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OSU Calorimetry Test BSS7322

Numerical Acquisition of OSU Airflow Data and Its Effects on Heat Release Results

Everett Unit and Comparison with Charleston Unit

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Topics of Discussion:

- Motivation behind continued OSU study

- Review observations from Charleston OSU machine

- Setup and testing using the Everett OSU machine

- Results and trends observed using the Everett OSU machine

- Compare results for Everett and Charleston machines

- Future Work: Government / Industry joint discussion – to follow up in task group meeting

Motivation Behind Study:

- **The Ohio State University Calorimetry (OSU) test used throughout the aircraft industry to determine the heat release of panels flown in the aircraft cabin interior**

  - Significant variation in round robin data acquired among industry labs has been noted
  - Roughly 50 % of variation remains unexplained
  - FTWG making progress in determining root cause
  - Airflow highly suspected

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

Observations from Charleston:

Presented at the FAA Meeting Huntington Beach, California February 2015

- **Total Airflow variation and Split Ratio variation *are not* accounted for during Calibration.**
  - Calibration constant varies with respect to airflow & split ratio changes
  - Peak and 2-min total heat release also vary with calibration constant change

- **Heat Release behaves linearly with respect to Airflow (both Aluminum & Standard coupons):**
  - Keeping 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.

  - Keeping 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 cal-constant
  - Fluctuating Split Ratio: The lower the split ratio, the higher the cal-constant

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Test Methodology / Matrix:

60 Tests targeted to check effect of total airflow and airflow split ratio on OSU parameters

TEST MATRIX (Airflow Nominal)

Note: X%/Y% means Bypass Airflow % / Chamber Airflow

Note: Total airflow in this testing should be set to 85

TEST SETUP 1 Targeting 75%/25% Split

AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
a	AL Run 1	α	STD Run 1
b	AL Run 2	β	STD Run 2
c	AL Run 3	γ	STD Run 3
d	AL Run 4	δ	STD Run 4
e	AL Run 5	ε	STD Run 5

TEST SETUP 2: Targeting 70%/30% Split

AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
f	AL Run 1	ζ	STD Run 1
g	AL Run 2	η	STD Run 2
h	AL Run 3	θ	STD Run 3
i	AL Run 4	ι	STD Run 4
j	AL Run 5	κ	STD Run 5

TEST SETUP 3: Targeting 60%/40% Split

AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
k	AL Run 1	λ	STD Run 1
l	AL Run 2	μ	STD Run 2
m	AL Run 3	ν	STD Run 3
n	AL Run 4	ξ	STD Run 4
o	AL Run 5	ο	STD Run 5

TEST SETUP 4: Targeting 50%/50% Split

AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
p	AL Run 1	π	STD Run 1
q	AL Run 2	ρ	STD Run 2
r	AL Run 3	σ	STD Run 3
s	AL Run 4	τ	STD Run 4
t	AL Run 5	υ	STD Run 5

TEST MATRIX (Airflow Low)

Note: X%/Y% means Bypass Airflow % / Chamber Airflow %

Note: Total airflow in this testing should be set to 65 SCFM.

TEST SETUP 5 Targeting 75%/25% Split

AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
u	AL Run 1	ϕ	STD Run 1
v	AL Run 2	χ	STD Run 2
w	AL Run 3	ψ	STD Run 3
x	AL Run 4	ω	STD Run 4
y	AL Run 5	αα	STD Run 5

TEST MATRIX (Airflow High)

Note: X%/Y% means Bypass Airflow % / Chamber Airflow %

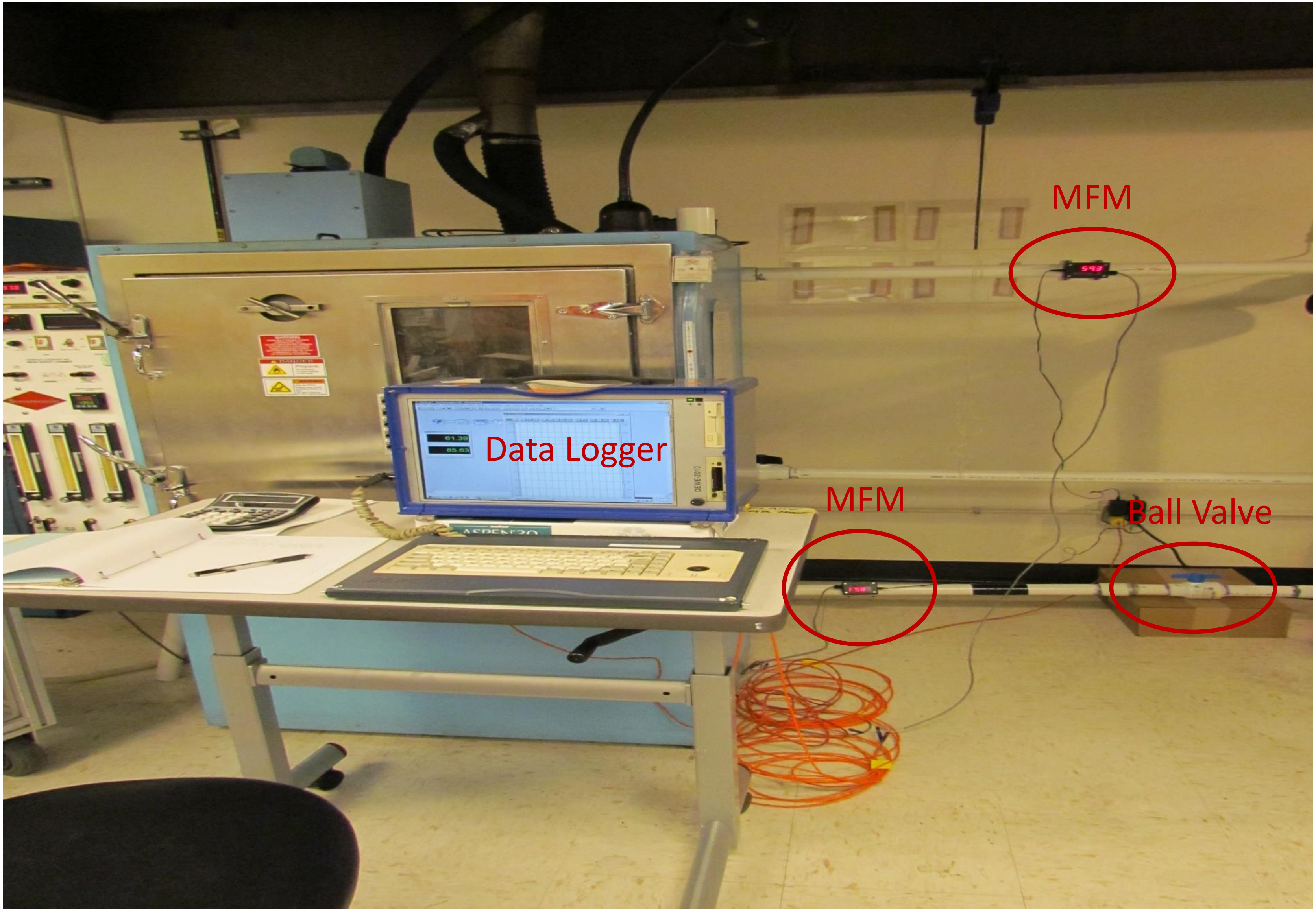
Note: Total airflow in this testing should be set to 105 SCFM.

TEST SETUP 6 Targeting 75%/25% Split

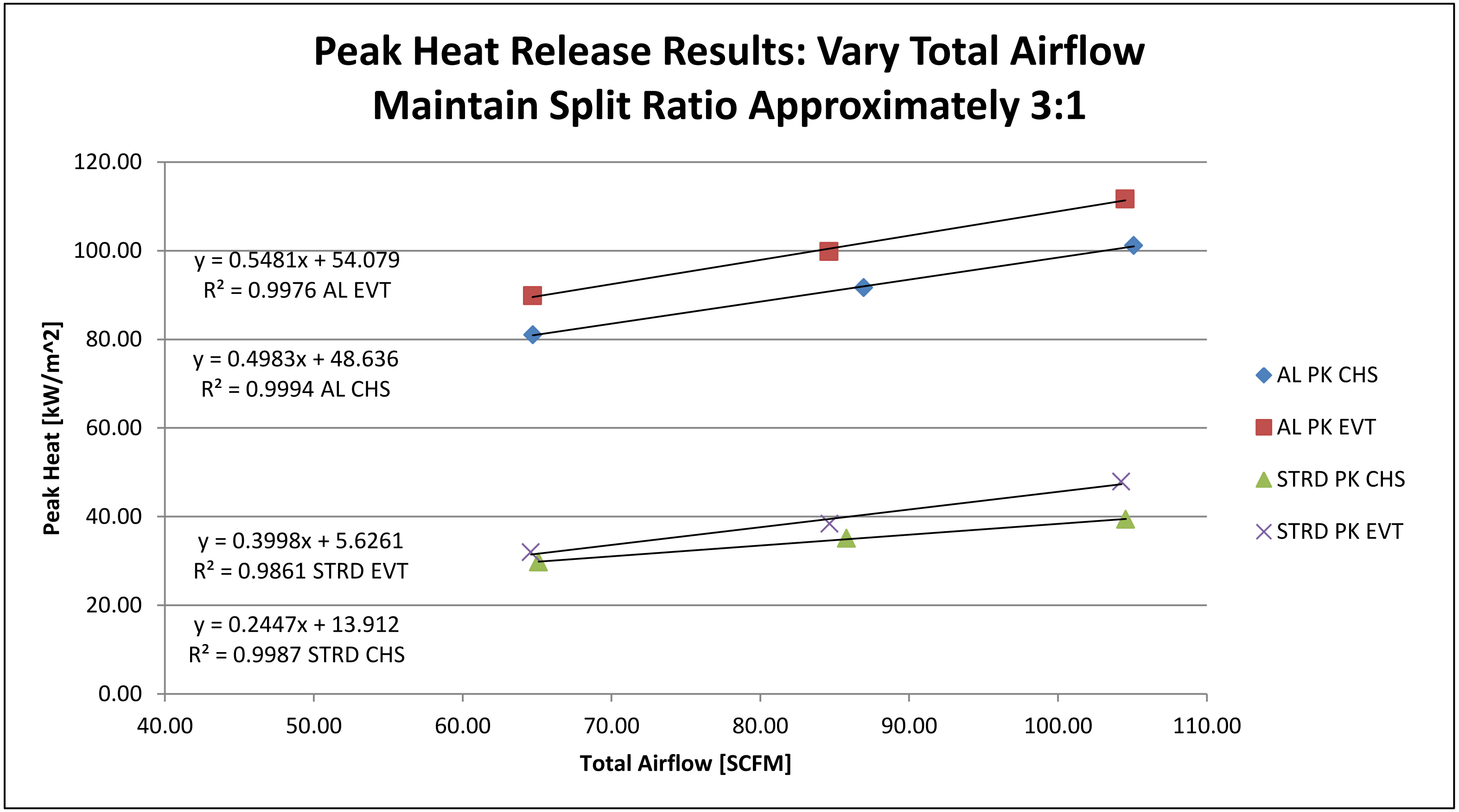
AL Panel Index	*AL Run*	*STD Panel Index*	*STD Run*
z	AL Run 1	αβ	STD Run 1
aa	AL Run 2	αγ	STD Run 2
ab	AL Run 3	αδ	STD Run 3
ac	AL Run 4	αε	STD Run 4
ad	AL Run 5	αζ	STD Run 5

Note: Wet test & both center and corner heat flux calibrations were performed during EACH change in airflow and EACH split ratio change.

Additionally, the ashes were vacuumed out during EACH run of the standard panel. Little to no debris accumulation in chamber.


MFM
Data Logger
MFM
Ball Valve

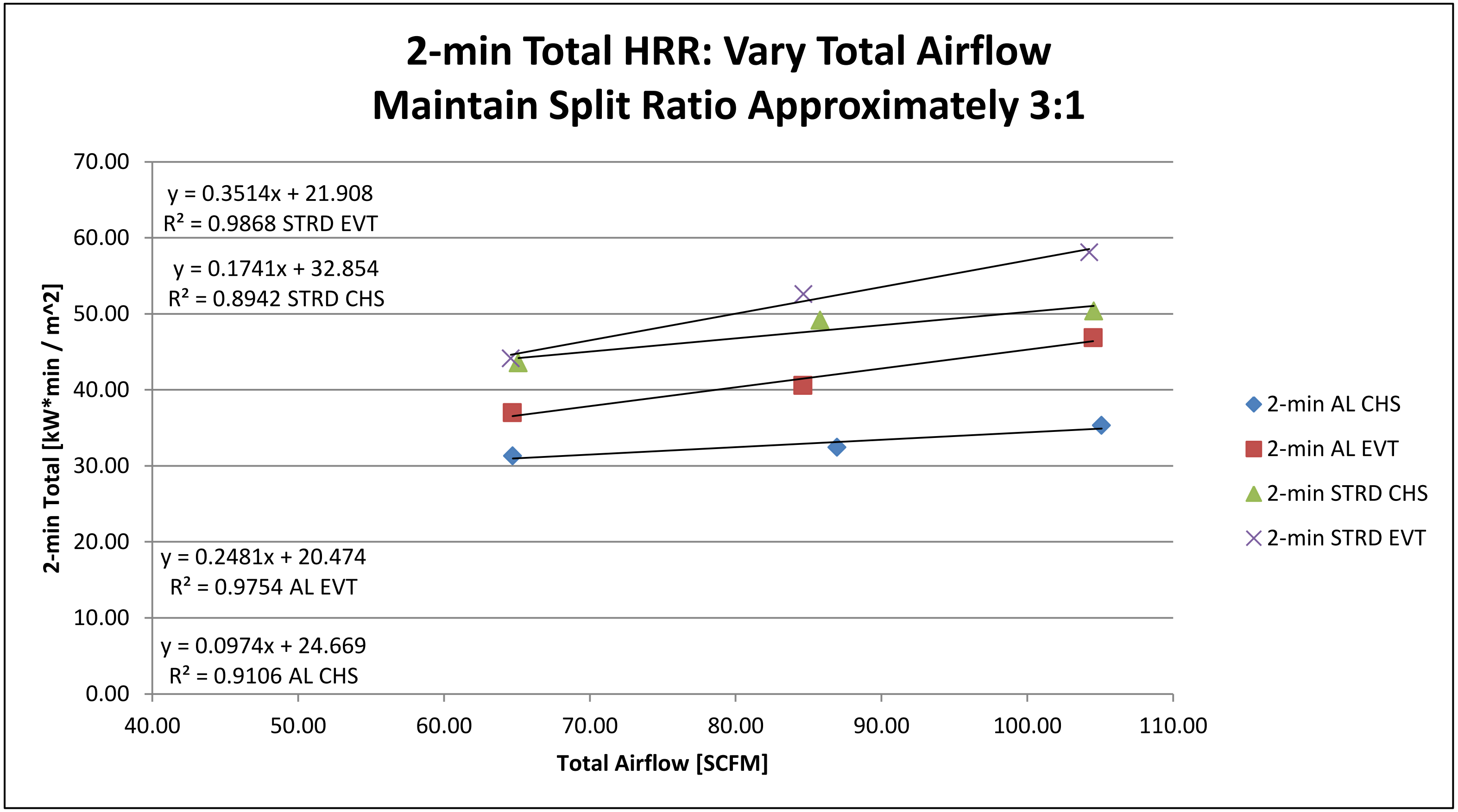
Effects of Varying Total Airflow
&
Maintaining Approximately 3:1 Split Ratio



Notes: Similar linear trend is observed between laboratories

Average Split Ratio During Testing (CHS): 3.11 (EVT): 2.92

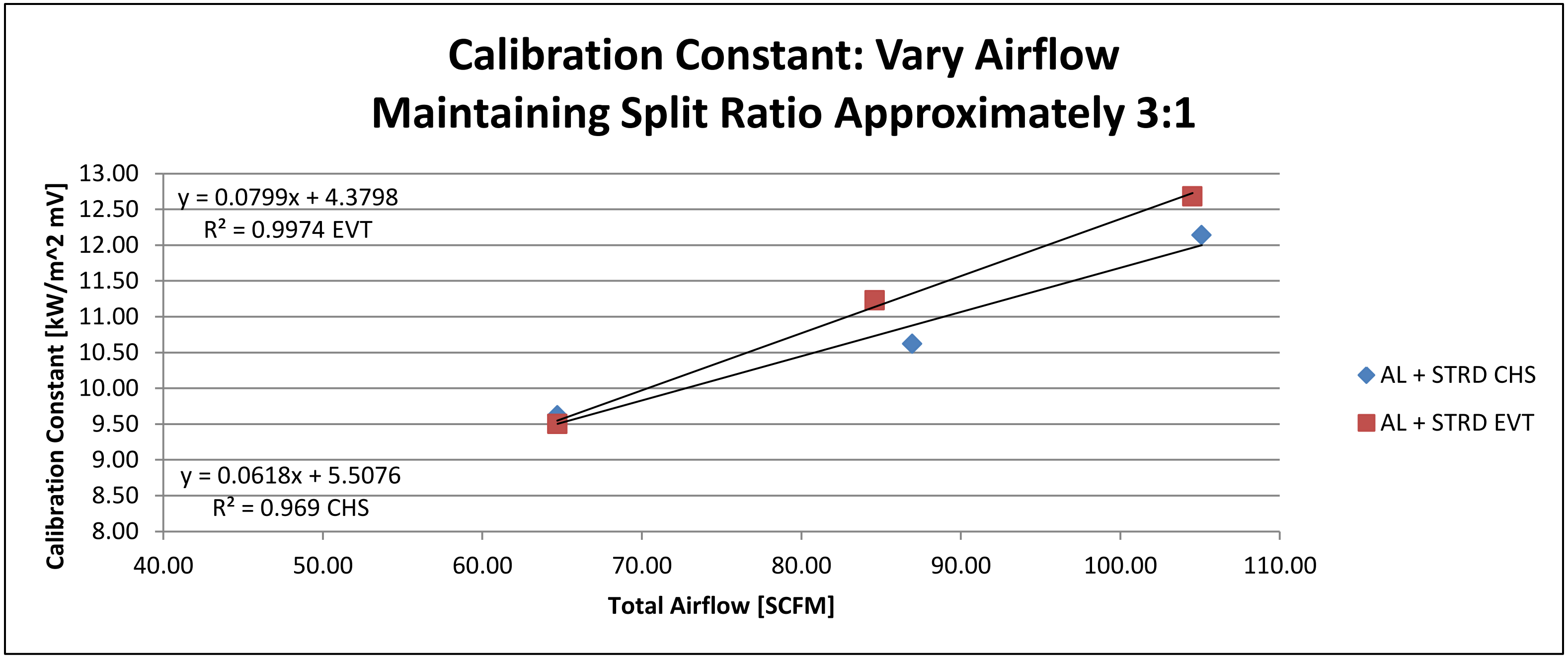
Observation: The more total air into the system, the higher the peak heat results



Notes: Similar linear trend is observed between laboratories

Average Split Ratio During Testing (CHS): 3.11 (EVT): 2.92

Observation: The more total air into the system, the higher the 2-min total results

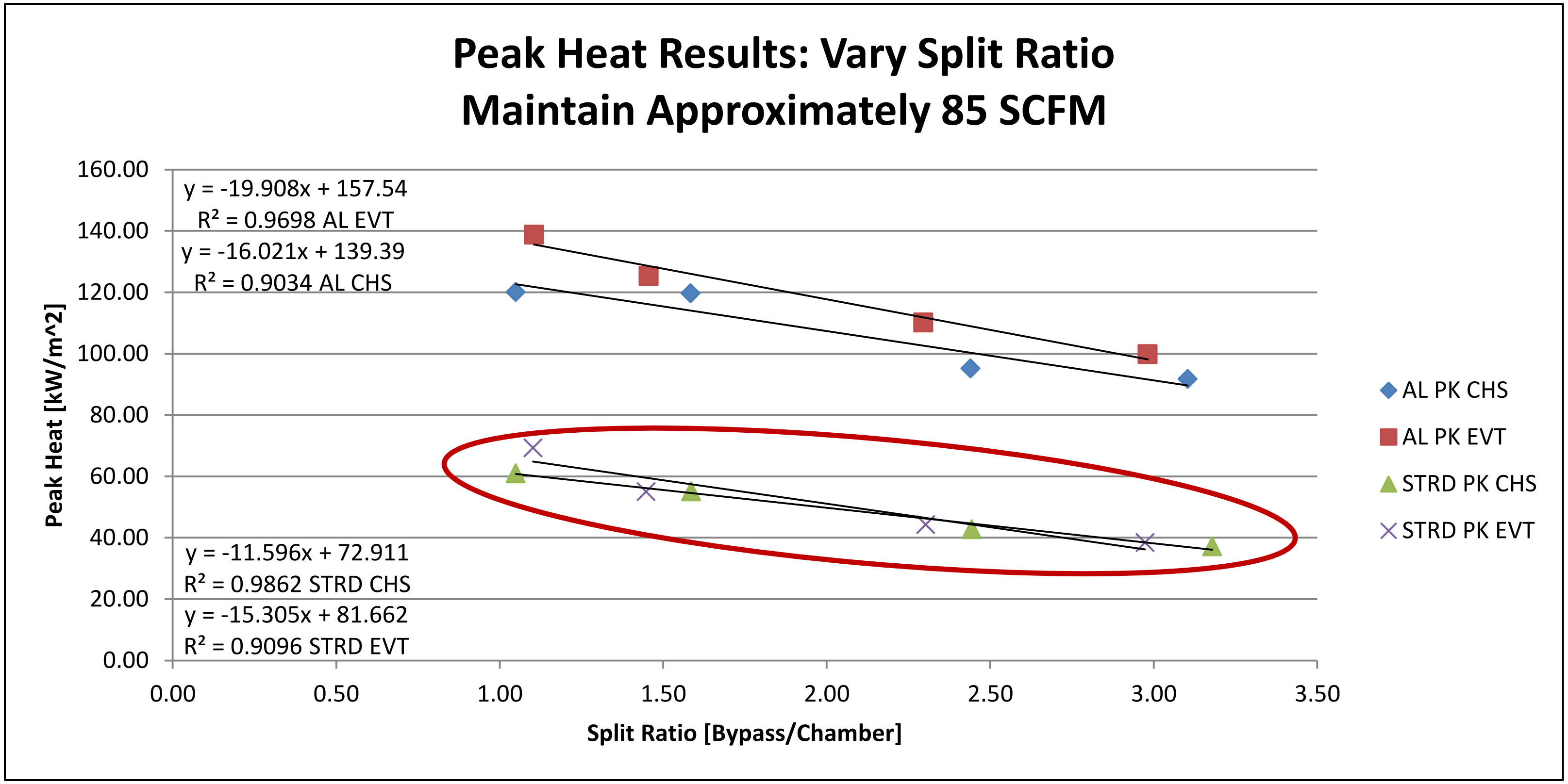


Notes: Similar linear trend is observed between laboratories

Average Split Ratio During Testing (CHS): 3.11 (EVT): 2.92

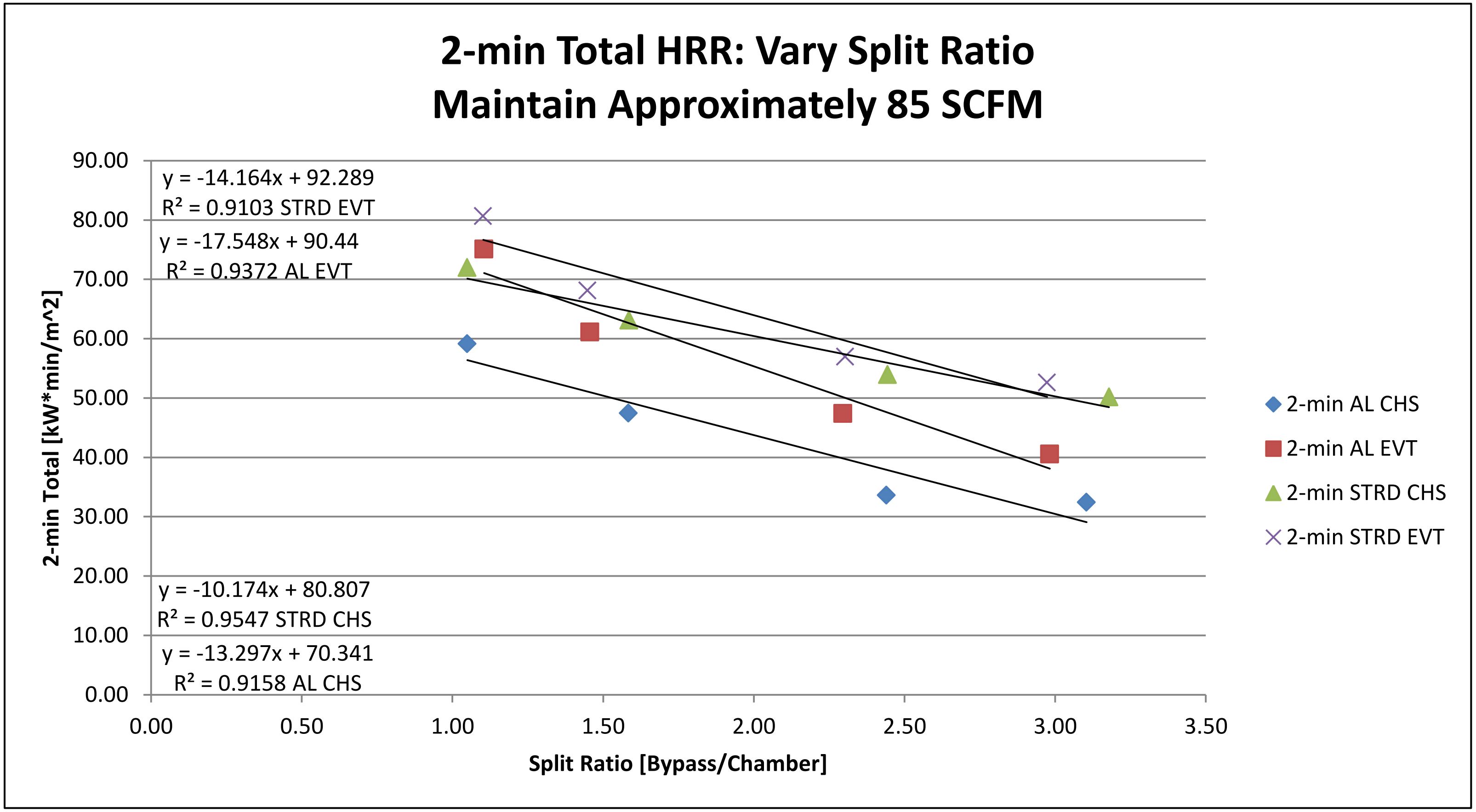
Observation: The more total air into the system, the higher the calibration constant

Effects of Varying Split Ratio
&
Maintaining 85 SCFM Total Airflow



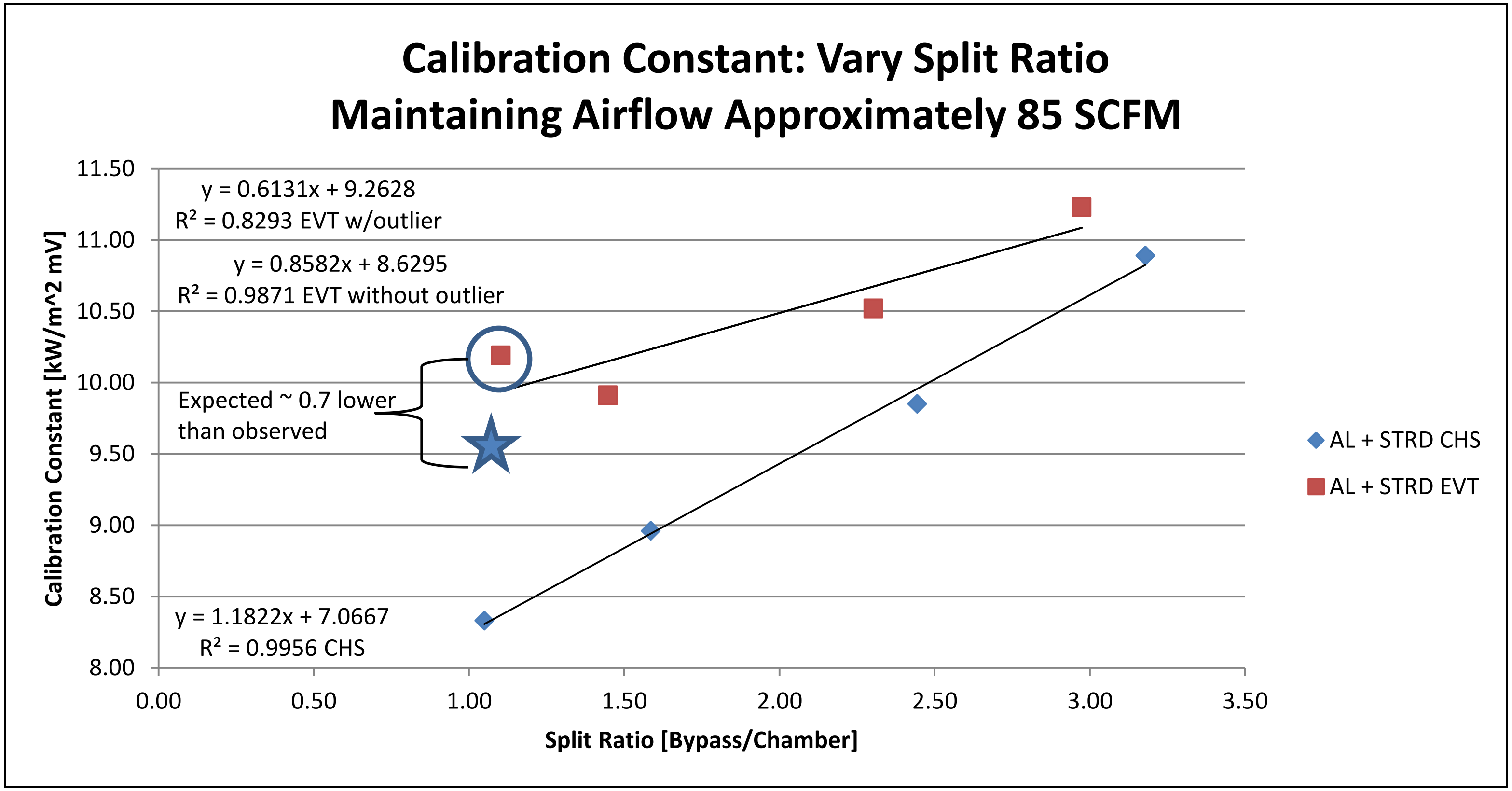
Notes: Similar linear trend is observed between laboratories

Observation: The lower the split ratio, the higher the peak heat results



Notes: Similar linear trend is observed between laboratories

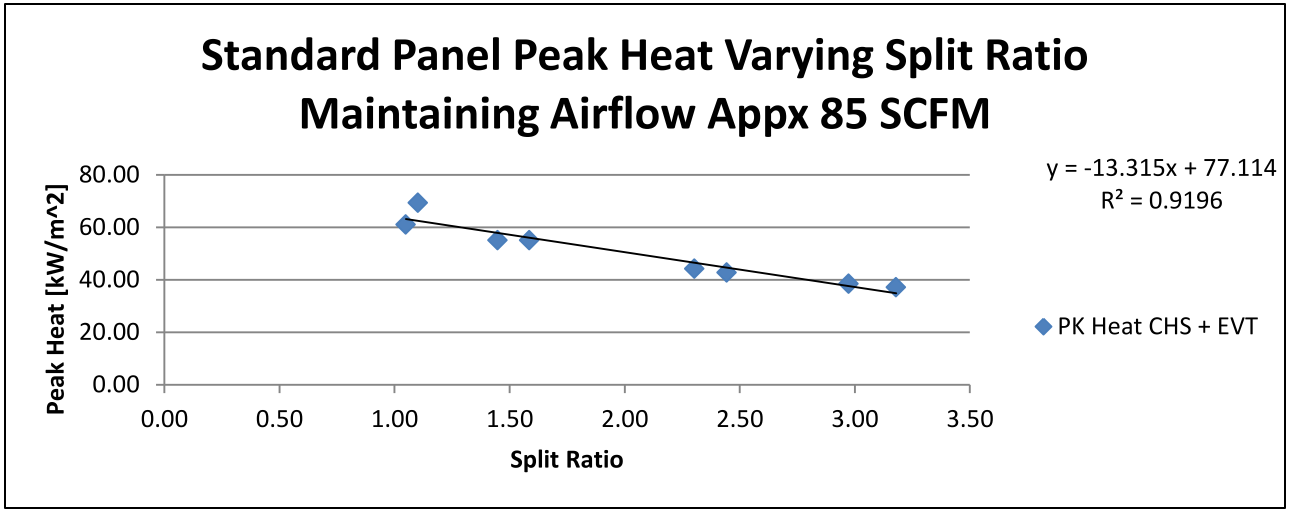
Observation: The lower the split ratio, the higher the 2-min total results



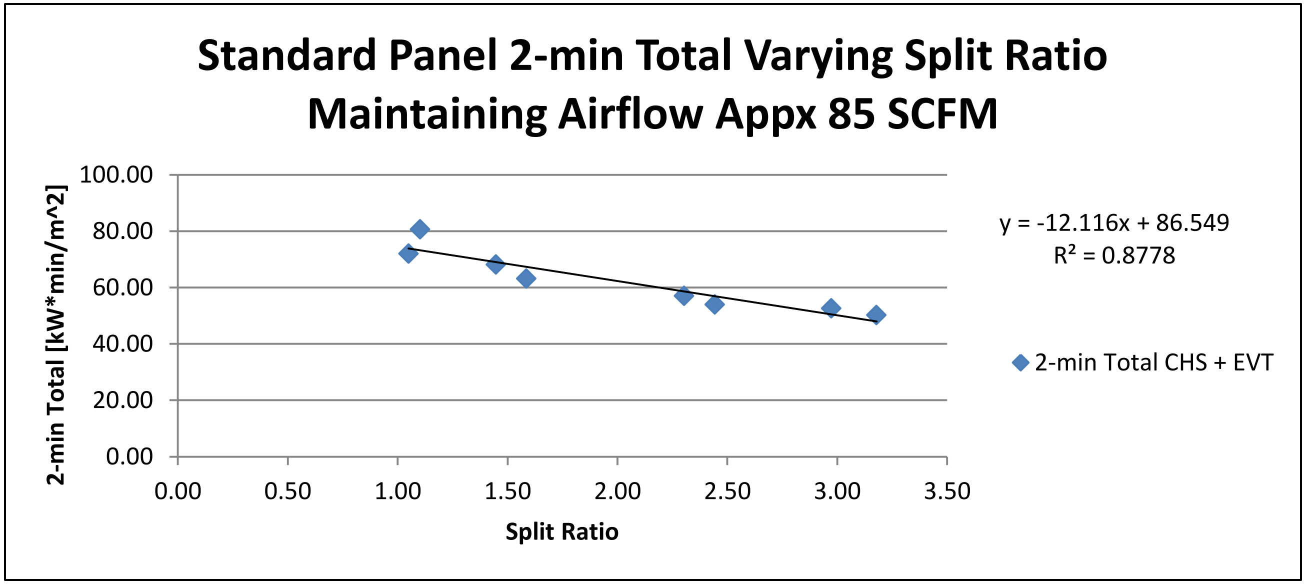
Notes: Generally similar linear trend is observed between laboratories

Observation: The lower the split ratio, the lower the calibration constant

Combined Results



Test	S	PK Heat
1 CHS	3.18	37.13
2 CHS	2.44	42.71
3 CHS	1.59	55.05
4 CHS	1.05	60.99
1 EVT	2.97	38.39
2 EVT	2.30	44.22
3 EVT	1.45	55.00
4 EVT	1.10	69.25



Test	S	2-min
1 CHS	3.18	50.18
2 CHS	2.44	53.91
3 CHS	1.59	63.12
4 CHS	1.05	72.00
1 EVT	2.97	52.58
2 EVT	2.30	56.96
3 EVT	1.45	68.10
4 EVT	1.10	80.65

Observations from Everett:

- **Piping system configuration in laboratory has an observed effect on split ratio.**
    - Split ratio changes can yield different results.

- **Trends seen in Charleston were observed in Everett using experimental piping system.**
    - In all cases, the more air entering the system will result in higher heat release results.
    - In all cases, the lower the split ratio, the higher the heat release results.
    - In all but one (outlier) case, the lower the split ratio, the lower the calibration constant.
    - Mathematical investigation needed to better explain offsets.
        - Would require additional testing.

Government & Industry Discussion for Task Group Meeting:

- **Evidence points to airflow and split ratio being a major contributor to OSU variability**
  - Now what ?

Possible paths forward:

(1) Status Quo: Significant variation is a natural phenomena under current regulation. We now know a major source. Maintain status quo.

(2) Directly Capture Air Data: Each lab captures their 'natural' airflow and determines split ratio by drilling a total of four holes in piping system for mass flow meter placement. Actual airflow and split ratio data can be used to 'normalize' prior round robin data and check for reduced variability. Data captured can also be used as information for concurrent HR2 DOE work / improvement.

(3) Recommendation from Task Group: Possible path forward to be discussed in meeting.

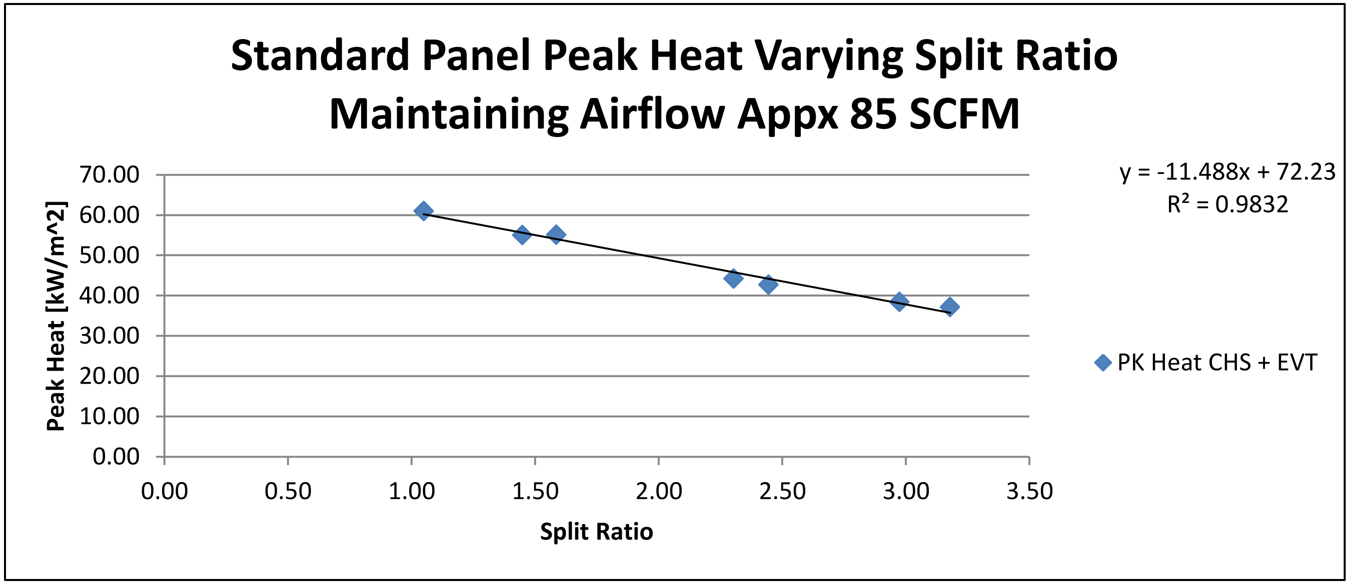
Backup

Chauvenet's criterion

1. Calculate μ and σ
2. If n · erfc(| xi - μ | / σ) < ½ then Reject xi

Test	S	PK Heat	μ	σ	|(Xi - μ)|/σ	n*erfc
1 CHS	**3.18**	**37.13**	50.34	11.51405965	1.147618685	0.836753202
2 CHS	**2.44**	**42.71**			0.662993786	2.787539248
3 CHS	**1.59**	**55.05**			0.409260517	4.501891451
4 CHS	**1.05**	**60.99**			0.924456736	1.528672269
1 EVT	**2.97**	**38.39**			1.038187256	1.136359434
2 EVT	**2.30**	**44.22**			0.531849772	3.615690938
3 EVT	**1.45**	**55.00**			0.404744299	4.536435889
4 EVT	**1.10**	**69.25**			1.642187949	0.161689351

Remove the outlier. Likely a result of anomalous calibration constant



Chauvenet's criterion

1. Calculate μ and σ
2. If n · erfc(| xi - μ | / σ) < ½ then Reject xi

Remove the outlier. Likely a result of anomalous calibration constant

Test	S	2-min	μ	σ	|(Xi - μ)|/σ	n*erfc
1 CHS	3.18	50.18	62.19	10.72387989	1.119277735	0.907558457
2 CHS	2.44	53.91			0.77220186	2.19846148
3 CHS	1.59	63.12			0.086629094	7.219948092
4 CHS	1.05	72.00			0.914687603	1.566530479
1 EVT	2.97	52.58			0.895478138	1.642967805
2 EVT	2.30	56.96			0.487416873	3.92501785
3 EVT	1.45	68.10			0.551759257	3.48168897
4 EVT	1.10	80.65			1.721298651	0.1193703