HR2 Evaluation

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Background

- HR2 Goal: reduce variation within and between machines relative to OSU. Details of target have yet to be defined.
- Reductions in variation within machine has not been shown yet (limited data generated to this point).
- Boeing proposed examining some of the behavior of the HR2. This plan was reviewed by the 2015 FTWG HR2 task group. Testing was conducted by the FAA TC
- Two phases were conducted:
  - Phase I: explore the effect of 4 factors (air flow rate, air flow rate to upper pilot burner, methane flow rate to upper pilot burner and center heat flux) on the thermopile output without samples
  - Phase II: based on phase I data, airflow was looked at more closely. Tests were conducted with and without samples.
- All testing was conducted at the FAATC lab in 2015.

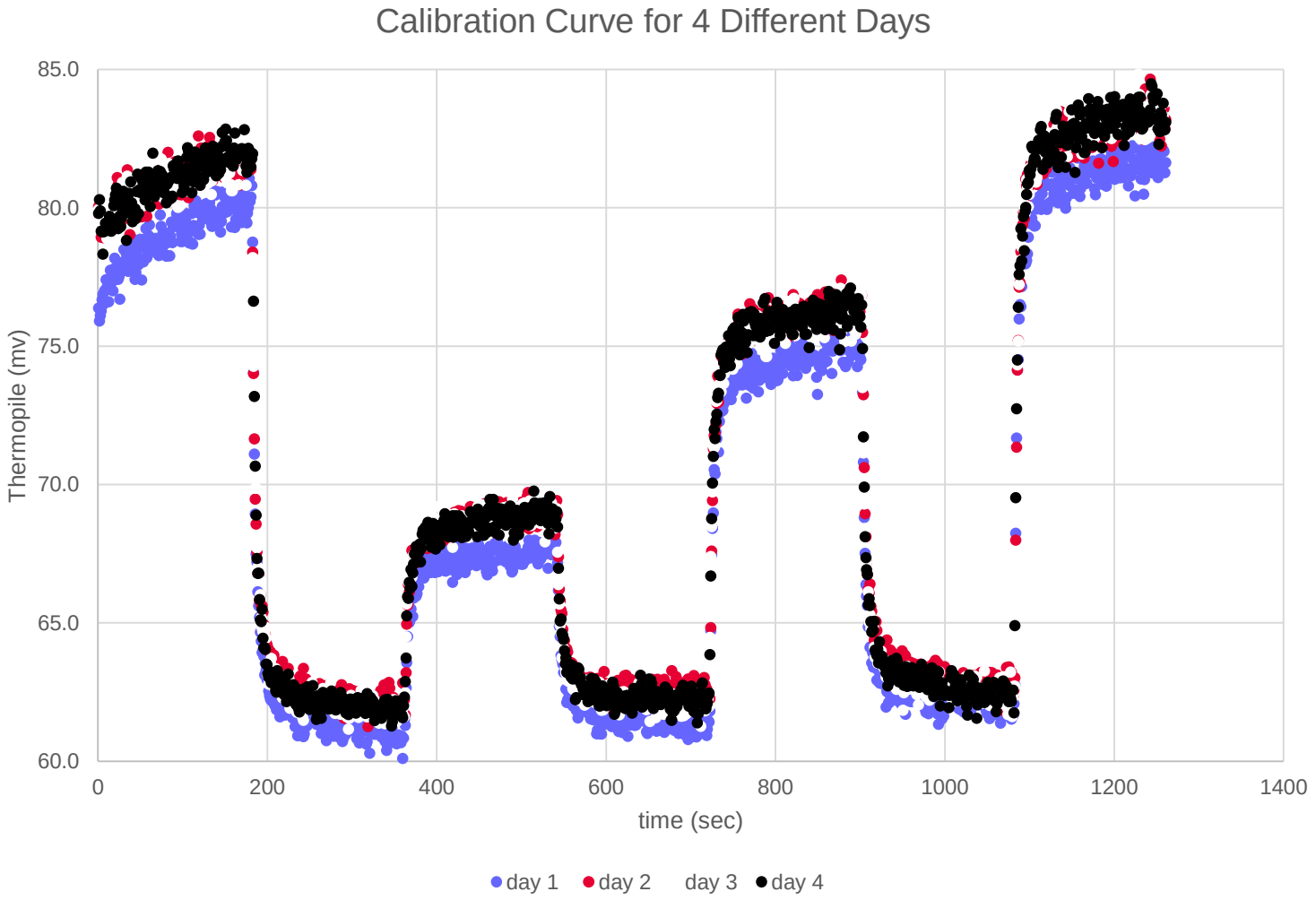
Phase I: 4 Factors Explored, No Samples

Plan (Phase I)

- Set air flow rate, center heat flux and upper pilot flame methane/air flow rates to the upper and lower limits prescribed by the handbook.
- Not randomized, no replicates.
- Only nominal values of inputs were recorded (i.e. no real time values) other than for the air flow rate.
- Collect thermopile mV output.
- Dates of experiment:
  - Day 1: 8/27/2015
  - Day 2: 9/2/2015
  - Day 3: 9/3/2015
  - Day 4: 9/8/2015

Day	Data Point	Airflow (SCFM)	Center Heat Flux (W/cm2)	Upper Pilot Flame Methane (L/min)	Upper Pilot Flame Air (L/min)
1	Cal	20	-	-	-
1	PRE	20	3.65	1.5	1
1	2	19	3.60	1.3	0.8
1	3	19	3.60	1.3	1.2
1	4	19	3.60	1.7	1.2
1	5	19	3.60	1.7	0.8
1	POST	20	3.65	1.5	1
2	Cal	20	-	-	-
2	PRE	20	3.65	1.5	1
2	2	19	3.70	1.3	0.8
2	3	19	3.70	1.3	1.2
2	4	19	3.70	1.7	1.2
2	5	19	3.70	1.7	0.8
2	POST	20	3.65	1.5	1
3	Cal	20	-	-	-
3	PRE	20	3.65	1.5	1
3	2	21	3.60	1.3	0.8
3	3	21	3.60	1.3	1.2
3	4	21	3.60	1.7	1.2
3	5	21	3.60	1.7	0.8
3	POST	20	3.65	1.5	1
4	Cal	20	-	-	-
4	PRE	20	3.65	1.5	1
4	2	21	3.70	1.3	0.8
4	3	21	3.70	1.3	1.2
4	4	21	3.70	1.7	1.2
4	5	21	3.70	1.7	0.8
4	POST	20	3.65	1.5	1

Calibration (Phase I)

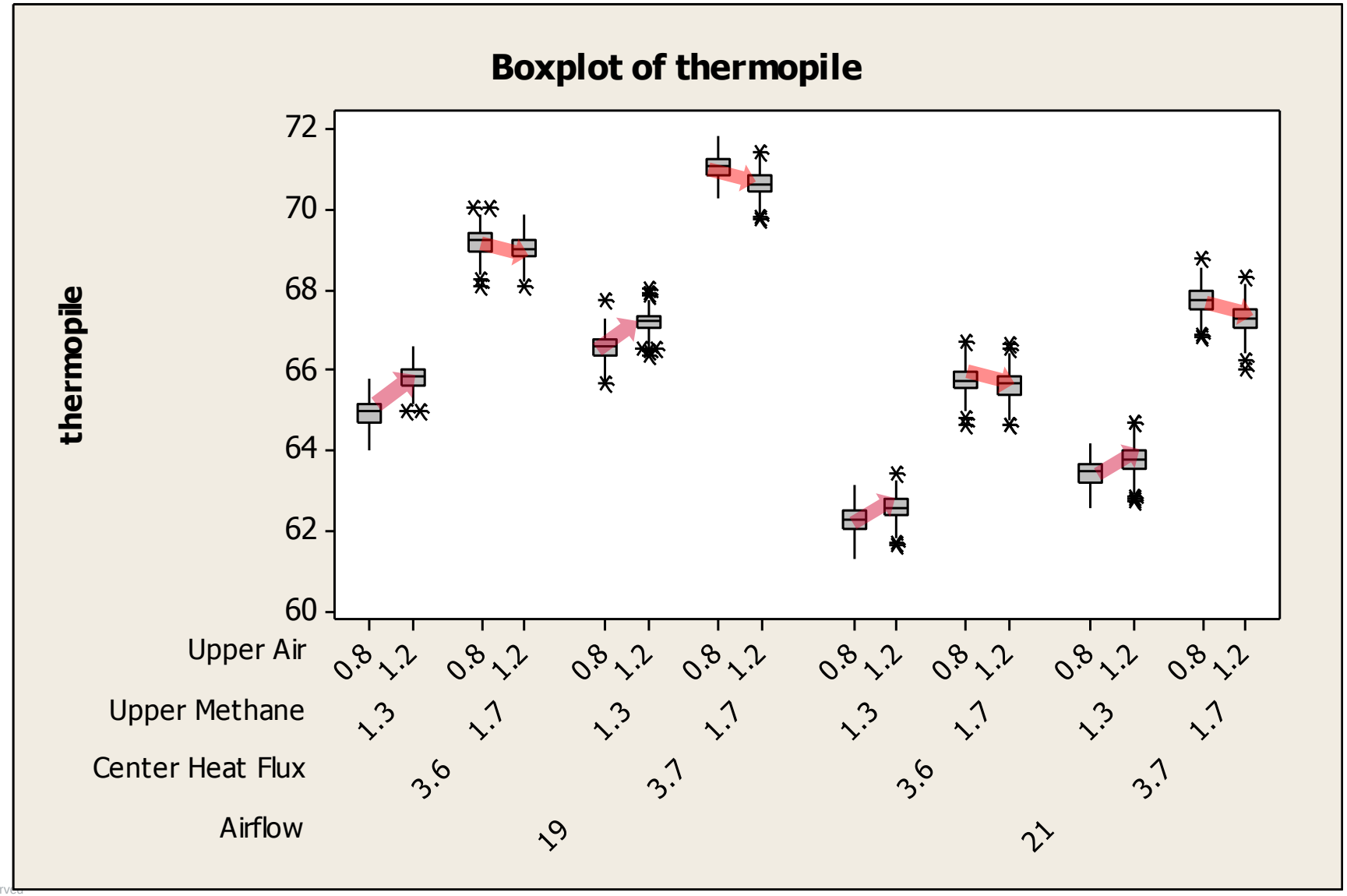


day	Cal factor	% difference from mean	Pressure (milibar)	Room temp (F)	Room RH (%)	Inlet air RH(%)
1	0.091	3.88%	1020	79.2	50	11.82
2	0.088	0.34%	1018	81	54	14.02
3	0.086	-2.17%	1014	81.1	53	13.4
4	0.086	-2.05%	1020	80.2	55	12.69

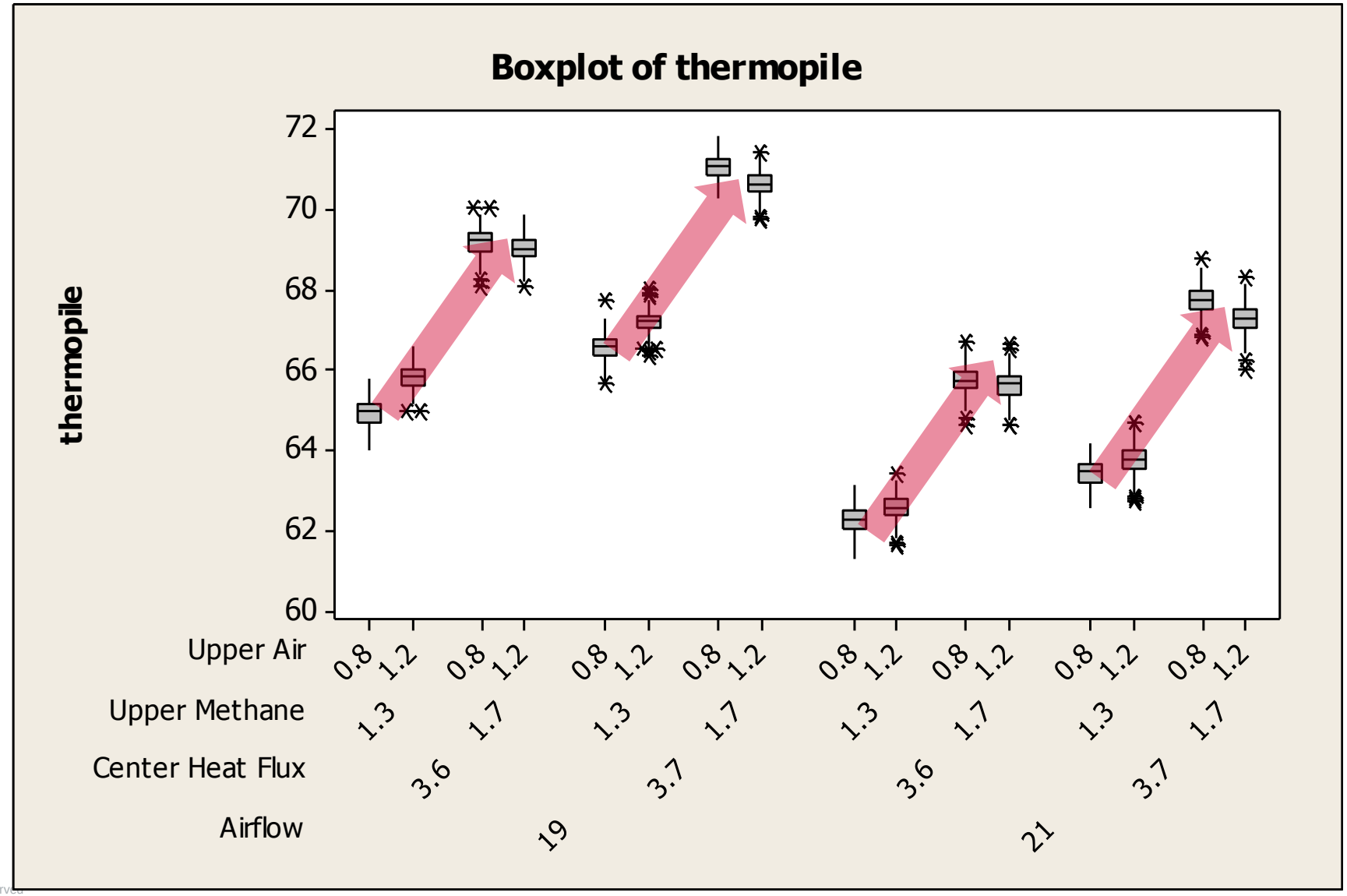
There is ~6% spread in in cal factor (same machine, same lab, same operator… etc), which will directly result in a 6% spread in the heat release rate assuming all other factors are constant

$$Heat\ Release\ Rate = (Test\ _{mV} - Baseline_{mV}) * (\frac{K_h}{0.02323})$$

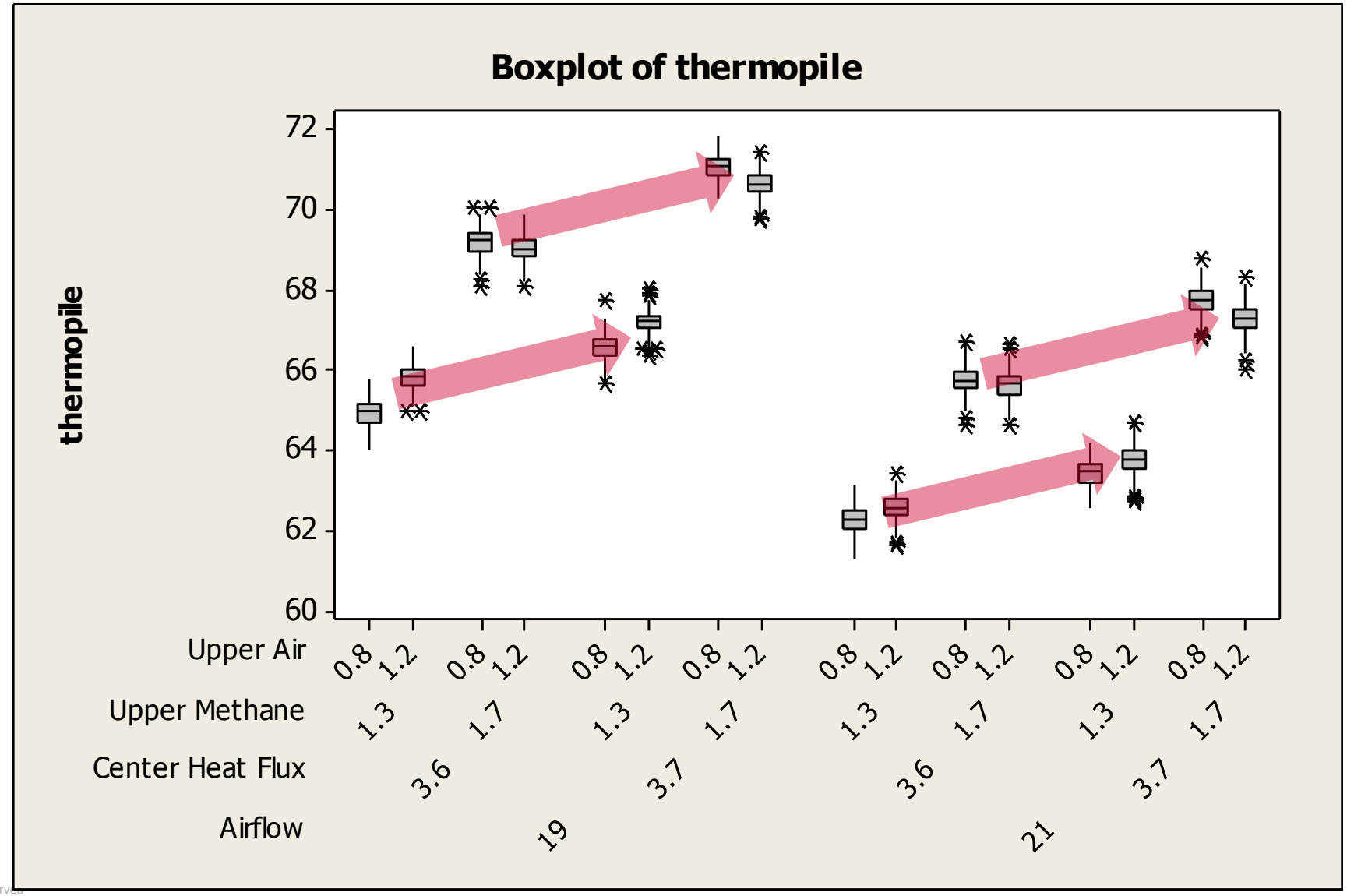
Upper Pilot Air Flow Rate (relatively small effect) - Phase I



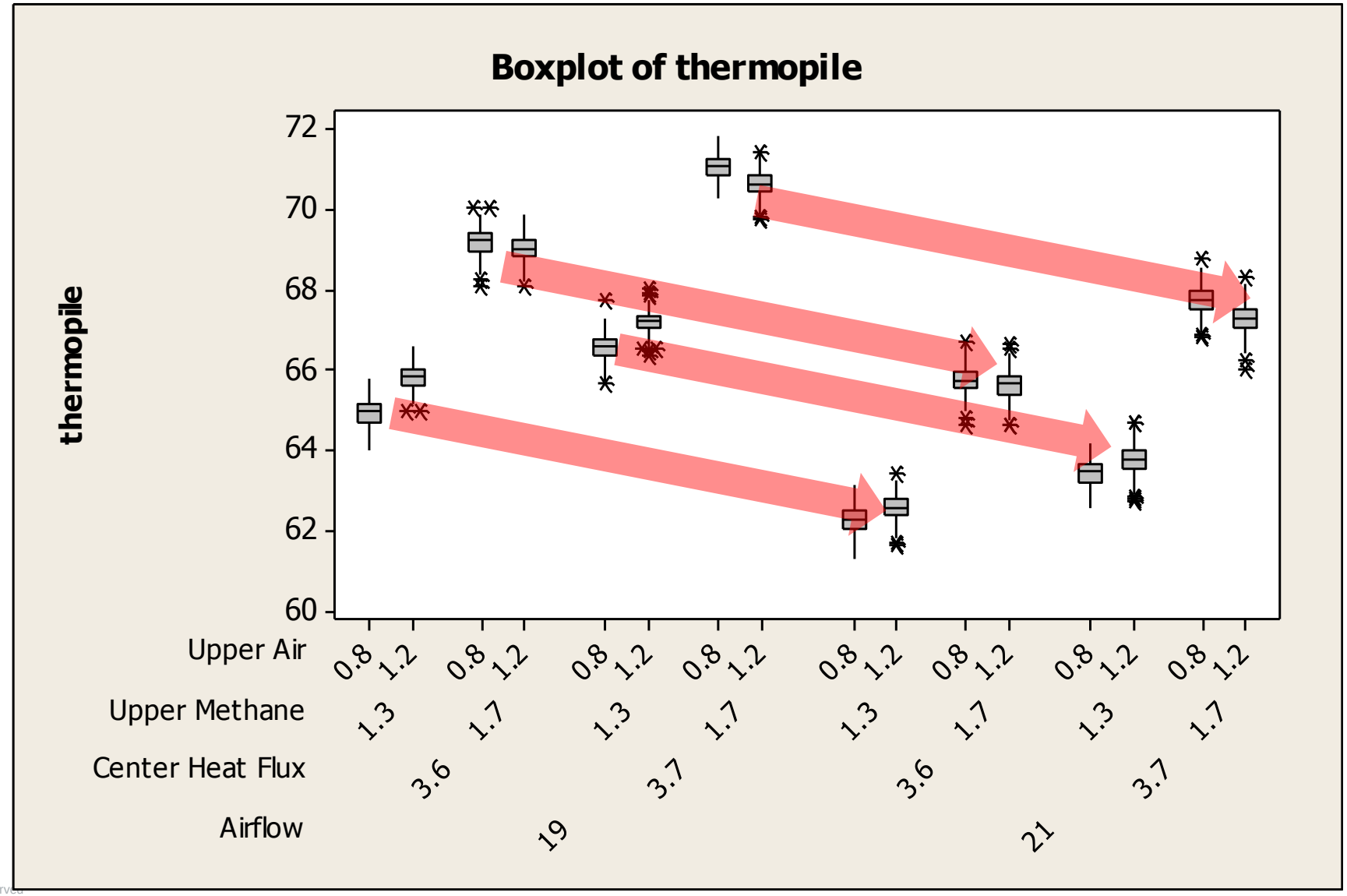
Upper Pilot Methane Flow Rate (large effect) – Phase I



Center Heat Flux (moderate effect) – Phase I



Airflow (large effect) – Phase I



Conclusions (Phase I)

- Under relatively controlled conditions (e.g. no samples, same unit, same lab, same operator, short time frame… etc.) the HR2 produced cal factors with a 6% spread. This may be too large considering production environment will be much less controlled.
- Airflow and upper methane flow rate seem to be major contributors to the mV output of the HR2 unit and should probably be controlled more tightly than is suggested by the Workbook.

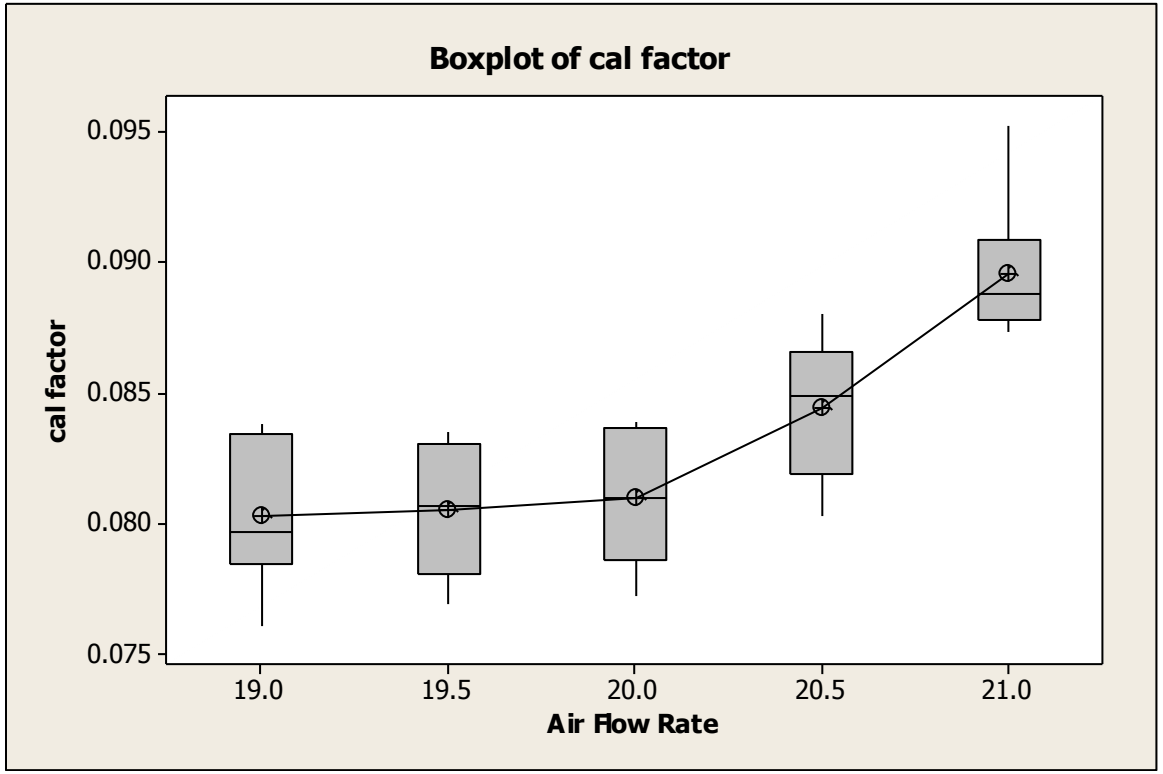
Phase II: Air Flow Rate Study

Plan (Phase II)

- Gas calibration:
  - Conduct calibration at 5 flow rates (19.0, 19.5, 20.0, 20.5 and 21.0 SCFM), 2 replicates each.
  - All other parameters were set to within Workbook limits prior to each calibration.
- Sample Testing:
  - Conduct testing at 5 flow rates (19.0, 19.5, 20.0, 20.5 and 21.0 SCFM), 3 replicates each.
  - Sample: Schneller honeycomb panel from the same batch, same relative ribbon direction during test.
  - A single calibration value was used (0.0816) to calculate all HRR results.
  - All other parameters were set to within Workbook limits prior to each test.

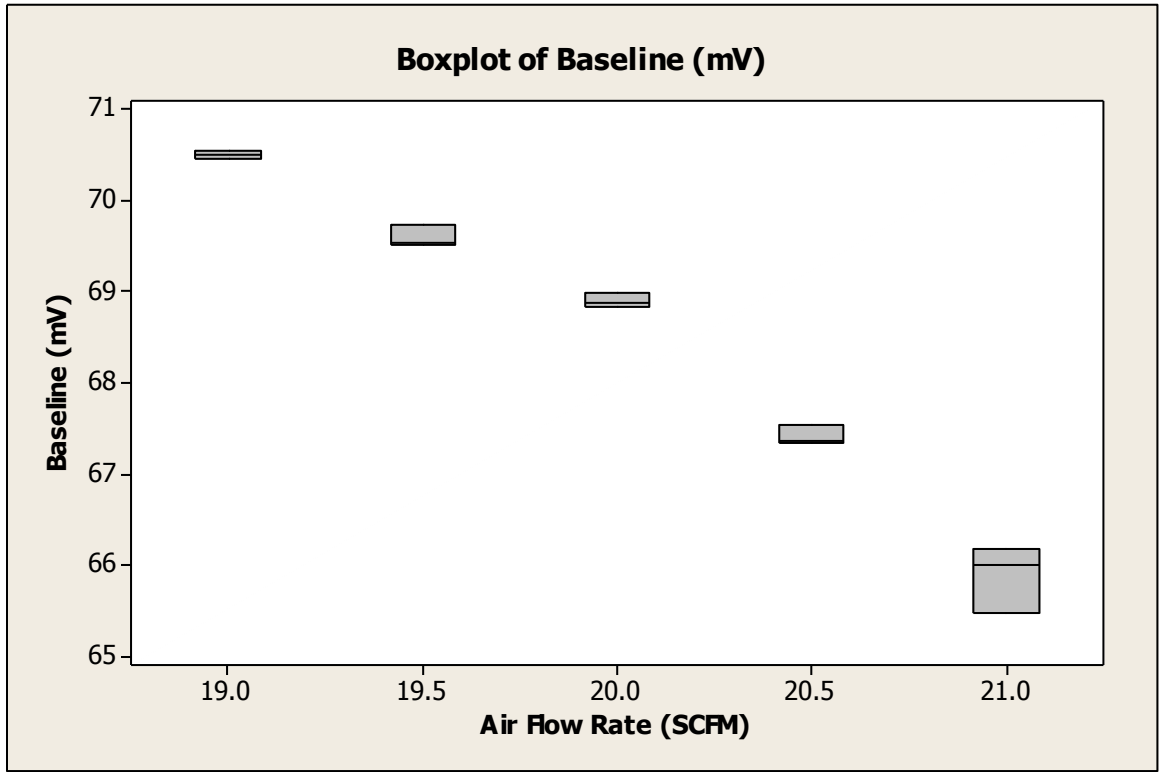
Calibration Data (Phase II)

- Agreeing with intuition, the increase in air through the system leads to an increase in the cal factor.
- The difference in means between air flow rates of 19 and 21SCFM is ~10%

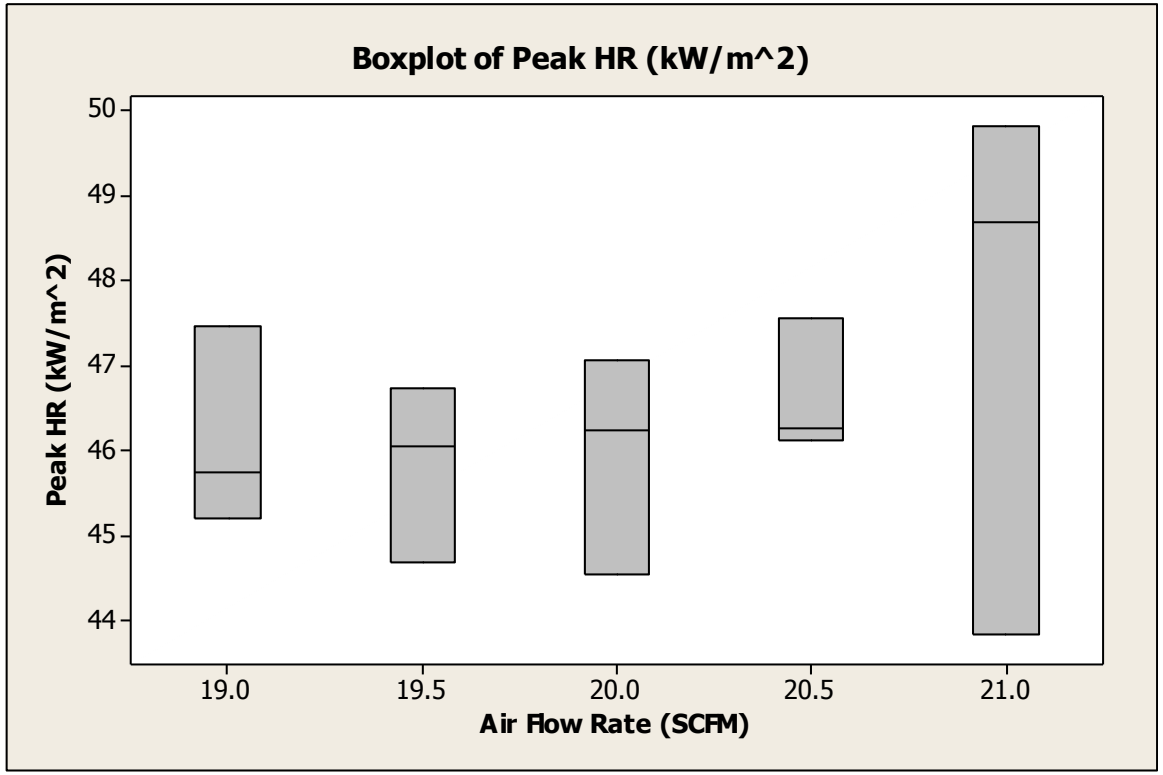


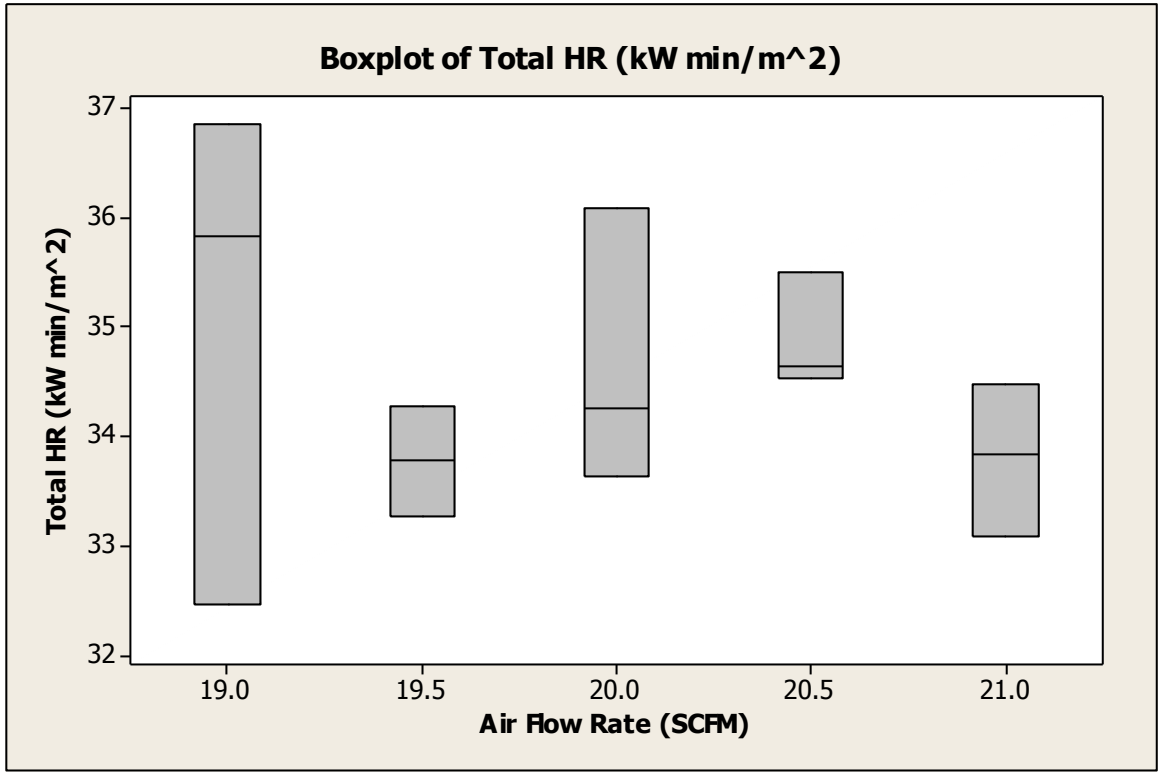
Baseline Data (Phase II)

- Agreeing with intuition, the increase in air through the system leads to a reduction in the outlet temperature of the gas.



Graphical Summary of Sample Test Data (Phase II)





Conclusions (Phase II)

- The air flow rate range identified in the workbook has an effect on the calibration factor.
  - All other things held constant, the calibration factor has a 1:1 effect on the HR results (i.e. a difference of 10% in the cal factor will cause a 10% difference in HR results for everything else being constant since it's directly multiplied).
- Test data is inconclusive. Too few samples and too much variability within testing.

Overall Recommendations

- Define clear/quantifiable end goal for HR2 (i.e. what level of variation is acceptable?)
- Step back from sample testing. Reassess HR2 parameters and procedure, too much inherent variability in the machine without samples.
- Task Group to define next phase of machine evaluation.
- Tighten air flow rate range in Workbook (e.g. 10% spread in cal factor given acceptable conditions within Workbook limits).
- Add hardware (mass flow controller) to the air inlet line to allow the flow rate to accurately be controlled.
- Further explore and improve the calibration procedure to ensure it's repeatable (e.g. 6% spread under same conditions).

Example of Exit Criteria for HR2

- Variation reduction targets:
  - X% reduction in within machine variance relative to OSU
  - Y% reduction in between machine variation relative to OSU
- OSUs and HR2s to use:
  - OSUs used in evaluation should be
    - Relatively new (less than 5 years old?)
    - Verified that they are still in compliance with OSU handbook
    - Made by different manufacturers
  - HR2s used should be:
    - Same number as OSUs
    - Made by different manufacturers
- Samples:
  - Use samples with minimal variation
  - Randomized
  - A statistically sufficient number of samples must be used