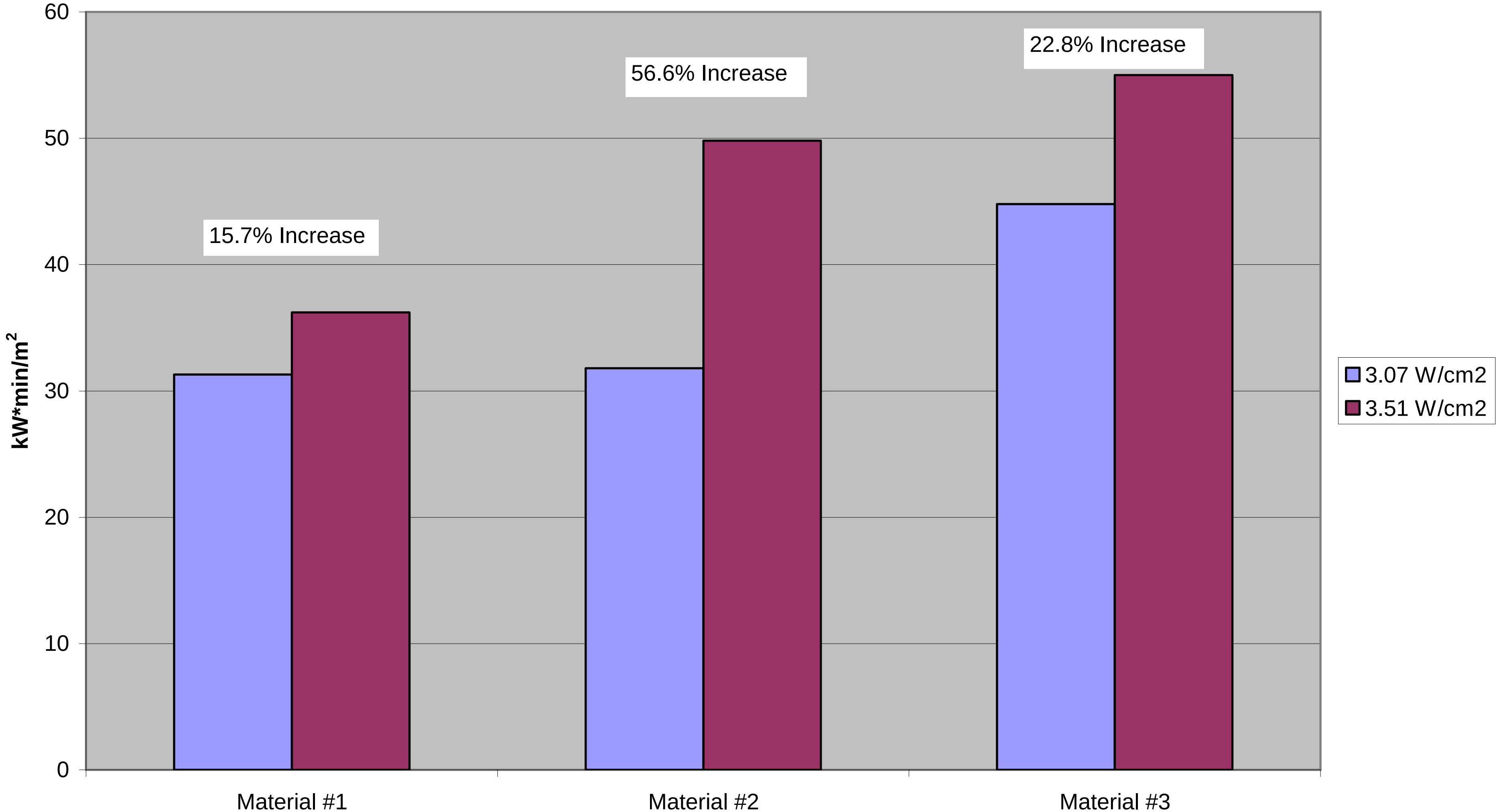
OSU Heat Flux Sensitivity Study
Avg. Peak Delta With 14.3% Increase In HF



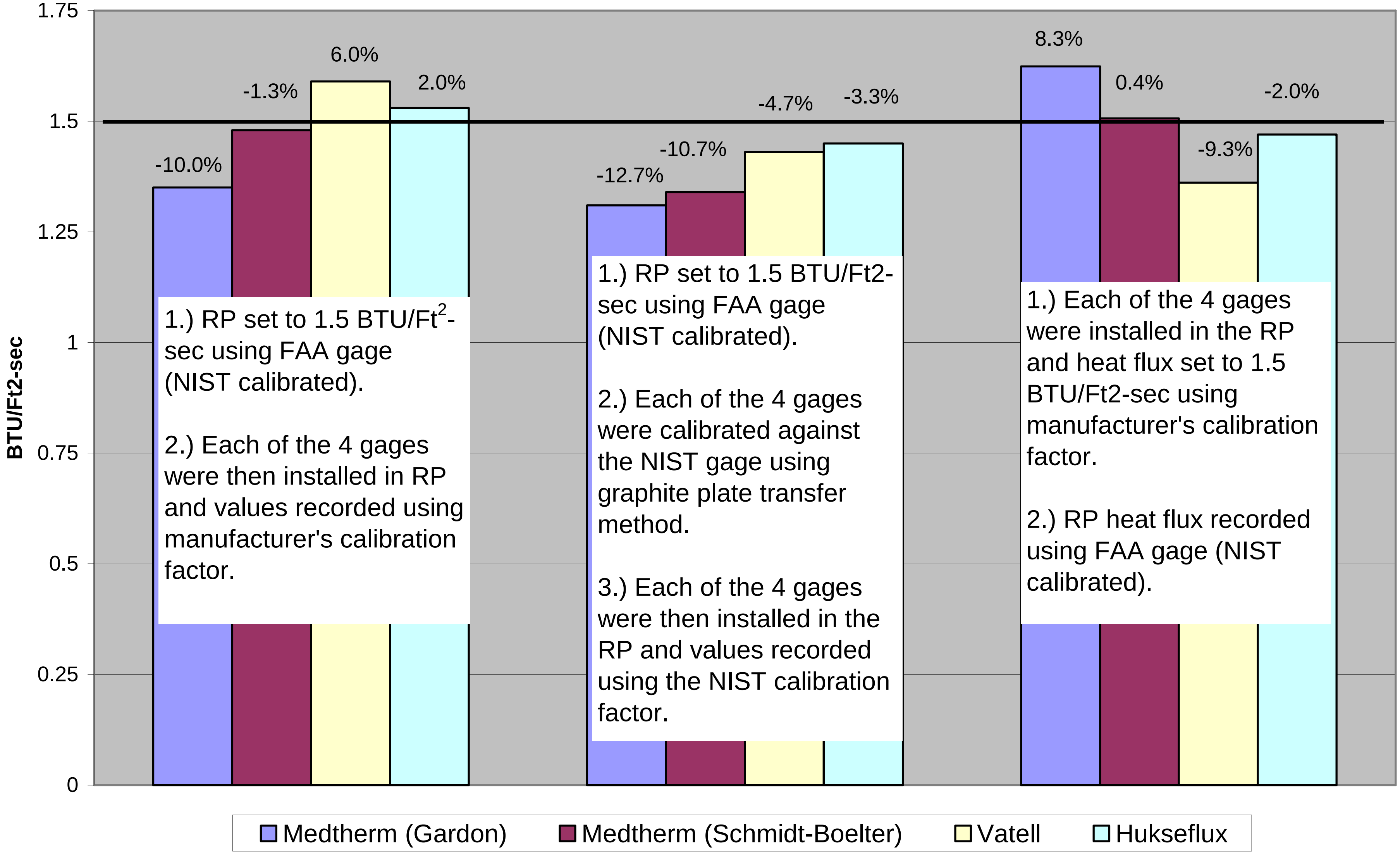
OSU Heat Flux Sensitivity Study
Avg. Time to Peak Delta With 14.3% Increase In HF



OSU Heat Flux Sensitivity Study
Avg. Total HR Delta With 14.3% Increase In HF



RP Heat Flux Sensitivity Study
Manufacturer's Calibration Factor vs. NIST Calibration Factor



RP Heat Flux Gage Calibration / Sensitivity Study

LOWER SETTING - 1.361 BTU/Ft2-sec

1.) Polyfab – Blocking Layer over 0.6 pcf Fiberglass

Setpoint	Thermocouple
1050 DegF	306 DegF

Afterflame (seconds)	Flame Propagation
0	0.75
0	0.75
0	0.75

2.) Polyimide film over 2 layers of 0.34 pcf Fiberglass

Setpoint	Thermocouple
1051 DegF	319 DegF

Afterflame (seconds)	Flame Propagation
0	0.75
0	0.75
0	0.75

3.) Metallized PEEK Film over 2 layers of 0.34 pcf Fiberglass

Setpoint	Thermocouple
1051 DegF	319 DegF

Afterflame (seconds)	Flame Propagation
0	0.75
0	0.75
0	0.75

RP Heat Flux Gage Calibration / Sensitivity Study

4.) Material 1

Setpoint	Thermocouple
1047 DegF	306 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	.75	Pass
0	0.5	Pass
0	0.75	Pass

5.) Material 2

Setpoint	Thermocouple
1047 DegF	306 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	0.75	Pass
0	1.0	Pass
0	1.0	Pass

6.) Material 3

Setpoint	Thermocouple
1047 DegF	306 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	0.75	Pass
*2.6	0.75	Pass
0	0.75	Pass

*** Burned in the well**

RP Heat Flux Gage Calibration / Sensitivity Study

7.) Material 4

Setpoint	Thermocouple
1047 DegF	306 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	0.5	Pass
1.0	0.75	Pass
0	0.75	Pass

HIGHER SETTING - 1.624 BTU/Ft2-sec

1.) Polyfab – Blocking Layer over 0.6 pcf Fiberglass

Setpoint	Thermocouple
*1139 DegF	338 DegF

*40 DegF Temperature drop upon opening drawer

Afterflame (seconds)	Flame Propagation
2.5	0.75
0	0.75
0	0.75

RP Heat Flux Gage Calibration / Sensitivity Study

2.) Polyimide film over 2 layers of 0.34 pcf Fiberglass

Setpoint	Thermocouple
*1143 DegF	354 DegF

***40 DegF Temperature drop upon opening drawer**

Afterflame (seconds)	Flame Propagation
0	0.75
1	0.75
3	0.75

3.) Metallized PEEK Film over 2 layers of 0.34 pcf Fiberglass

Setpoint	Thermocouple
1143 DegF	354 DegF

Afterflame (seconds)	Flame Propagation
0	1.5
0	1.0
0	1.75

4.) Material 1

Setpoint	Thermocouple
1142 DegF	350 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	1.0	Pass
0	1.0	Pass
0	0.75	Pass

RP Heat Flux Gage Calibration / Sensitivity Study

5.) Material 2

Setpoint	Thermocouple
1142 DegF	350 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	1.25	Pass
*6.5	0.75	Fail
0	0.75	Pass

*Around top of ignitor

6.) Material 3

Setpoint	Thermocouple
1142 DegF	350 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	1.0	Pass
0	0.75	Pass
0	1.5	Pass

7.) Material 4

Setpoint	Thermocouple
1142 DegF	350 DegF

Afterflame (seconds)	Flame Propagation	Pass/Fail
0	1.0	Pass
0	1.0	Pass
0	1.0	Pass

Seat Test Heat Flux Gage Calibration / Sensitivity Study

- **Compared which method of seat testing would be most affected by heat flux measurements, the handbook method or the rule.**
  - Two Vatell gages of same range (0-20 BTU) using Manufacturer's Calibration factor and FAA (NIST) Calibration Factor

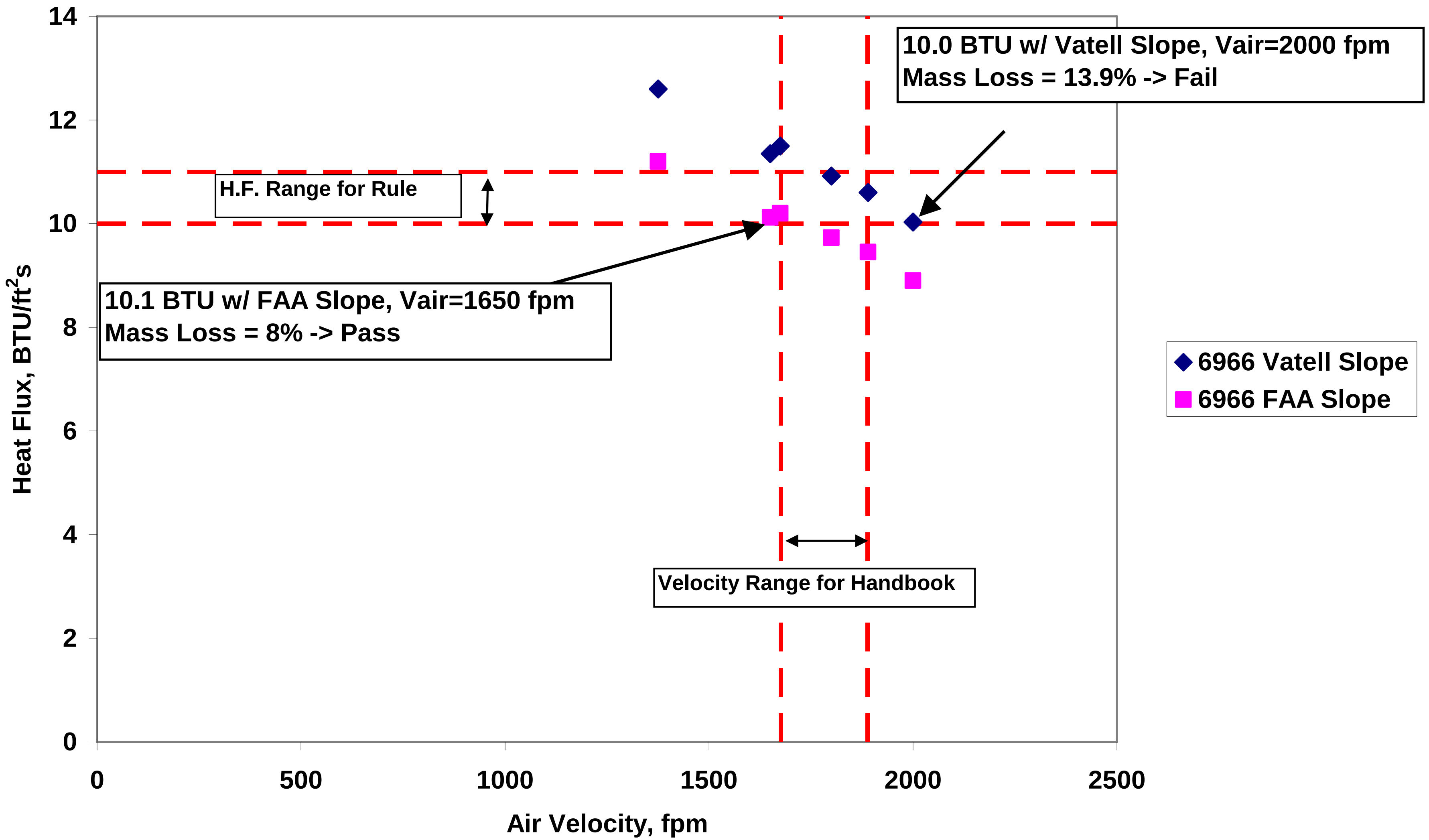
- **Handbook**
  - Air velocity is restricted to a certain range but the heat flux must be a minimum of 10 BTU/ft^{2*}sec (no maximum).
- **Rule**
  - No specification for velocity - Any air velocity that gets you to a specified range of heat flux (10.5 BTU/ft2s +/- 0.5 BTU/ft2s).

- **Typically the measured flame temperatures are difficult to achieve, while heat flux is relatively easy to get.**

- **Measured temperatures at two air velocities and found the temperatures to be in calibration.**

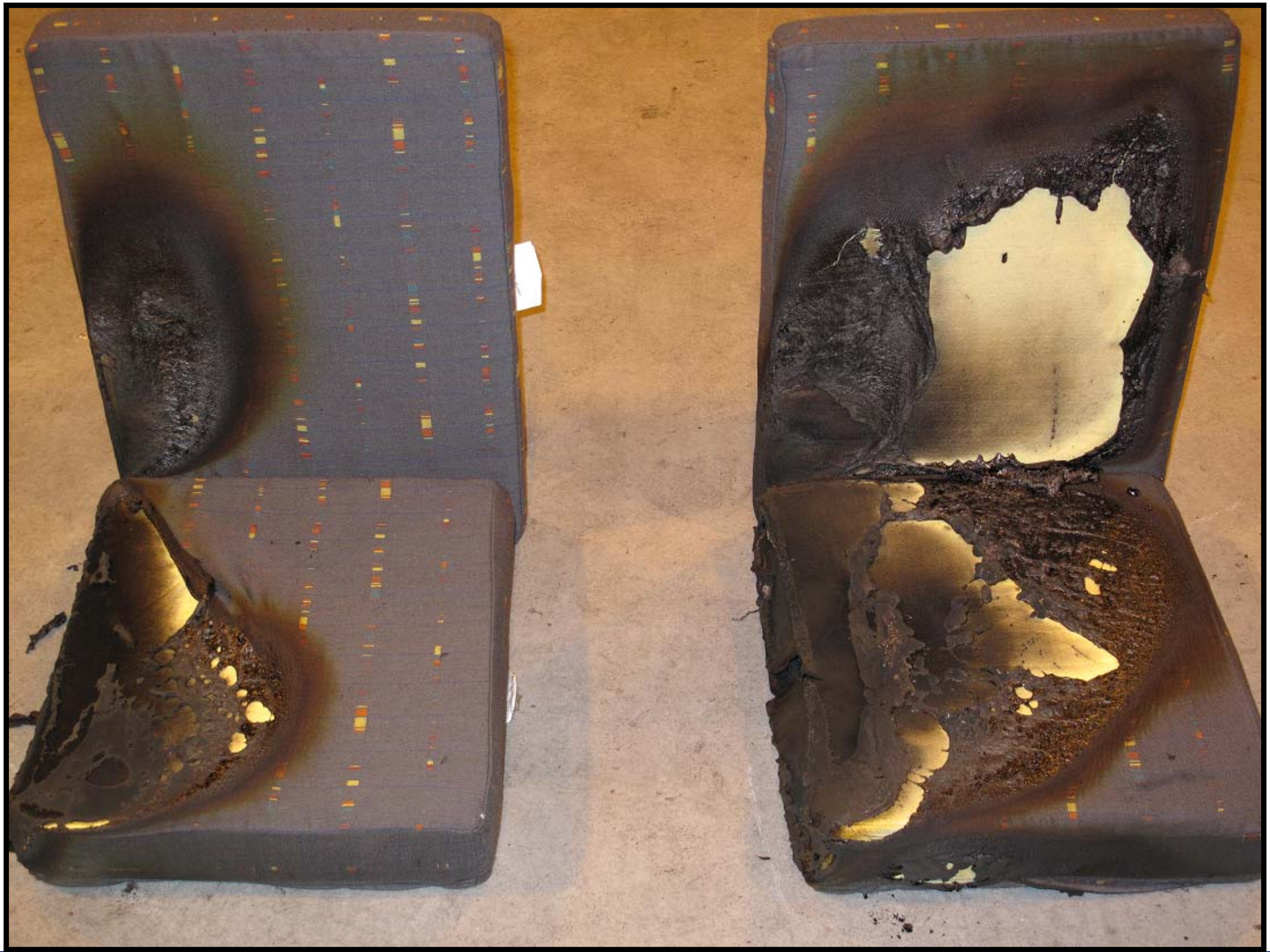
- **Looked at how measured heat flux changes with air velocity and what the test results would be at the minimum heat flux (10 BTU/ft^2*sec) for the FAA (NIST) Calibration Factor and Vatell Calibration Factor.**

Measured H.F. vs. Burner Inlet Air Velocity



V_{air}=1650 fpm; H.F.=10.1 BTU/ft^{2}s (FAA Slope) Mass Loss = 8% → Pass

V_{air}=2000 fpm; H.F.=10.0 BTU/ft^{2}s (Vatell Slope) Mass Loss = 13.9% → Fail



- **Results**
  - As inlet air velocity increases, measured heat flux decreases.
  - Since the handbook has a specified range of air velocities, we ran the tests by the rule, which has an unlimited velocity range but specified H.F range.
  - We wanted to see that if you set the burner for 10 BTU/ft^2*sec (minimum H.F.) with both of the slopes, how the results would compare.
- **Vatell Calibration Factor**
  - Set Burner to 10 BTU/ft^2*sec
    - Increased air velocity to 2000 fpm
  - Tested seat - mass loss of 13.9% (failure)
- **FAA (NIST) Calibration Factor**
  - Set burner to 10 BTU/ft^2*sec
    - Decrease of air velocity to 1650 fpm
  - Tested seat - mass loss of 8% (pass)
- **Summary**
  - Just going by heat flux, if a lab wanted to run at 10 BTU/ft2s, which one would assume would give you the least conservative flame, the test would fail if you used the vatell slope and pass If you used the FAA slope.
  - This is opposite of what everyone else is probably seeing, because for the radiant heat sources, a vatell slope will give you a heat flux that is higher than what the true heat flux is with the FAA slope, and materials that pass with a vatell slope will fail with an FAA slope.
  - This burner has a convective portion of total heat transfer that is probably close to the magnitude of the radiant portion.
  - Gardon gauges are particularly sensitive to convection, and since they are calibrated with a pure radiation source, they may be giving readings that aren't indicative of the actual total heat flux to the surface in the oil burner.