OSU Calorimetry Test BSS7322

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

Charleston Unit

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Topics of Discussion:

- **Motivation Behind the Study**

- **Setup of Experimental Piping System**

- **Test Matrix / Methodology**

- **Test Data Obtained**

- **Discussion on Effect of Total Airflow on Heat Release**

- **Discussion on Effect of Varying Split Ratio on Heat Release**

-**Observations**

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**

Setup of Experimental Piping System:

Note: More steady / laminar airflow observed than ‘approved’ piping system

Total Airflow: 86.3 SCFM (Should be 85)
Bypass Air: 66.6 SCFM (Should be 63.75)
Split Ratio: 3.38 (Should be 3.0)

Test Methodology / Matrix:

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

63 Tests performed (Test Setup 1 coupons α, β, γ were re-performed due to OSU shutdown)

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.

Test Data Obtained:

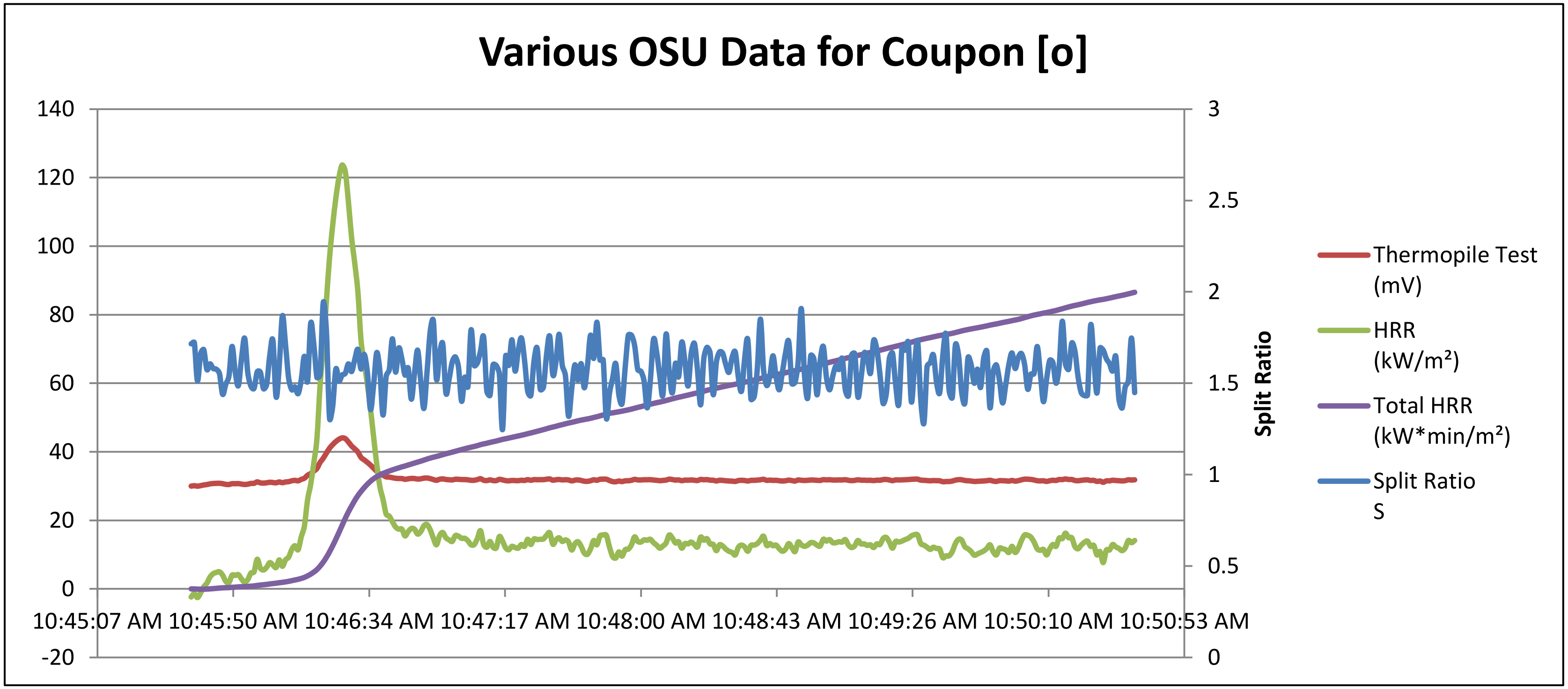
BOEING

Coupon o:									
Ref Time + Sec	MFM Total [SCFM]	MFM Bypass [SCFM]	MFM Chamber [SCFM]	Split Ratio S	Thermopile Test (mV)	HRR (kW/m²)	NoNeg HRR (kW/m²)	Total HRR (kW*min/m²)	Thermopile Warmup (mV)
10:45:37	84.675	53.49375	31.18125	1.715574	29.99	-2.36	-2.36	0	30
10:45:38	83.5125	52.8375	30.675	1.722494	30.1	-1.38	-1.38	-0.02	30.32
10:45:39	85.2	51.3	33.9	1.513274	29.97	-2.54	-2.54	-0.07	30.27
10:45:40	85.55625	53.4	32.15625	1.660641	30.12	-1.2	-1.2	-0.09	30.45
10:45:41	84.3375	52.9125	31.425	1.683771	30.32	0.59	0.59	-0.08	30.24
10:45:42	83.71875	51.20625	32.5125	1.574971	30.44	1.67	1.67	-0.05	30.45
10:45:43	84.4875	52.06875	32.41875	1.606131	30.64	3.46	3.46	0.01	30.44
10:45:44	86.90625	53.23125	33.675	1.580735	30.75	4.44	4.44	0.08	30.89
10:45:45	87.3	53.41875	33.88125	1.576646	30.79	4.8	4.8	0.16	30.74
10:45:46	86.19375	52.425	33.76875	1.552471	30.81	4.98	4.98	0.25	30.61
10:45:47	85.95	50.71875	35.23125	1.439596	30.7	4	4	0.31	30.51
10:45:48	85.40625	51.16875	34.2375	1.494524	30.5	2.2	2.2	0.35	30.73
10:45:49	85.575	51.8625	33.7125	1.538376	30.46	1.85	1.85	0.38	30.78
10:45:50	84.1875	53.025	31.1625	1.701564	30.7	4	4	0.45	30.45
10:45:51	83.925	51.16875	32.75625	1.562106	30.69	3.91	3.91	0.51	30.15
10:45:52	86.025	51.43125	34.59375	1.486721	30.72	4.17	4.17	0.58	30.11
10:45:53	85.40625	52.9875	32.41875	1.634471	30.58	2.92	2.92	0.63	30.25
10:45:54	83.68125	53.2125	30.46875	1.746462	30.47	1.93	1.93	0.66	30.13
10:45:55	84.4125	51.4125	33	1.557955	30.56	2.74	2.74	0.71	30.32
10:45:56	86.11875	51.45	34.66875	1.484045	30.77	4.62	4.62	0.79	30.32
10:45:57	88.1625	52.5	35.6625	1.472135	30.81	4.98	4.98	0.87	30.38
10:45:58	87.20625	53.175	34.03125	1.562534	31.22	8.65	8.65	1.01	30.29
10:45:59	85.74375	52.25625	33.4875	1.56047	30.93	6.06	6.06	1.11	30.27
10:46:00	86.7375	51.61875	35.11875	1.469834	30.87	5.52	5.52	1.21	30.31
10:46:01	86.38125	51.73125	34.65	1.492965	30.96	6.32	6.32	1.31	30.01
10:46:02	85.0125	52.96875	32.04375	1.653013	31.11	7.67	7.67	1.44	29.83

Coupon o:									
Ref Time + Sec	MFM Total [SCFM]	MFM Bypass [SCFM]	MFM Chamber [SCFM]	Split Ratio S	Thermopile Test (mV)	HRR (kW/m²)	NoNeg HRR (kW/m²)	Total HRR (kW*min/m²)	Thermopile Warmup (mV)
Average:	**85.11901993**	**52.01891611**	**33.10010382**	**1.577997**	**32.17887043**	**123.68**			
Stdev:	**1.365385154**	**1.292095751**	**1.861062397**	**0.118406**	**2.183263319**				

Test Data Obtained:

Using data recorders allows for multiple characteristics to be simultaneously plotted



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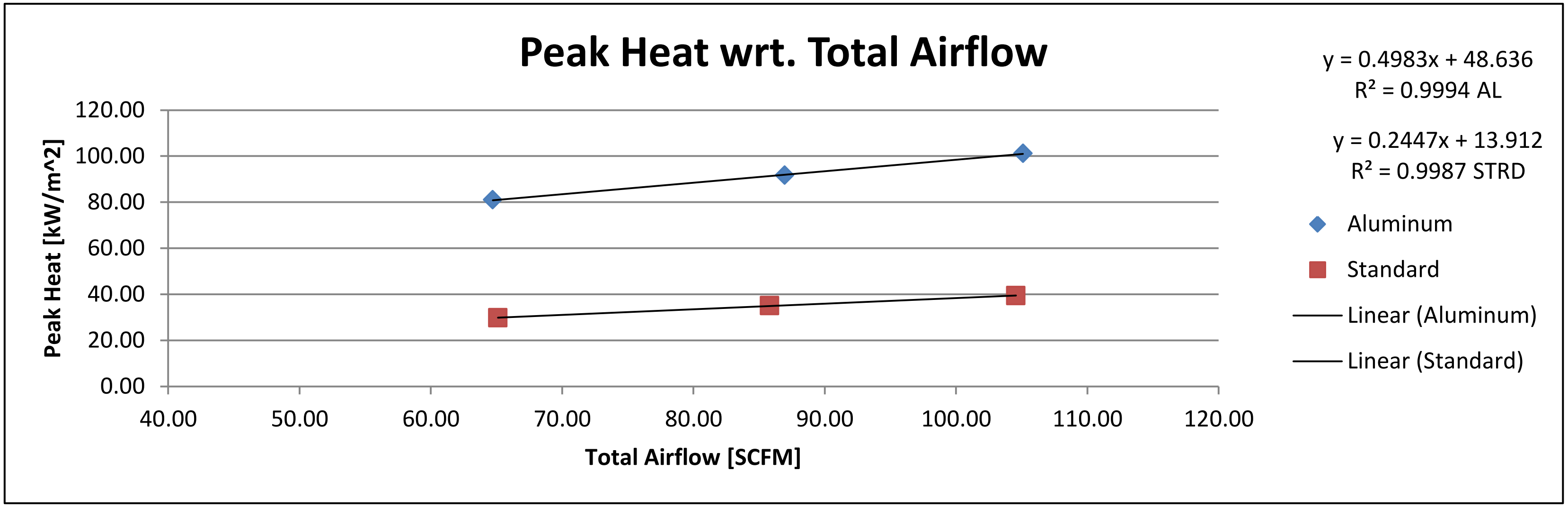
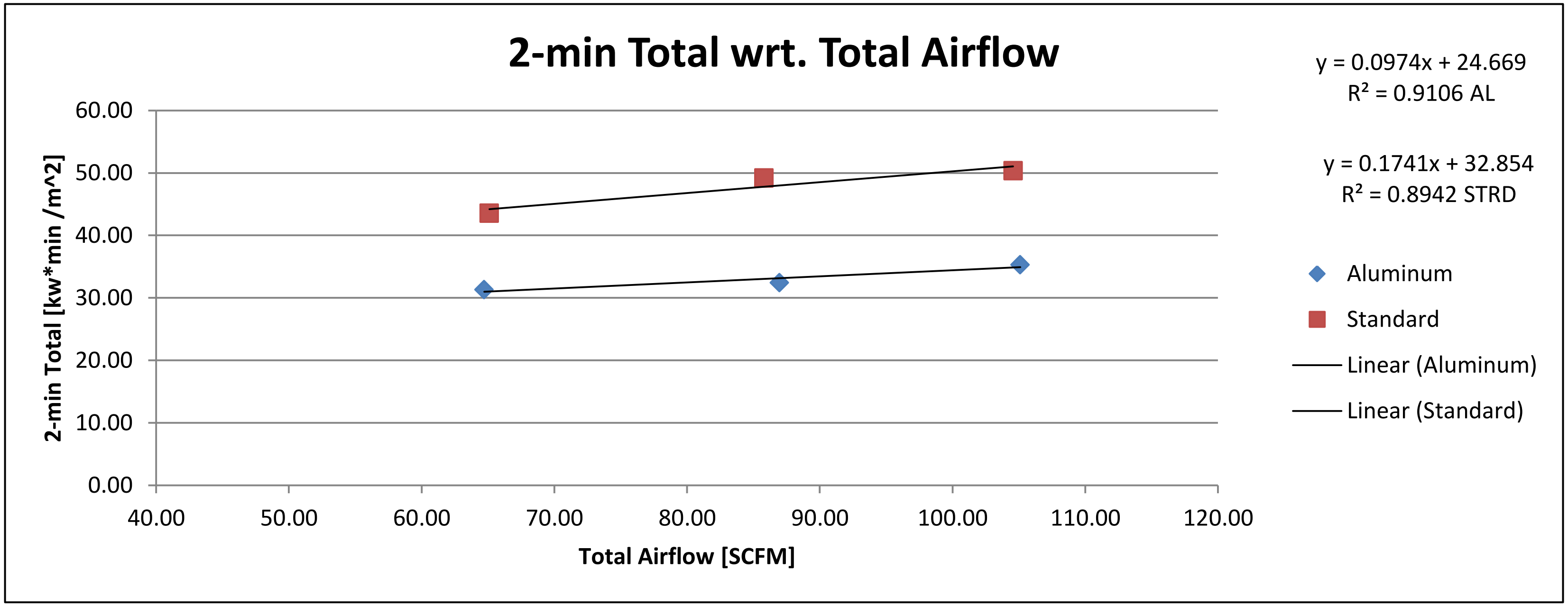
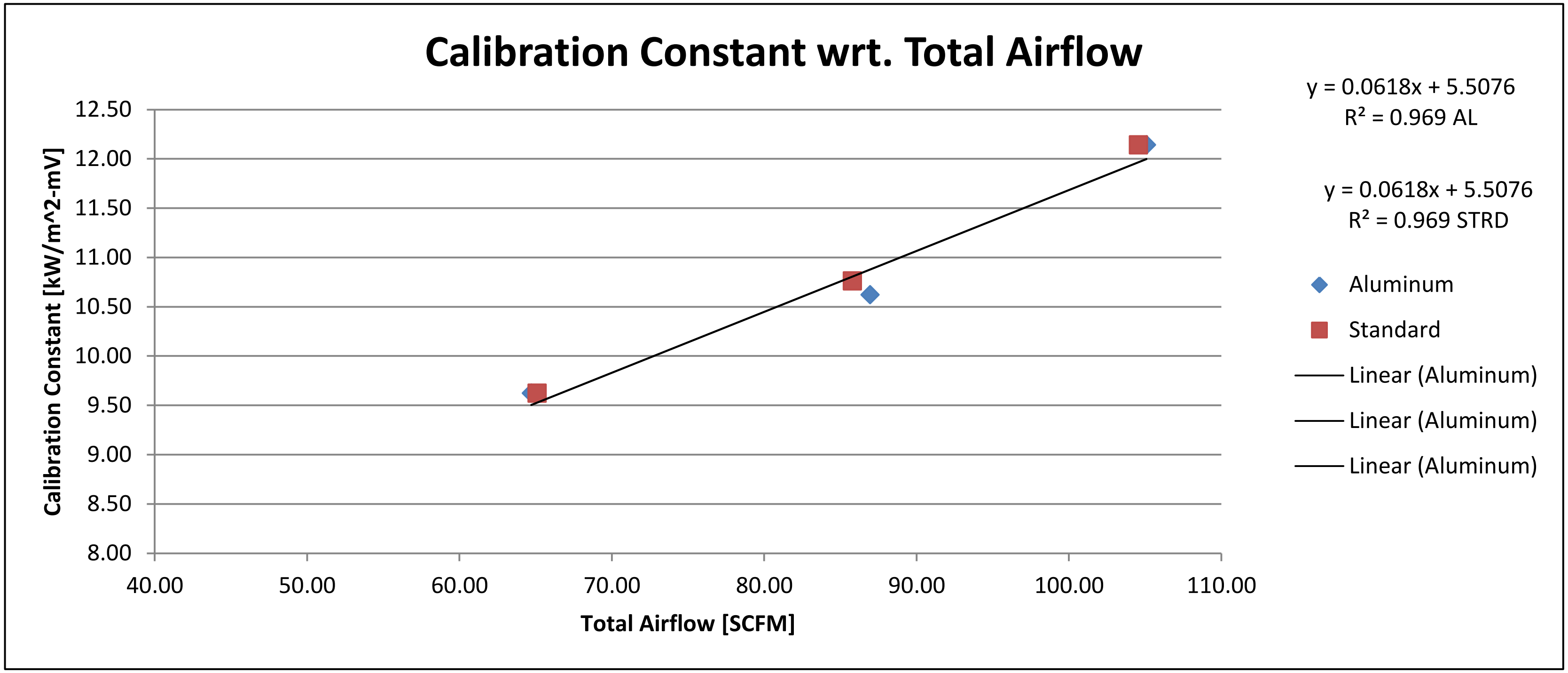
Effects of Varying Total Airflow
&
Maintaining a 3:1 Split Ratio

Effects of Varying Total Airflow; Maintaining 3:1 Split Ratio





Effects of Varying Total Airflow; Maintaining 3:1 Split Ratio



Notes for both Standard and Aluminum Coupons (Vary Airflow & Maintain 3:1 Split):

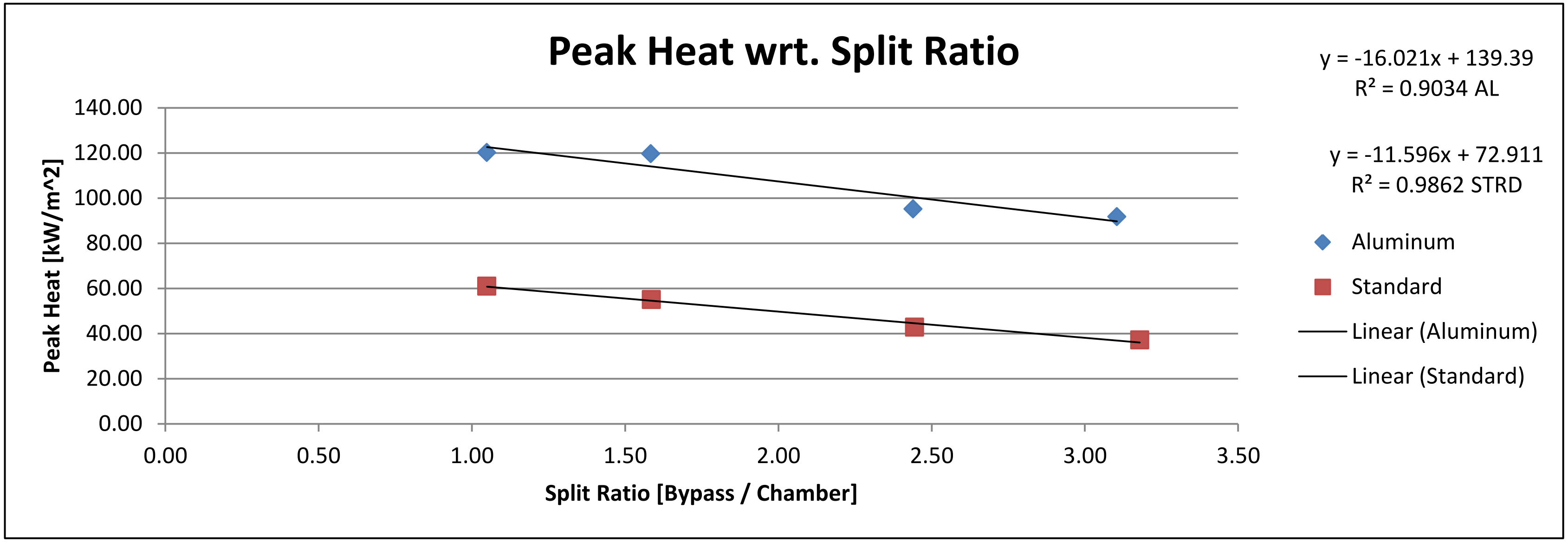
There is a linear correlation between peak heating and total airflow.

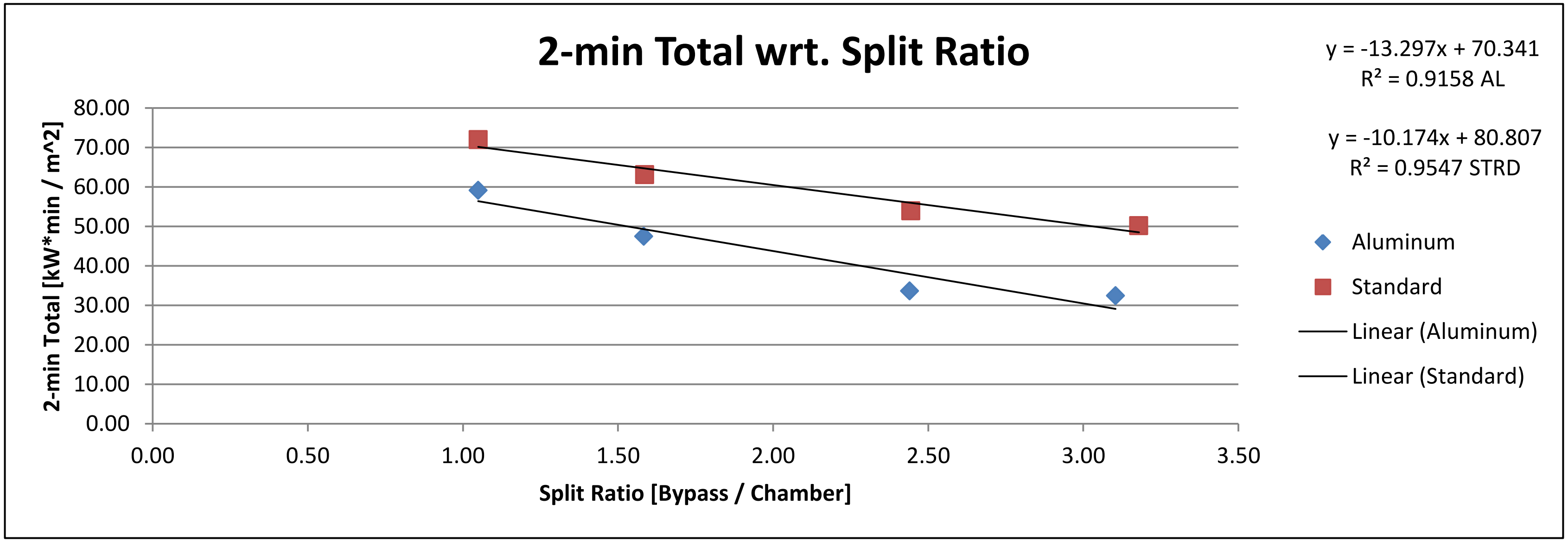
There is a near-linear correlation between two minute total heat release and total airflow

There is a linear correlation between calibration constant and total airflow.

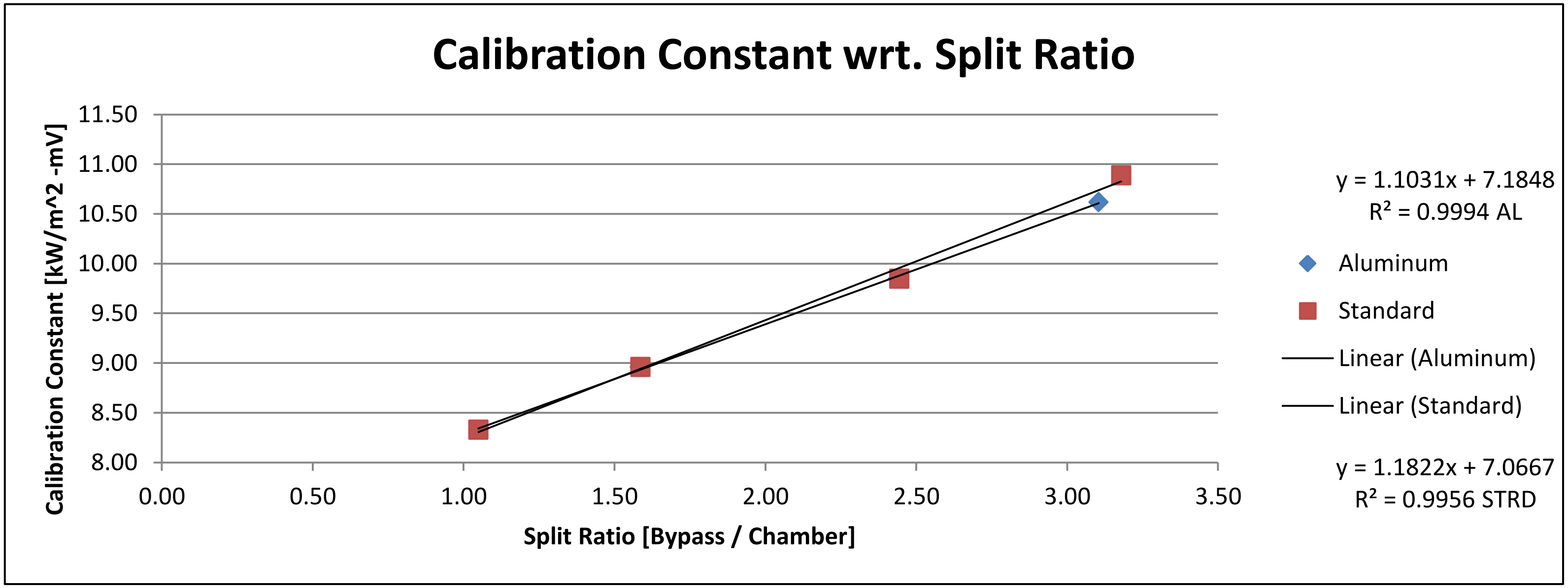
Effects of Varying Split Ratio
&
Maintaining 85 SCFM Total Airflow

Effects of Varying Split Ratio; Maintaining 85 SCFM Total Airflow





Effects of Varying Split Ratio; Maintaining 85 SCFM Total Airflow



Notes for both Standard and Aluminum Coupons (Maintain Airflow / Vary Split Ratio):

There is a near linear correlation between peak heating and split ratio.

There is a near-linear correlation between two minute total heat release and split ratio

There is a linear correlation between calibration constant and split ratio.

IDEAL CONDITIONS:

Based on the above graphs, the following are ideal results for CHS Unit; Can be used as comparison with other OSU Machines.
Total Air: 85 SCFM; S=3:1

-Peak Heat AL: 91.33kW/m^2
-2-min Total AL: 30.45 kW*min/m^2
-Cal Constant AL: 10.49 kW/m^2-mV

-Peak Heat STRD: 38.12 kW/m^2
-2-min Total STRD: 50.29 kW*min/m^2
-Cal Constant STRD: 10.61 kW/m^2-mV

DATA TABLE:

			ALUMINUM PANELS						STANDARD PANELS		
	Total Airflow	S	PK Heat	2-min Tot	Cal Constant	Split	Total Airflow	S	PK Heat	2-min Tot	Cal Constant
Test 5 Avg	64.72	3.16	81.01	31.29	9.62	75/25	65.10	3.12	29.75	43.54	9.62
Test 1 Avg	86.95	3.10	91.68	32.43	10.62	75/25 ★	85.80	3.14	35.11	49.16	10.76
Test 6 Avg	105.10	3.06	101.16	35.30	12.14	75/25	104.56	3.06	39.39	50.35	12.14
Test 1 Avg	86.95	3.10	91.68	32.43	10.62	Repeat for graph	85.15	3.18	37.13	50.18	10.89
Test 2 Avg	84.50	2.44	95.16	33.63	9.85	70/30	84.40	2.44	42.71	53.91	9.85
Test 3 Avg	85.11	1.58	119.63	47.44	8.96	60/40	85.03	1.59	55.05	63.12	8.96
Test 4 Avg	83.66	1.05	120.09	59.13	8.33	50/50	83.64	1.05	60.99	72.00	8.33

★ Note: The three samples that were subsequently interrupted were included in the average as the calibration constant and heat flux were approximately equal. No significant change to value.

Observations:

- **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):**
  - 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

Proposed Next Step:

- Recommend the same tests be performed on a different OSU unit to validate observations and trends.

Thank you for your attention !

Thanks especially to the Boeing Team for the help in running this test !

Kyle Clayton
Yonas "Yoshi" Behboud
Chris Ballew
Yaw Agyei
Hank Lutz