Summary of Airflow Effects on Material Heat Release Results using OSU Calorimeter

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ECCN 9E991

Discussion Topics

- Summary of airflow studies conducted in recent past
- Proposed testing to be conducted in the near future
- Further discussion

Goal: Establish an accurate baseline for the OSU tests industry-wide by understanding and then controlling the possible variation due to airflow

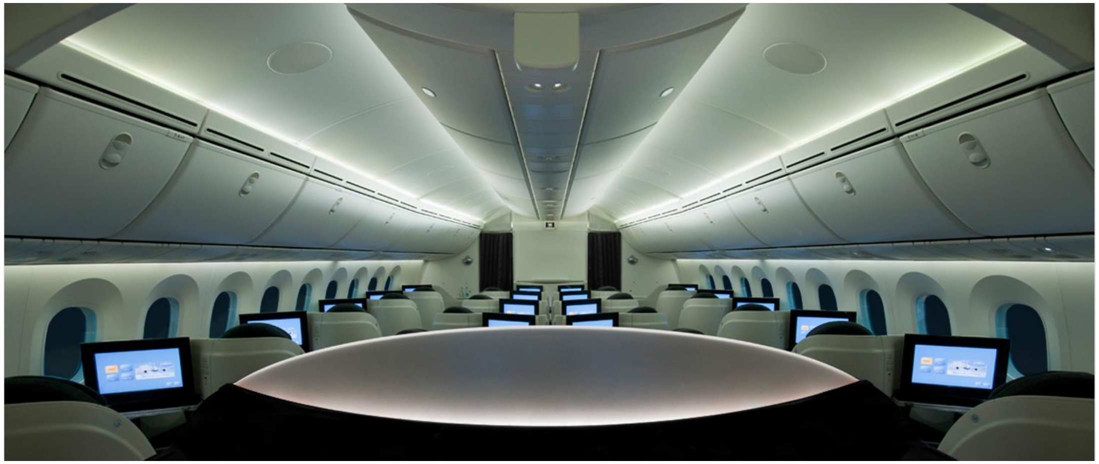
Material Heat Release Testing

Heat Release is the amount of heat energy created by a material when burned[1]

The heat release of materials used (in airplanes) drives occupant survivability …dictating how quickly the conditions progress to flashover[2].

The heat release rate test measures both total heat release and peak heat release rate.

Large surfaces in the passenger cabin, including partitions, ceilings, and wall panels must meet heat release rate (HRR) requirements.

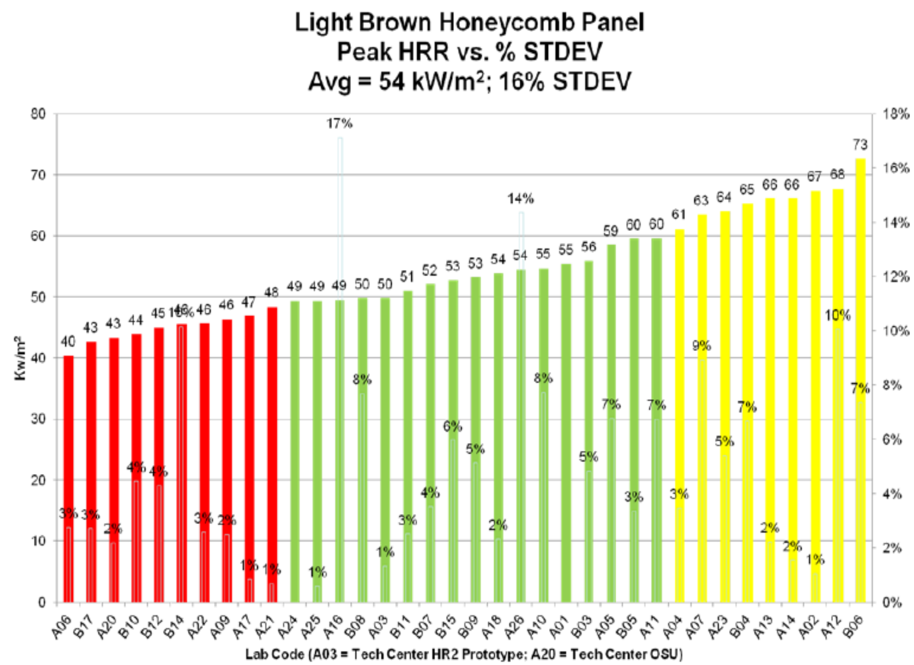


787 business class interior illustrating multiple large surfaces requiring heat release testing

[1,2]**Federal Register** /Vol. 84, No. 128 /Wednesday, July 3, 2019 / Proposed Rules

OSU - Current Material Heat Release Test Method

- Reproducibility challenges persist
- Specification does not tightly control some key parameters
- Decades of certification data in use



*Data compiled by FAA and *Presented June 2012*

14CFR25.853(d)

- 65/65 requirement added in 1990
- Current § 25.853(d) and Part IV of Appendix F to Part 25
- Applicable to large exposed interior surfaces
- Regulates heat release as a function of time

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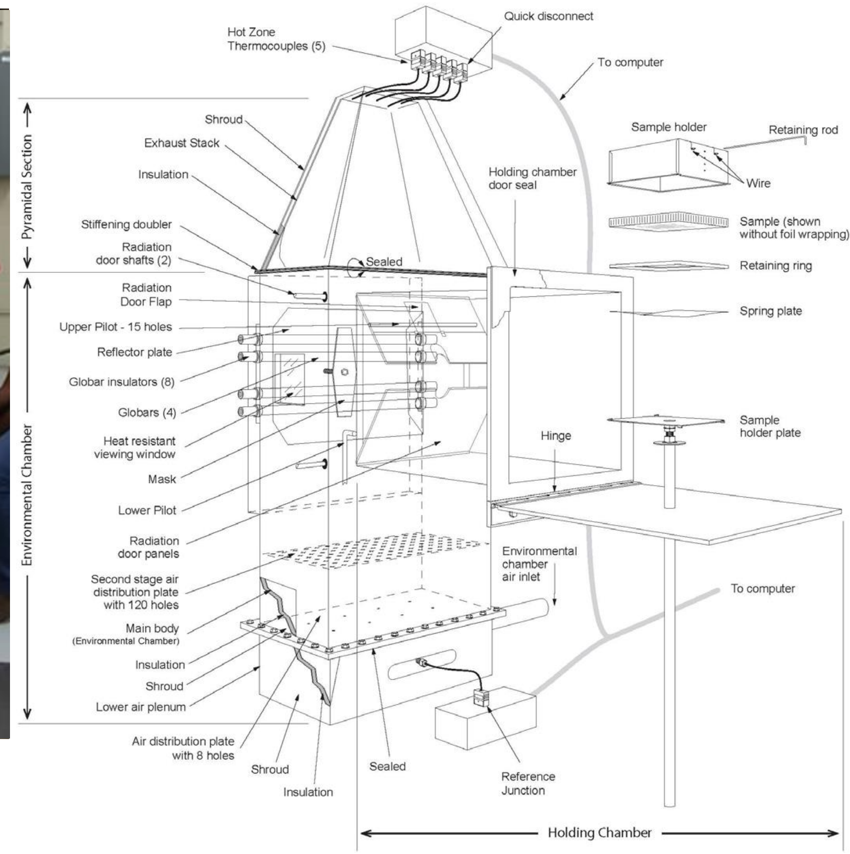
HR2 - Next Generation Material Heat Release Test Method



Aircraft Materials Fire Test Handbook, Revision 3, Chapter A-4

Design and Other Changes

- Aircraft Materials Fire Test Handbook, Revision 3, Chapter A-4
- Elimination of cooling flow / inner chimney
- Construction & procedural improvements
- Mass flow controlled air and gas flows
- Tighter operating parameter ranges vs. OSU

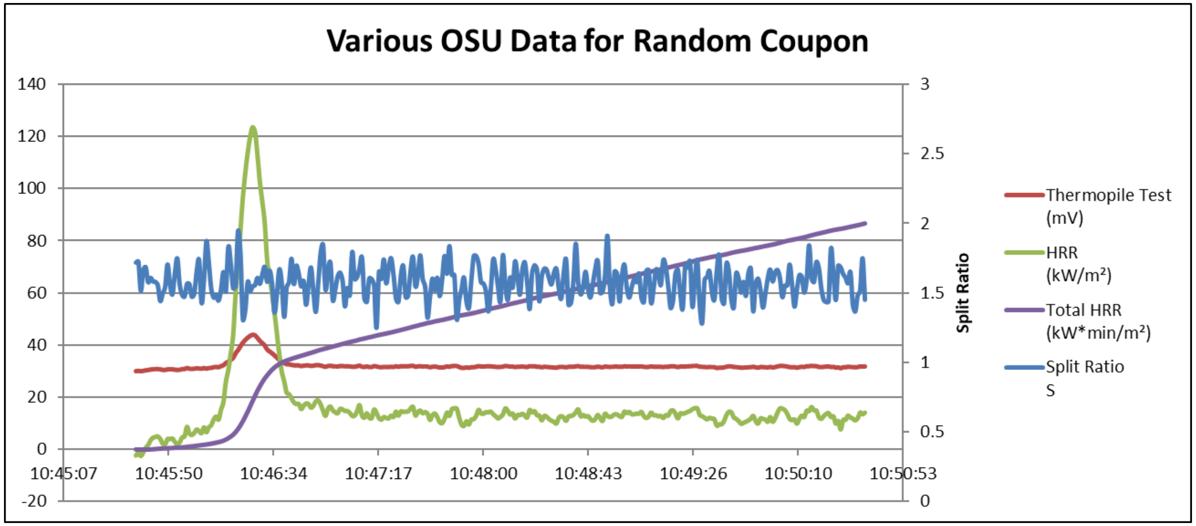
Anticipated Improvements

- *Repeatability* driven by design and cal changes
- *Reproducibility* increased via spec controls
- Cross industry variation greatly reduced

**Presented June 2017*

Airflow Studies Summary

- In 2015, data was presented from an OSU unit based in Charleston that checked the effect of total airflow and the airflow split ratio on the OSU parameters (peak heat, 2-minute total, and peak time).
- The test utilized common honeycomb sandwich panel with standard decorative laminate as well as a thin aluminum panel with a standard 3-M homogeneous tape.
- Data loggers recorded multiple parameters simultaneously, allowing for an in-depth review of heat release behavior.



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Airflow Studies Summary

- **Multiple relationships were observed with high correlations:**

Note: Split Ratio 3:1 Cooling Air / Chamber Air

- Total Airflow variation and Split Ratio variation *are not* accounted for during calibration

- Heat Release behaves linearly with respect to Airflow (both aluminum & standard coupons):
  - Maintaining a 3:1 Split Ratio: The more total air into the system, the higher the peak.
  - Fluctuating Split Ratio: The lower the split ratio, the higher the peak.
  - Maintaining a 3:1 Split Ratio: The more total air into the system, the higher the 2-min total
  - Fluctuating Split Ratio: The lower the split ratio, the higher the 2-min total.

- Regarding the Calibration Constant (both aluminum & standard coupons):
  - Keeping a 3:1 Split Ratio: The more total air into the system, the higher the calibration constant
  - Fluctuating Split Ratio: The lower the split ratio, the higher the calibration constant

Airflow Studies Summary

- Later in 2015, the Charleston experiment was repeated using an OSU based in Everett, Washington.
- The same trends observed in Charleston were observed in Everett
- Evidence pointed to airflow and split ratio being major contributors to OSU variability.
- Government / Industry team agrees to conduct round robin capturing multiple parameters and submitted data for trend analysis

Airflow Studies Summary

- The Great Round Robin of 2016 captured data from a total of 31 Laboratories

Summary of the critical parameters are shown below:

Total Airflow:
- **Average (μ): 87.74 CFM (Expecting 85 CFM)**
- **Standard Deviation (σ): 9.67**
- **Coefficient of Variation (% σ): 11.02 %**

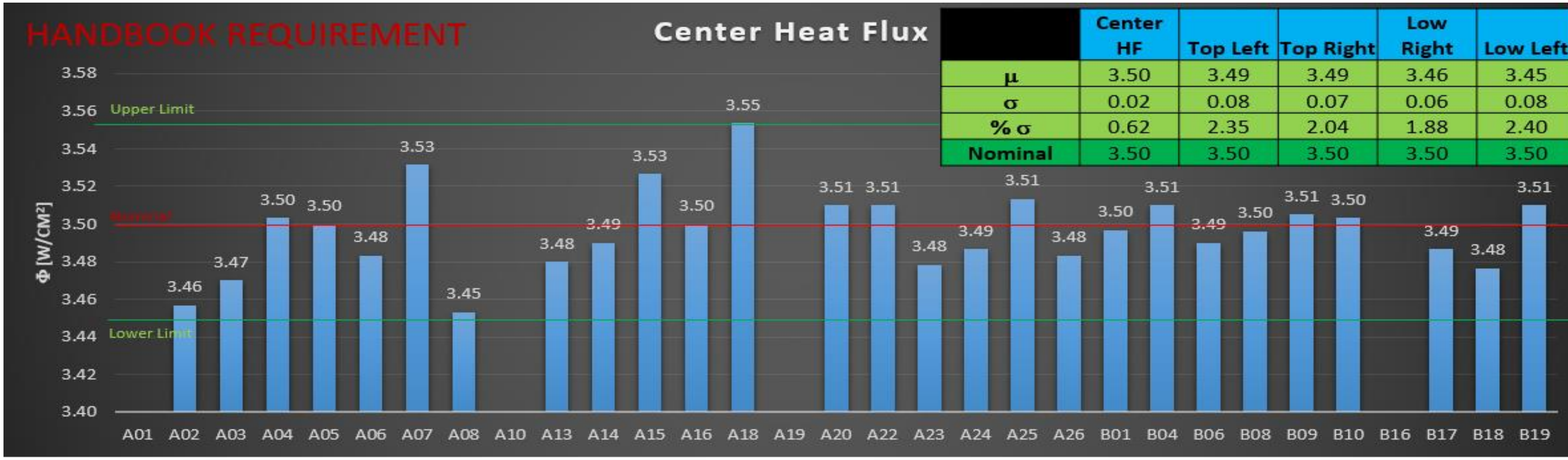
Split Ratio:
- **Average (μ): 3.22 (Expecting 3.0)**
- **Standard Deviation (σ): 0.78**
- **Coefficient of Variation (% σ): 24.17 %**

Differential Pressure:
- **Average (μ): 106.81 in H2O (Expecting 107 in H2O)**
- **Standard Deviation (σ): 2.90**
- **Coefficient of Variation (% σ): 2.72%**

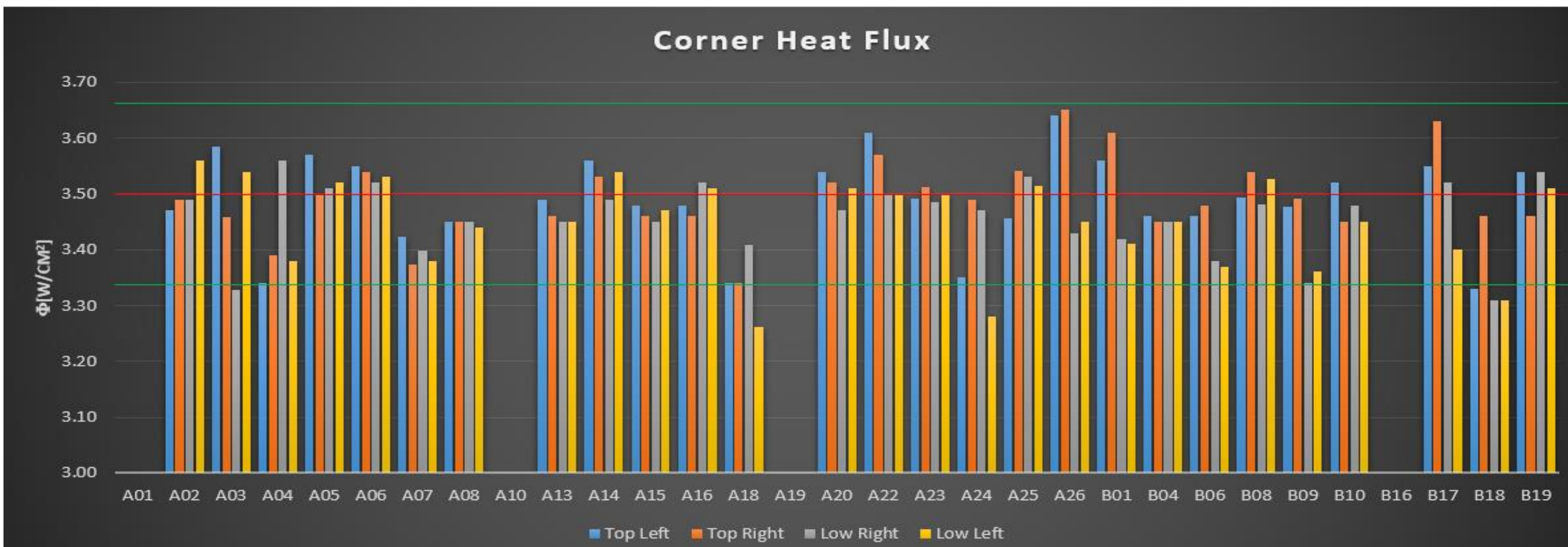
*Data compiled by FAA and *Presented in Kansas City, June 2016*

Airflow Studies Summary

*Data compiled by FAA and *Presented in Kansas City, June 2016*



	Center HF	Top Left	Top Right	Low Right	Low Left
μ	3.50	3.49	3.49	3.46	3.45
σ	0.02	0.08	0.07	0.06	0.08
% σ	0.62	2.35	2.04	1.88	2.40
Nominal	3.50	3.50	3.50	3.50	3.50



Airflow Studies Summary

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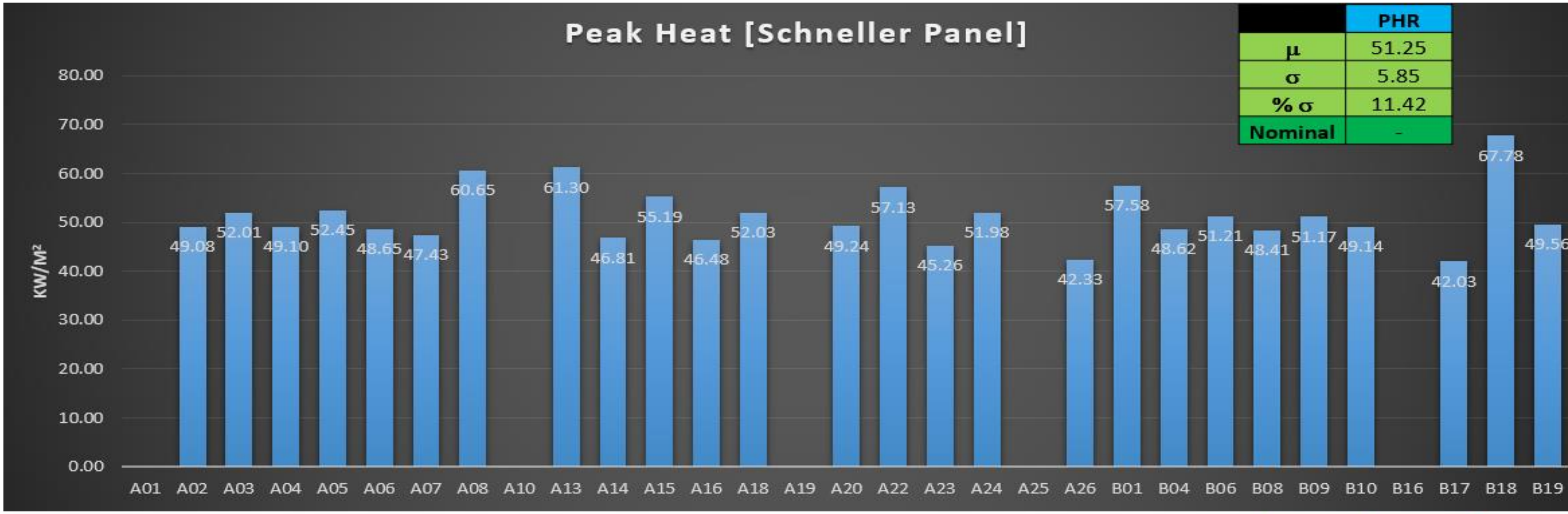
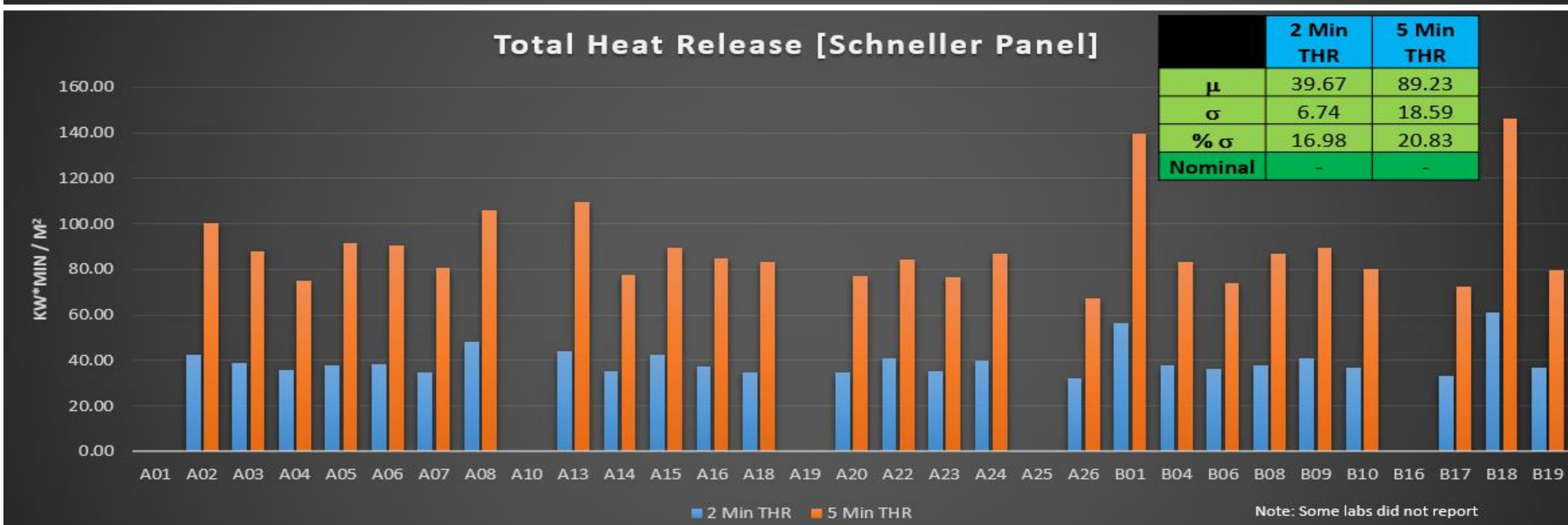




Airflow Studies Summary

- The results of the Great Round Robin of 2016 raised more questions:

- No root cause regarding industry HRR variability was evident in the data captured during the 2016 round robin. Observed correlations (airflow to HRR) presented during previous meetings not evident in data with industry as a whole.

- An increase in correlations among OSU parameters occurs when analyzing data per manufacturer – suggesting another source of variability can be introduced during the manufacturing of individual OSU equipment.

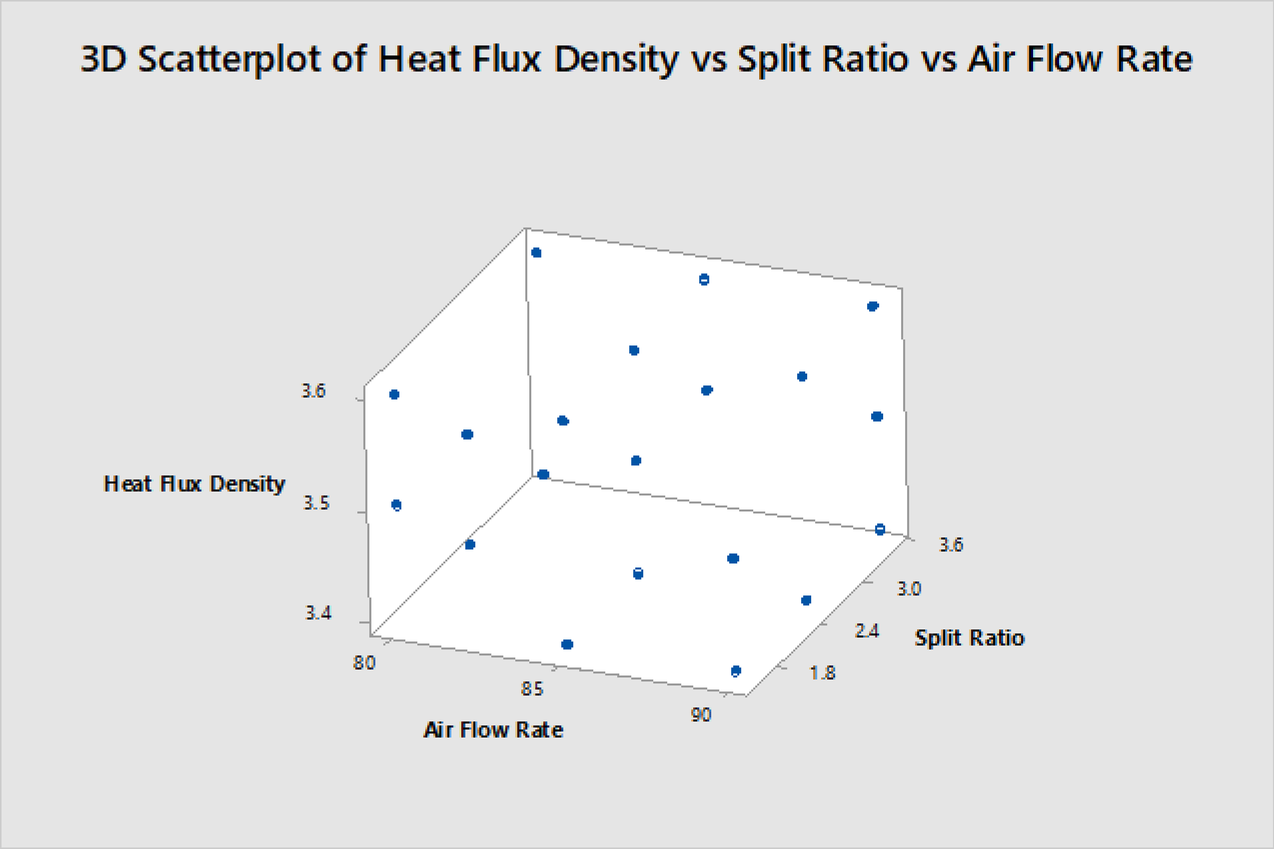
- However, as more laboratories reported data from OSUs made by the same manufacturer, the observed correlations decreased in values – suggesting variability is individualized per machine (equipment manufacturing, operation, system set up, local conditions etc….)

- If variability is unique to each machine, resolving it becomes extremely difficult.

Next Steps / Future Testing

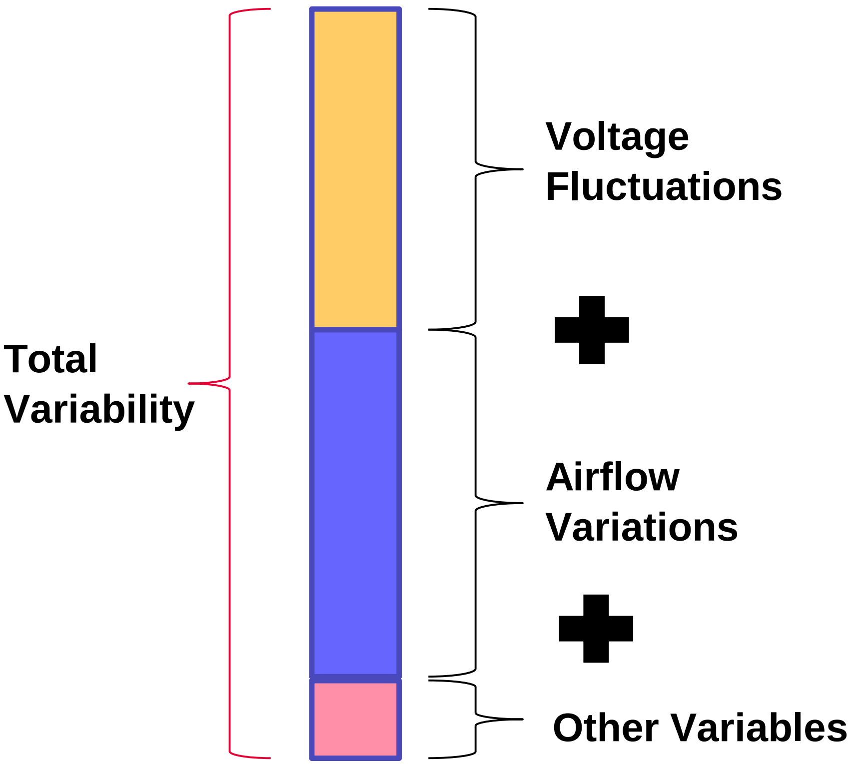
Conduct Design of Experiment testing to determine the individual contribution of each of the three variables (Airflow, Split Ratio, and Voltage Fluctuation) to the Heat Release Results

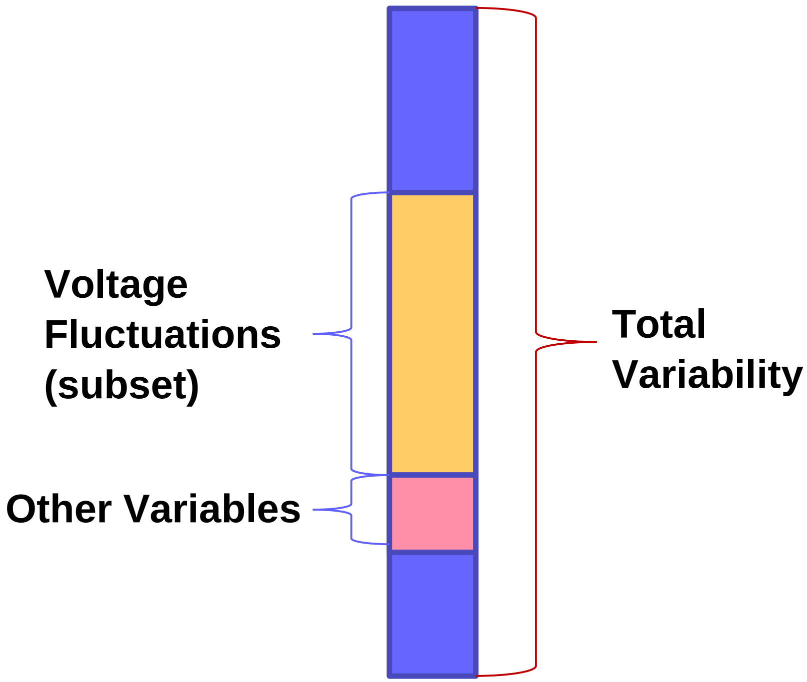
- The experiment will provide a 3-Dimensional scatter plot, allowing for simultaneous analysis of key parameters



Next Steps / Future Testing

The DOE study may also be able to statistically show if variations due to voltage fluctuations and airflow variations are additive or if they are integrated





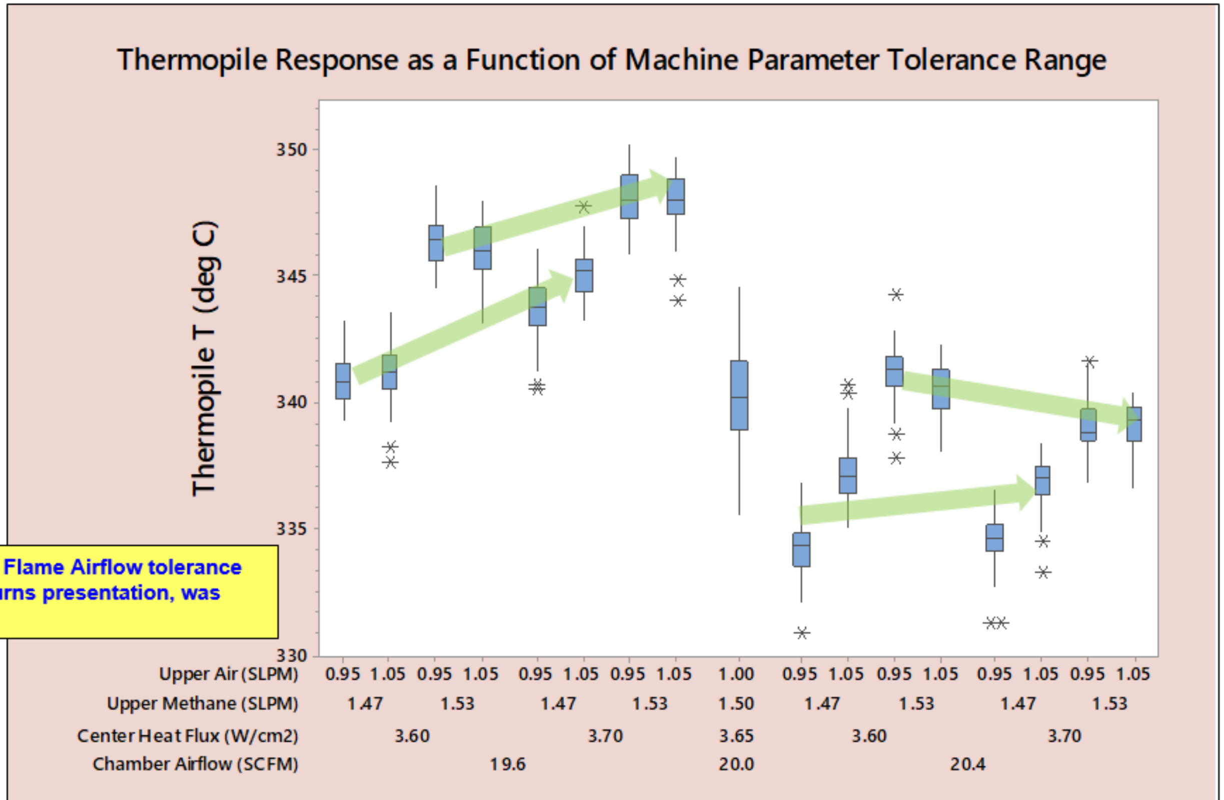
ADDITIVE EFFECTS

INTEGRATED EFFECTS

Next Steps / Future Testing Rationale

HR2 DOE II study presented by Boeing statistician Dr. Thomas W. Little in Atlantic City, NJ 2017 concluded:

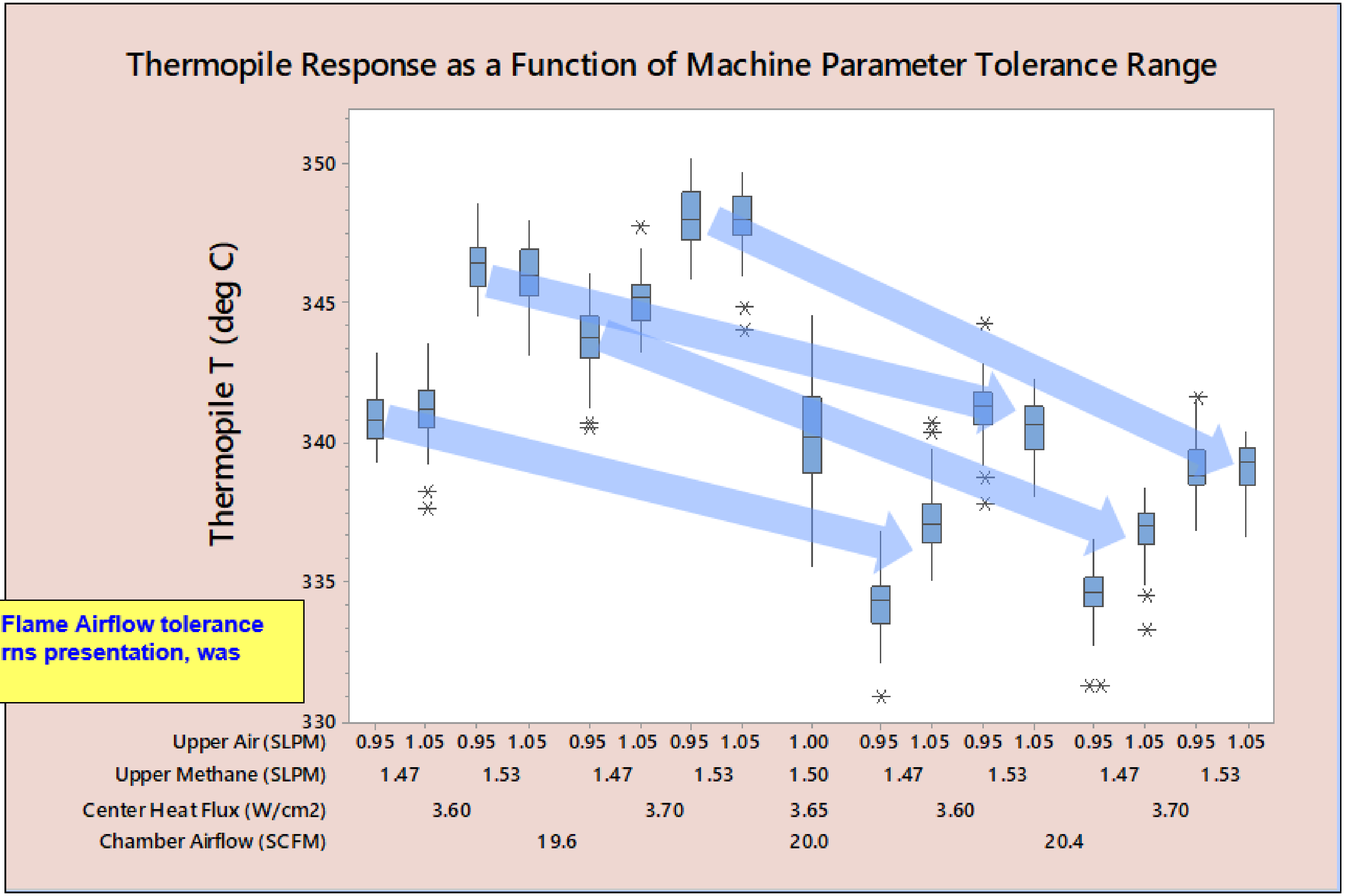
- **Factor Effects**
  - **Heat Flux**: 3.65±0.05 W/cm^2
  - "Moderate" impact: ΔT approximately -2 to +3 deg C for full-scale swing of 3.60 -> 3.70 W/cm^2



Actual Upper Pilot Flame Airflow tolerance range, per Mike Burns presentation, was 1.00±0.02.

Next Steps / Future Testing Rationale

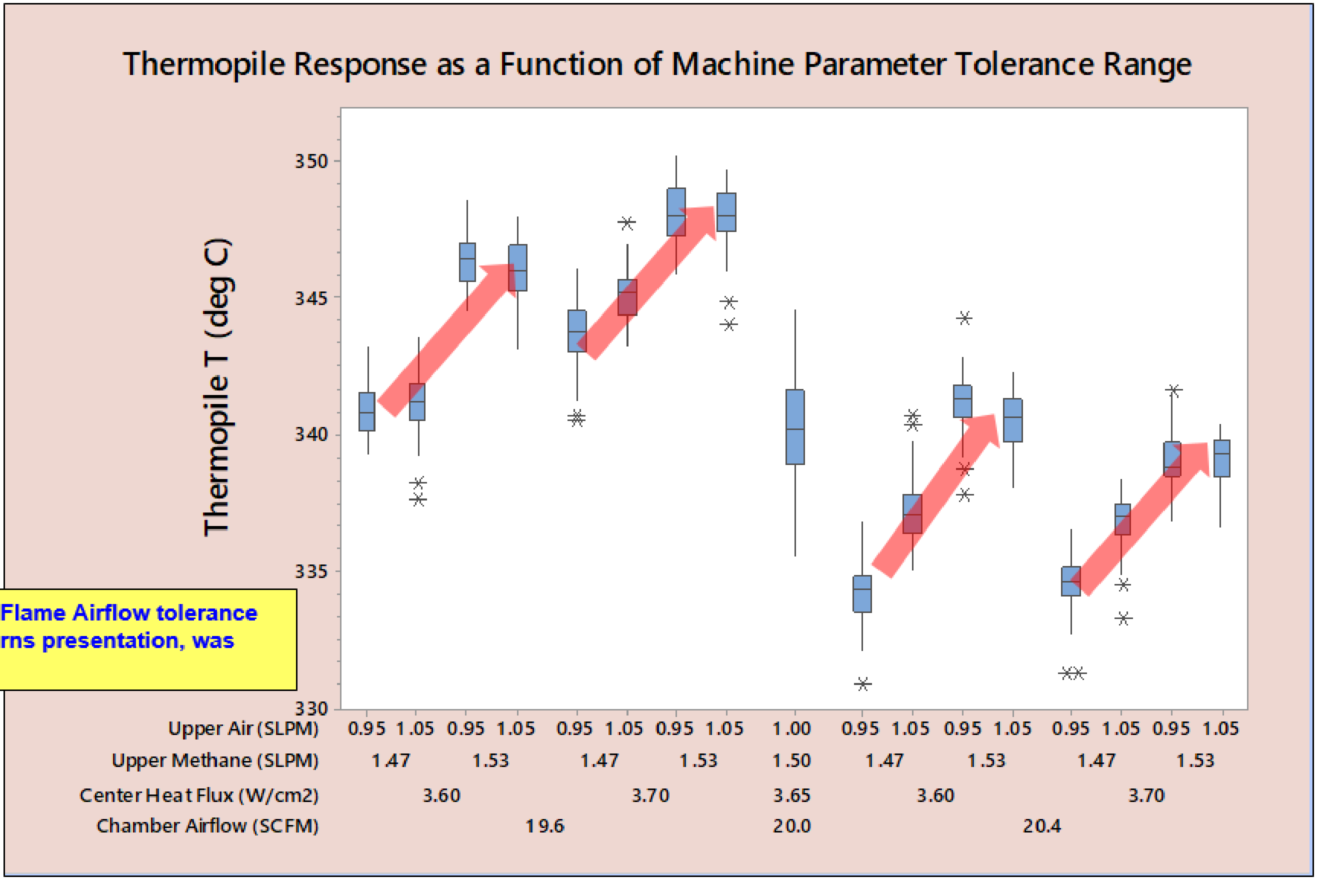
- **Factor Effects**
  - **Chamber Airflow**: 20±0.4 SCFM
  - "Large" impact: ΔT approximately -5 to -9 deg C for full-scale swing of 19.6 -> 20.4 SCFM



Actual Upper Pilot Flame Airflow tolerance range, per Mike Burns presentation, was 1.00±0.02.

Next Steps / Future Testing Rationale

- **Factor Effects**
  - **Upper Pilot Methane Flow**: 1.50±0.03 SLPM
  - “Large” impact: ΔT approximately +5 deg C for full-scale swing of 1.47 -> 1.53 SLPM



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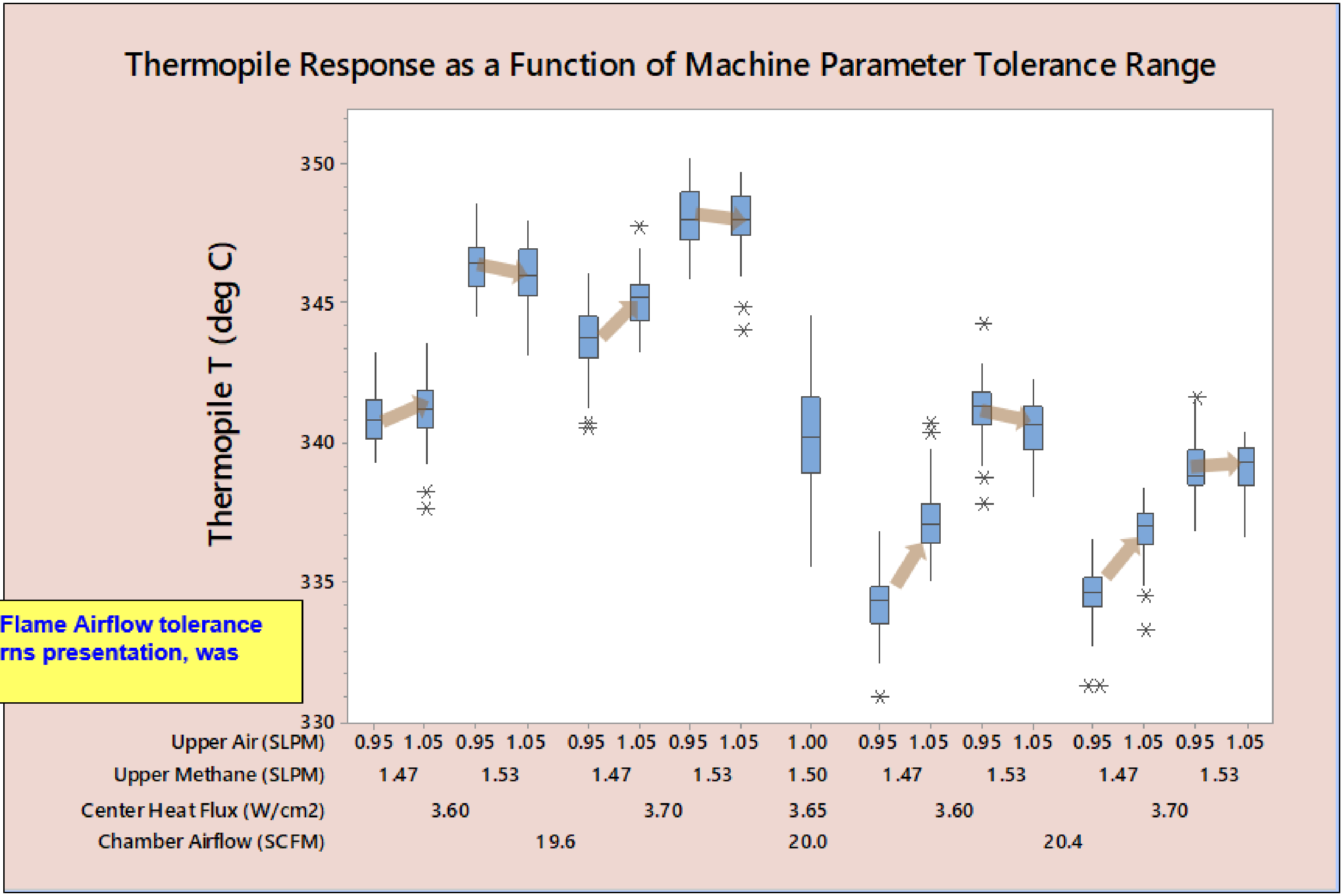
Next Steps / Future Testing Rationale

- **Factor Effects**
  - **Upper Pilot Airflow**: 1.00±0.0.05 SLPM
  - "Slight" impact: ΔT approximately -0.4 to +2 deg C for full-scale swing of 0.95 -> 1.05 SLPM

0.98 -> 1.02 SLPM



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Presented by: Dr. Little, Atlantic City, NJ Oct 2017

Next Steps / Future Testing Rationale

- **Factor Effects Summary**
  - Assessment of machine tolerance ranges
    - Heat flux: Moderate effect
    - Chamber airflow: Large effect
    - Upper methane flow: Large effect
    - Upper air flow: Slight effect

Applicable to OSU improvement & HR2 implementation

Future Test / Test Methodology

$y = \beta_{HFD}x_{HFD} + \beta_{SR}x_{SR} + \beta_{AR}x_{AR} + \beta_{HFD*SR}x_{HFD*SR} + \beta_{HFD*AR}x_{HFD*AR} + \beta_{SR*AR}x_{SR*AR} + \beta_{HFD*AR*SR}x_{HFD*AR*SR} + \epsilon$ where $\epsilon \sim N(0, \sigma^2)$

Heat Flux Density W/cm^2	Split Ratio	Air Flow Rate SCFM
3.6	3.5	95
3.6	3.5	85
3.6	2.5	95
3.6	3.5	75
3.4	3.5	95
3.6	1.5	95
3.4	3.5	85
3.5	1.5	95
3.6	2.5	85
3.4	2.5	95
3.6	1.5	75
3.5	3.5	75
3.5	1.5	75
3.4	2.5	85
3.5	3.5	85
3.5	2.5	95
3.6	1.5	85
3.6	2.5	75
3.4	3.5	75
3.4	1.5	95
3.5	2.5	85
3.4	1.5	85
3.4	2.5	75
3.5	2.5	75
3.5	1.5	85
3.4	1.5	75
3.5	1.5	75
3.5	3.5	95
3.4	3.5	85
3.5	2.5	85

Experimental Procedure Preparations

1. Reconfigure air flow piping to independently distribute air to the lower plenum and cooling manifold
2. Connect voltage logger to heat release unit electrical terminal to measure and record electrical supply voltage to the unit
3. Assemble methane gas calibration tools

Conducting Tests

1. Set total air flow to desired flow rates
2. Set lower plenum and cooling manifold to desired air flow rates
3. Stabilize OSU unit for 1.5 hours
4. Set heat flux density to desired heat flux
5. Conduct methane gas calibration at the set air flow rates and heat flux density
6. Test two standard coupons and record data in matrix
7. Repeat for next run

Discussion

- Data gathered expected to be presented at next meeting (March 2020)
- Industry laboratories may use data to improve individual OSUs.
  Note: Some changes to configuration may require FAA approval.
- Data may be used by HR2 development teams to further tweak parameters

Questions?

Thank you for your time !

Contact Information

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