HEAT RELEASE RATE Updates

Virtual Materials Working Forum

HR2 Sonic Choke Research

Michael Burns, FAA Tech Center

April 20th, 2021

Federal Aviation Administration

Problem Definition

- Interest in possibly replacing a costly/bulky main airflow mass flow controller (requiring annual calibration) with a sonic choke/venturi to control mass airflow through the heat release rate test apparatus (HR2).
- Compare OEM MFC, two sonic choke units purchased through a single manufacturer (Fox Instruments) and a third choke purchased through an alternative manufacturer (Flow Systems).
- Average values for Thermal Stability Temperature (°C), Calibration Factor (W/°C), Baseline (°C) and Delta T (°C) are calculated and compared.

Problem Definition

Sierra Instruments

Mass Flow Controller

Sonic Choke

Pressure Regulator

Pressure Xducer

Design Specification (Mass flow control for main airflow)

1.) OEM MFC - Sierra Instruments, Inc.

S/N: n/a

P/N: C100H1-NR-16-OV1-SV1-PV2-V1-S1-C3

Range: 0 – 20 SCFM

2.) Sonic Choke: Fox Valve, Inc.

S/N: 001

P/N: 625442

Range: 0 – 65 SCFM

Design Specification (Mass flow control for main airflow)

3.) Sonic Choke: Fox Valve, Inc.

S/N: 002

P/N: 625442

Range: 0 – 65 SCFM

4.) Flow Systems – 0.208" (+0.000/-0.001”) Diameter

S/N: 001

Quote number: Q-18498

Range: 0 – 65 SCFM

Concept Design

- A ControlAir 7100 Precision Pressure regulator was used to maintain an accurate and well controlled supply pressure.
- Threaded into the regulator was a pressure transducer (psig), Type “K” thermocouple and sonic choke.
- The choke outlet was plumbed into a straight section of pipe housing a redundant mass flow meter (CDI).

Accuracy: 5% of reading plus 1% of range for flows from 10% to 100% of indicated range at air temperatures between 20°F and 120°F

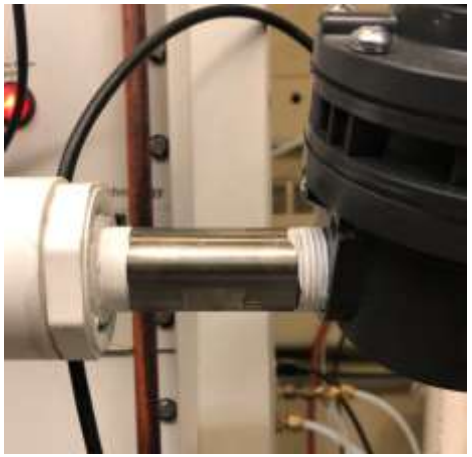
- After the CDI meter, the piping mounted into the lower plenum air inlet port of the HR2.

Pressure Control

- Pressure Regulator

✓ ControlAir #7100-EAE

✓ ~ $340 each

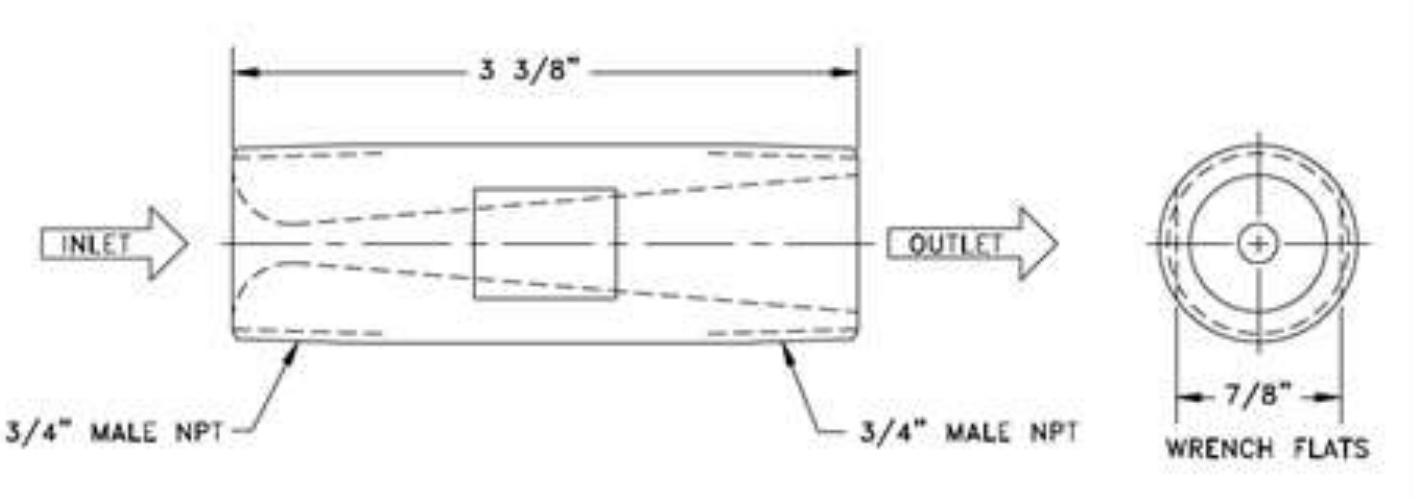


- High-Accuracy Pressure Gauge

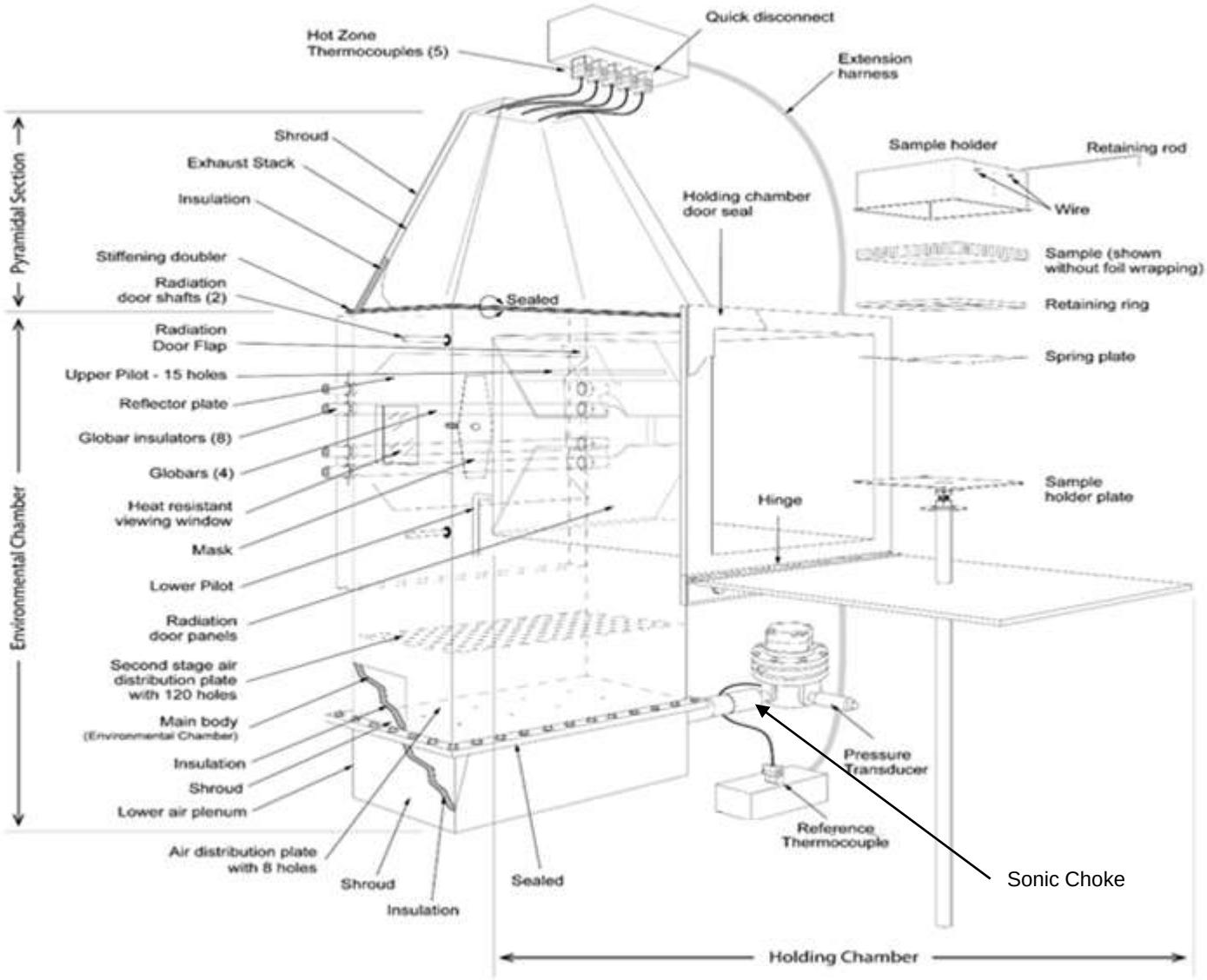
✓ PX309-050G10V

✓ ~ $270 each

HR2 Sonic Choke Specifications



Reference conditions (STP): 0°C @ 1 atmosphere (760 mmHg)
Setpoint: 20.0 PSIG @ 22.5 °C (72.5 °F)
Inlet diameter: 0.62 inches (15.7 mm)
Throat diameter: 0.208 inches (5.3 mm)
Mass flow rate: 96.84 lbs./hr
Cost: ~ $950 US Dollars


Hot Zone
Thermocouples (5)
Quick disconnect
Extension
harness
Pyramidal Section
Shroud
Exhaust Stack
Insulation
Stiffening doubler
Radiation
door shafts (2)
Sealed
Holding chamber
door seal
Sample holder
Retaining rod
Wire
Sample (shown
without foil wrapping)
Retaining ring
Spring plate
Environmental Chamber
Radiation
Door Flap
Upper Pilot - 15 holes
Reflector plate
Globar insulators (8)
Globars (4)
Heat resistant
viewing window
Mask
Lower Pilot
Radiation
door panels
Second stage air
distribution plate
with 120 holes
Main body
(Environmental Chamber)
Insulation
Shroud
Lower air plenum
Air distribution plate
with 8 holes
Shroud
Insulation
Sealed
Hinge
Sample
holder plate
Pressure
Transducer
Reference
Thermocouple
Sonic Choke
Holding Chamber

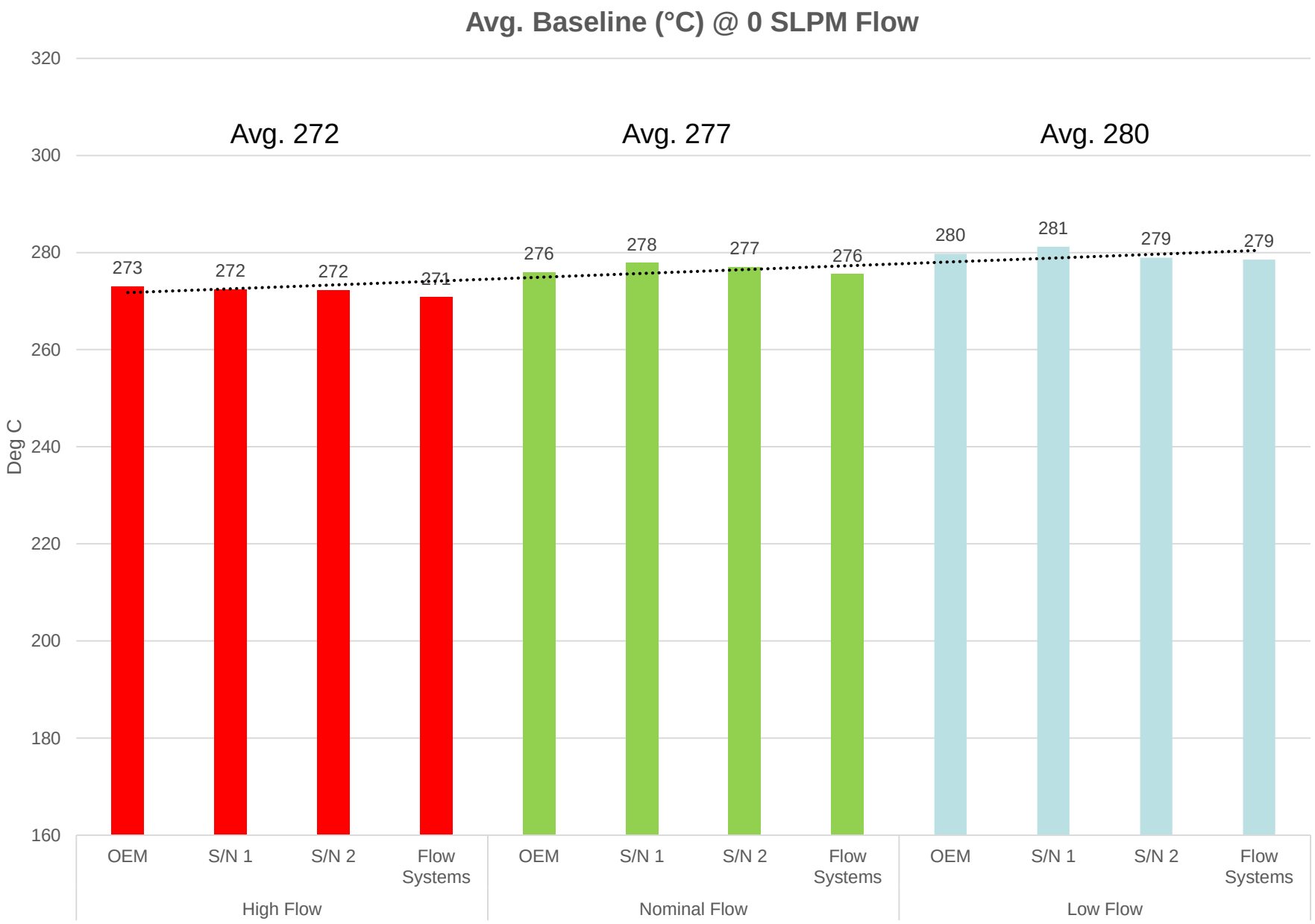
HR2 System Pressure Recording

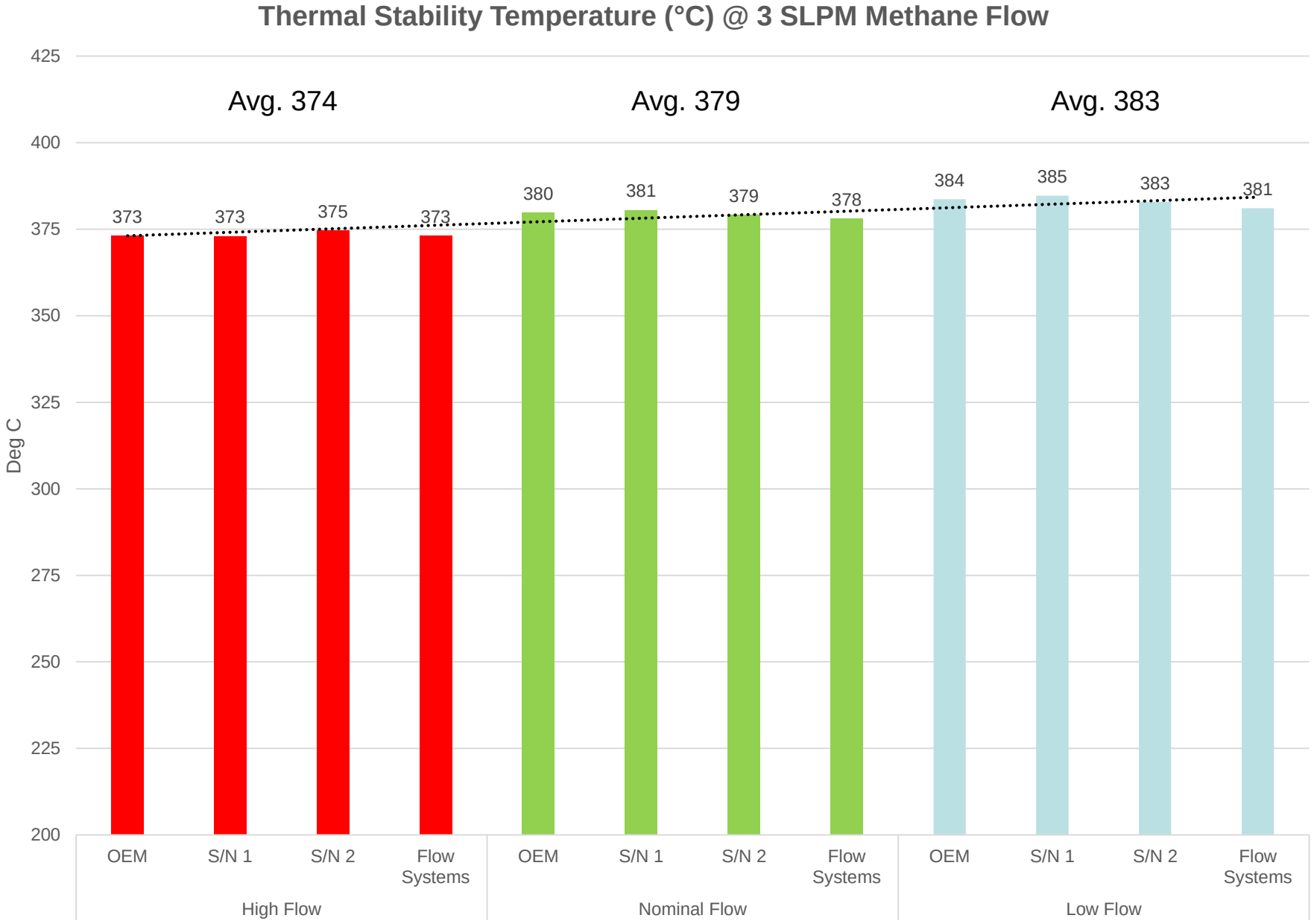
Pressure values in two areas were recorded using a digital manometer and an 1/8” stainless steel probe:

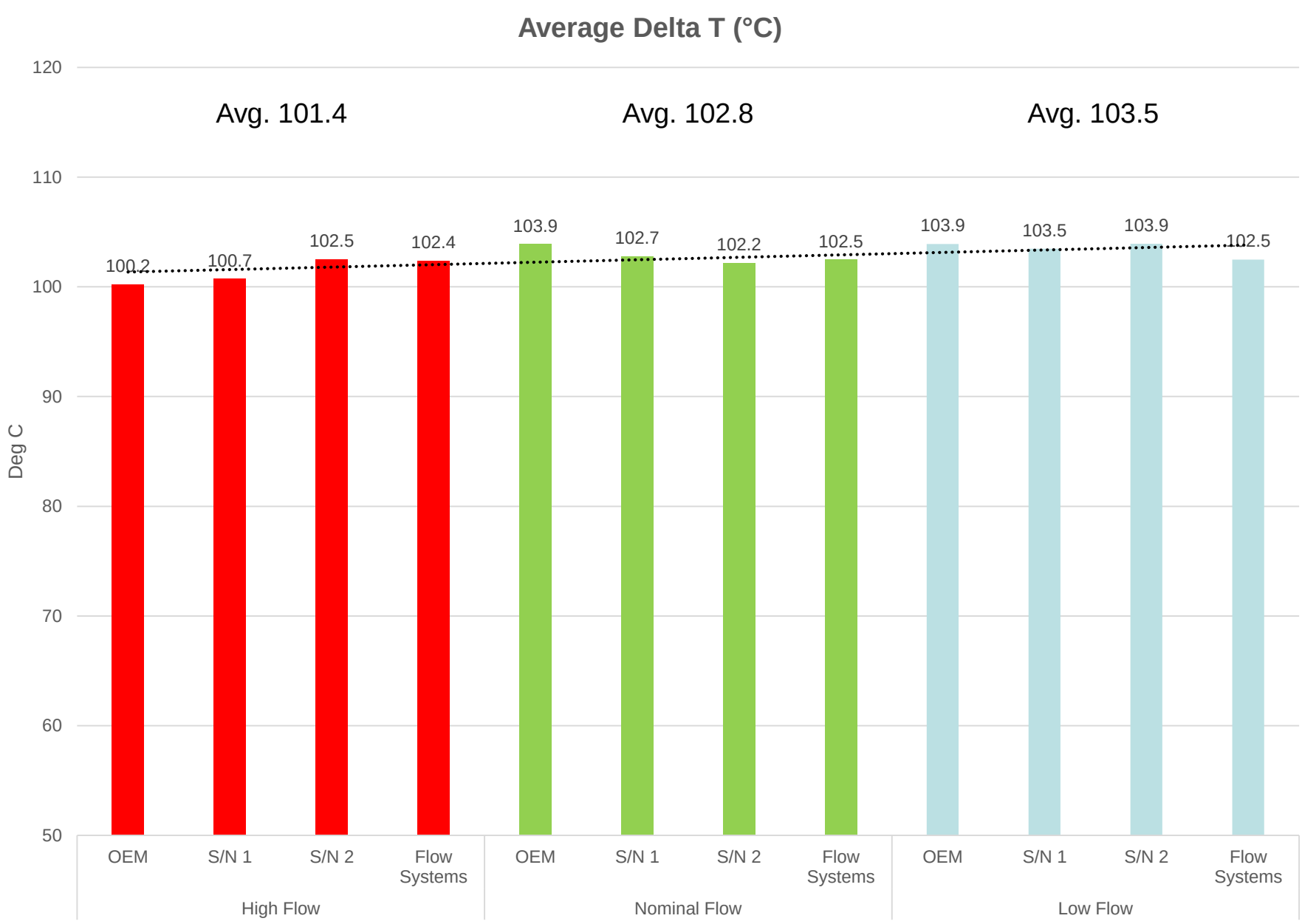
- Lower plenum pressure: This is the lowest chamber in the HR2 having the highest pressure in the entire system.
- Interspace pressure: This is an area between the lower plenum main air distribution plate and a secondary 120 hole plate.
- Prior to taking readings, the meter was zeroed out in ambient conditions having no pressure differential.
- For all conditions, the chamber was cold when pressure measurements were taken.

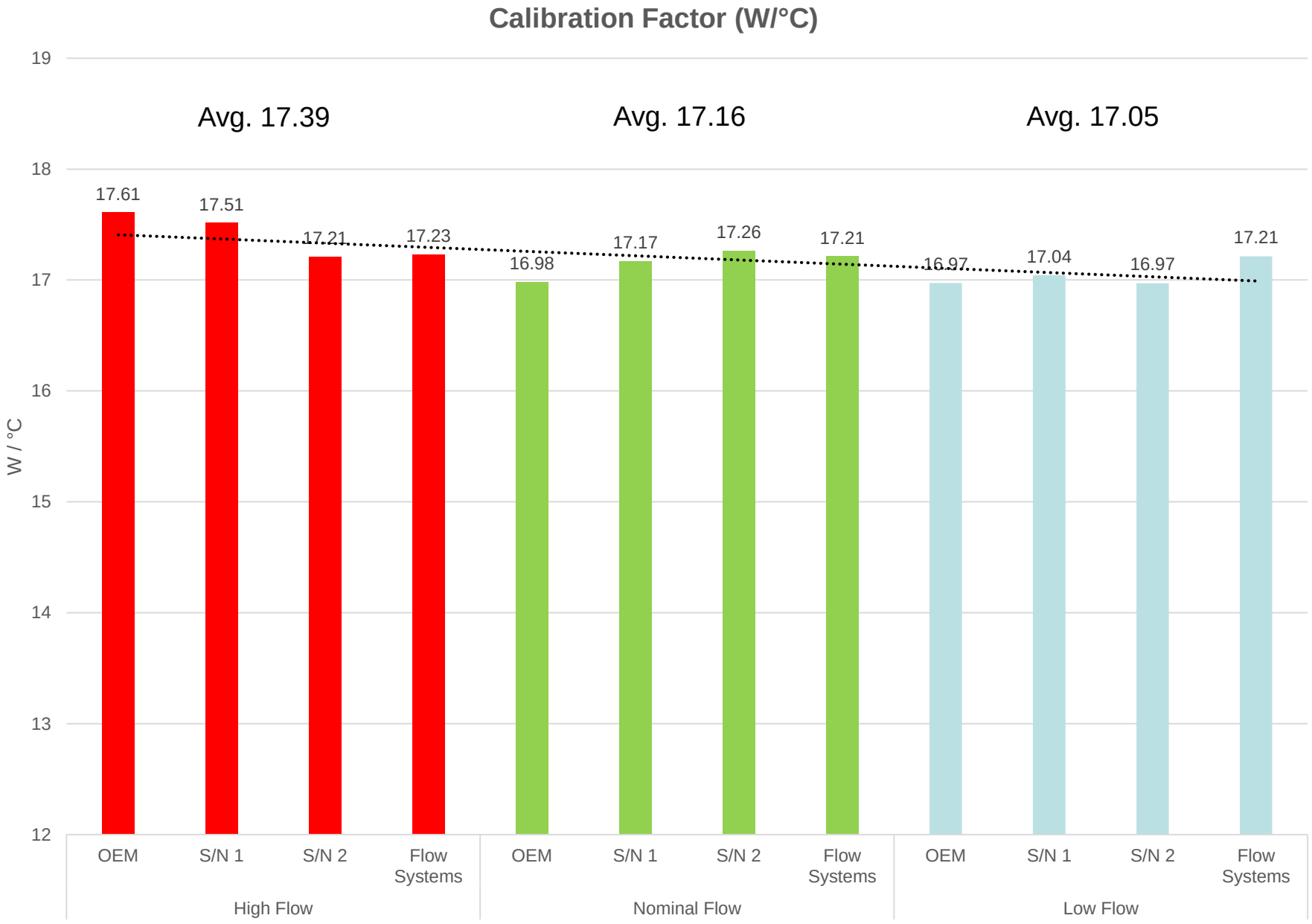
Test Plan

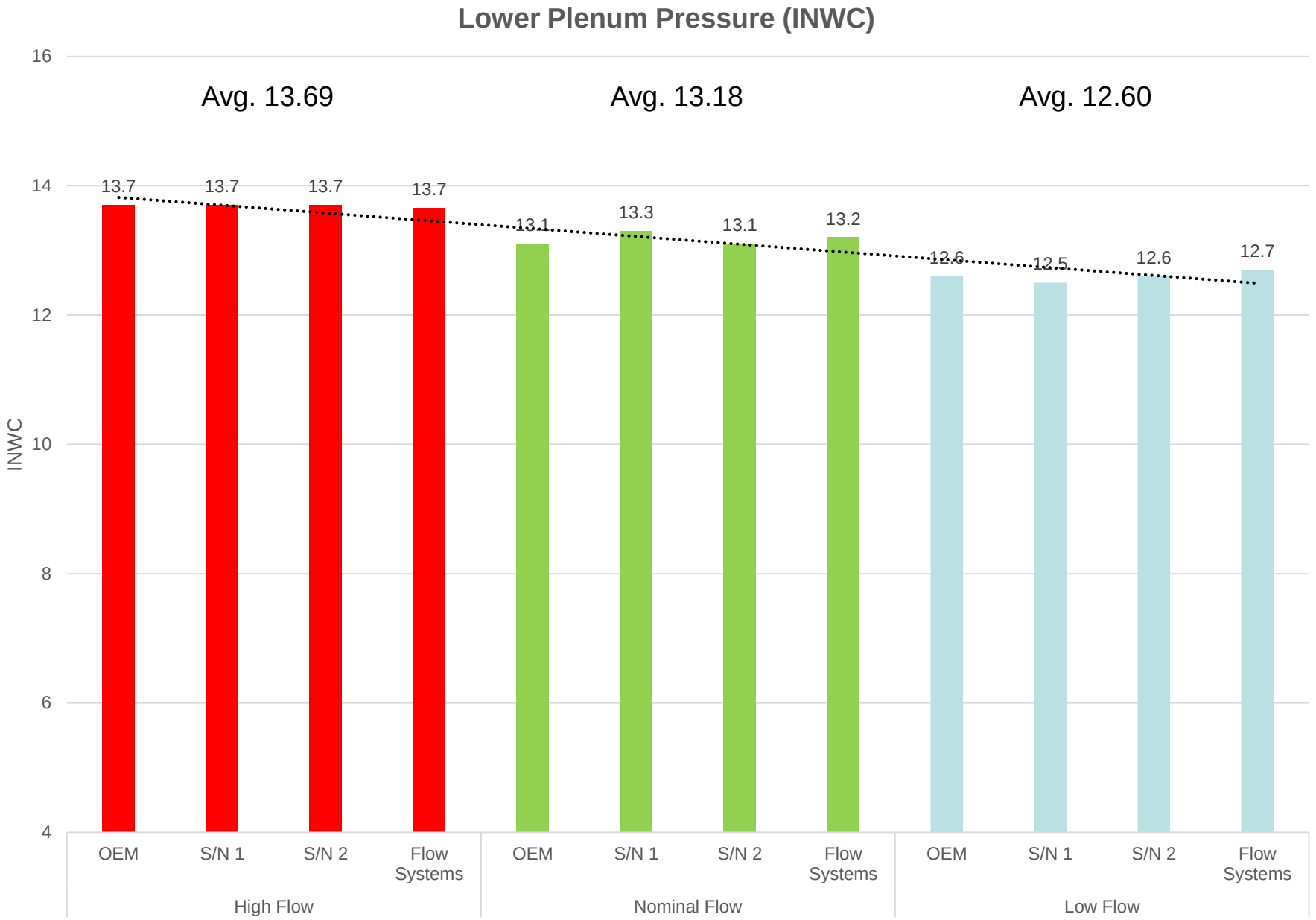
- An average of 3 calibration cycles were completed for each of the 4 devices
- For each device, minimum flow (19.6 SCFM), nominal flow (20 SCFM) and maximum flow (20.4 SCFM) for recorded.
- Each day heat flux measurement was verified to be within nominal range and the stability requirements were satisfied.
- Heat flux was monitored to see what the impact high & low flow conditions had (no measurable impact was noted).
- All exhaust gas thermopiles were cleaned daily.
- Initially the nominal flow of 20 SCFM was established followed by a minimum flow condition then the maximum flow as specified in the test matrix.
- For each calibration, test lab conditions were recorded as well as upper and lower globar power settings.
- Schneller Panel Test HRR data: Average of 3 runs for nominal flow

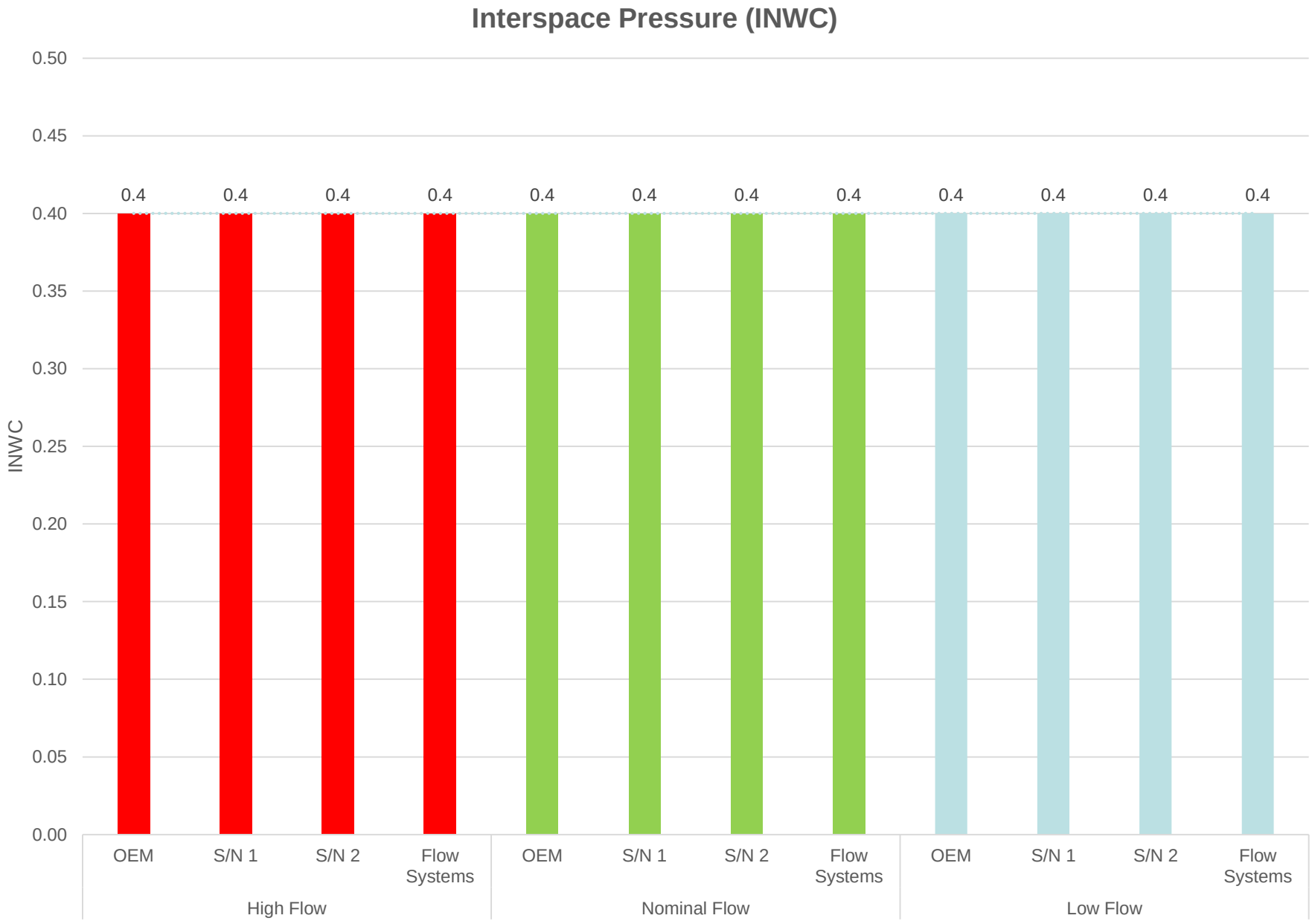

Avg. Baseline (°C) @ 0 SLPM Flow
320
300
280
260
240
220
200
180
160
Deg C
Avg. 272
Avg. 277
Avg. 280
273
272
272
271
276
278
277
276
280
281
279
279
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
High Flow
Nominal Flow
Low Flow

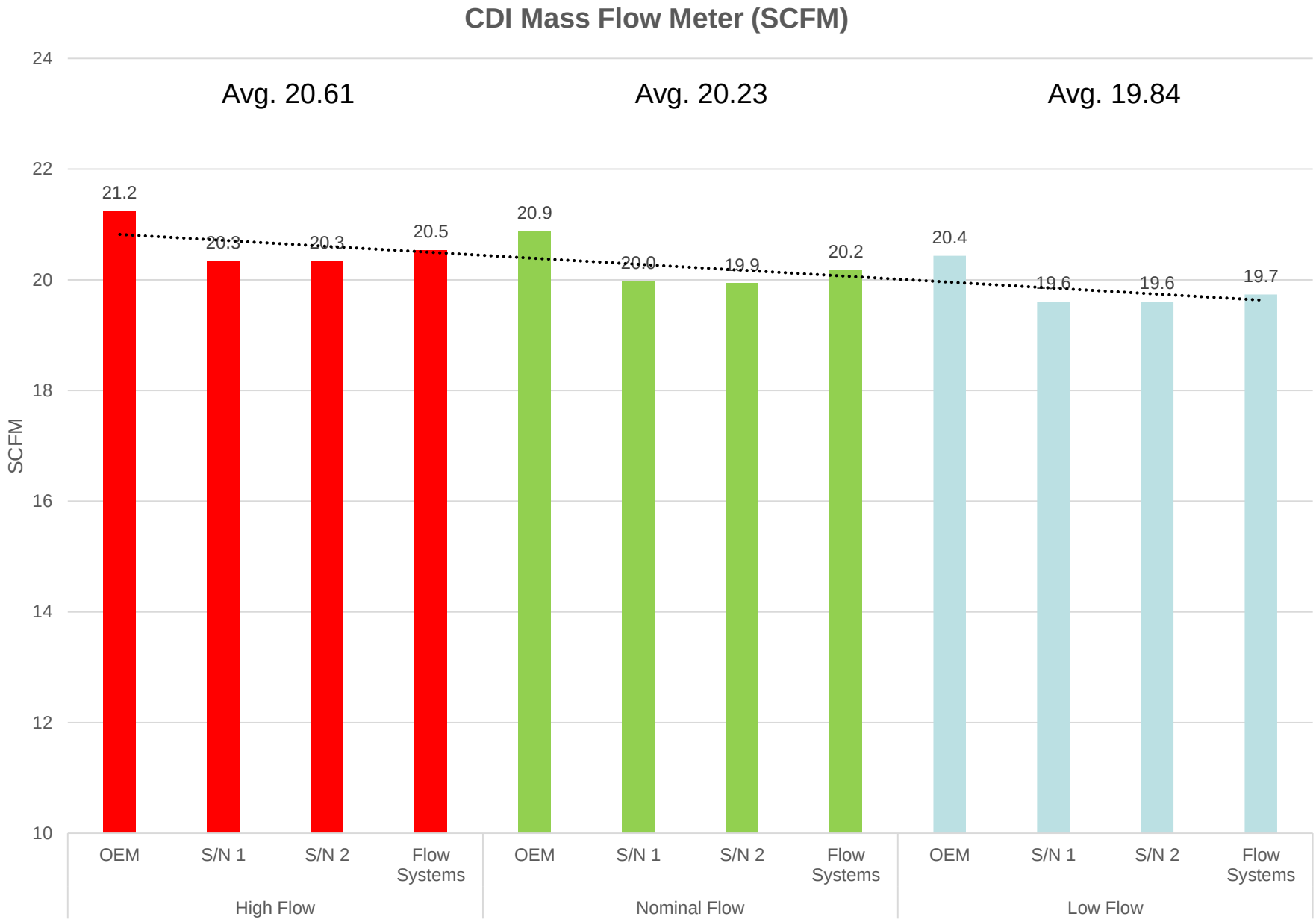

Thermal Stability Temperature (°C) @ 3 SLPM Methane Flow
Avg. 374
Avg. 379
Avg. 383
Deg C
425
400
375
350
325
300
275
250
225
200
373
373
375
373
380
381
379
378
384
385
383
381
OEM
S/N 1
S/N 2
Flow Systems
High Flow
OEM
S/N 1
S/N 2
Flow Systems
Nominal Flow
OEM
S/N 1
S/N 2
Flow Systems
Low Flow

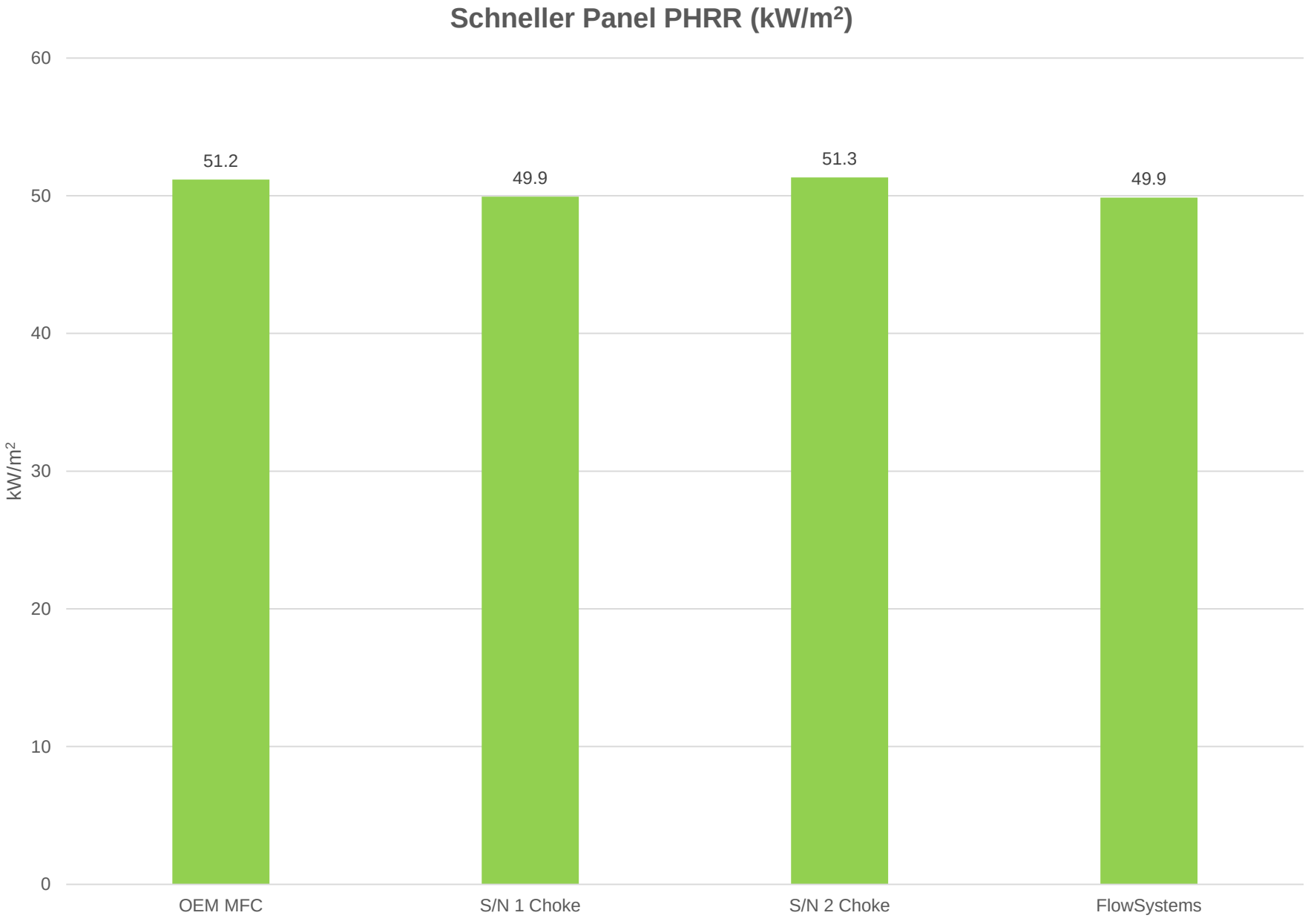

Average Delta T (°C)
Avg. 101.4
Avg. 102.8
Avg. 103.5
Deg C
120
110
100
90
80
70
60
50
100.2
100.7
102.5
102.4
103.9
102.7
102.2
102.5
103.9
103.5
103.9
102.5
OEM
S/N 1
S/N 2
Flow Systems
High Flow
OEM
S/N 1
S/N 2
Flow Systems
Nominal Flow
OEM
S/N 1
S/N 2
Flow Systems
Low Flow

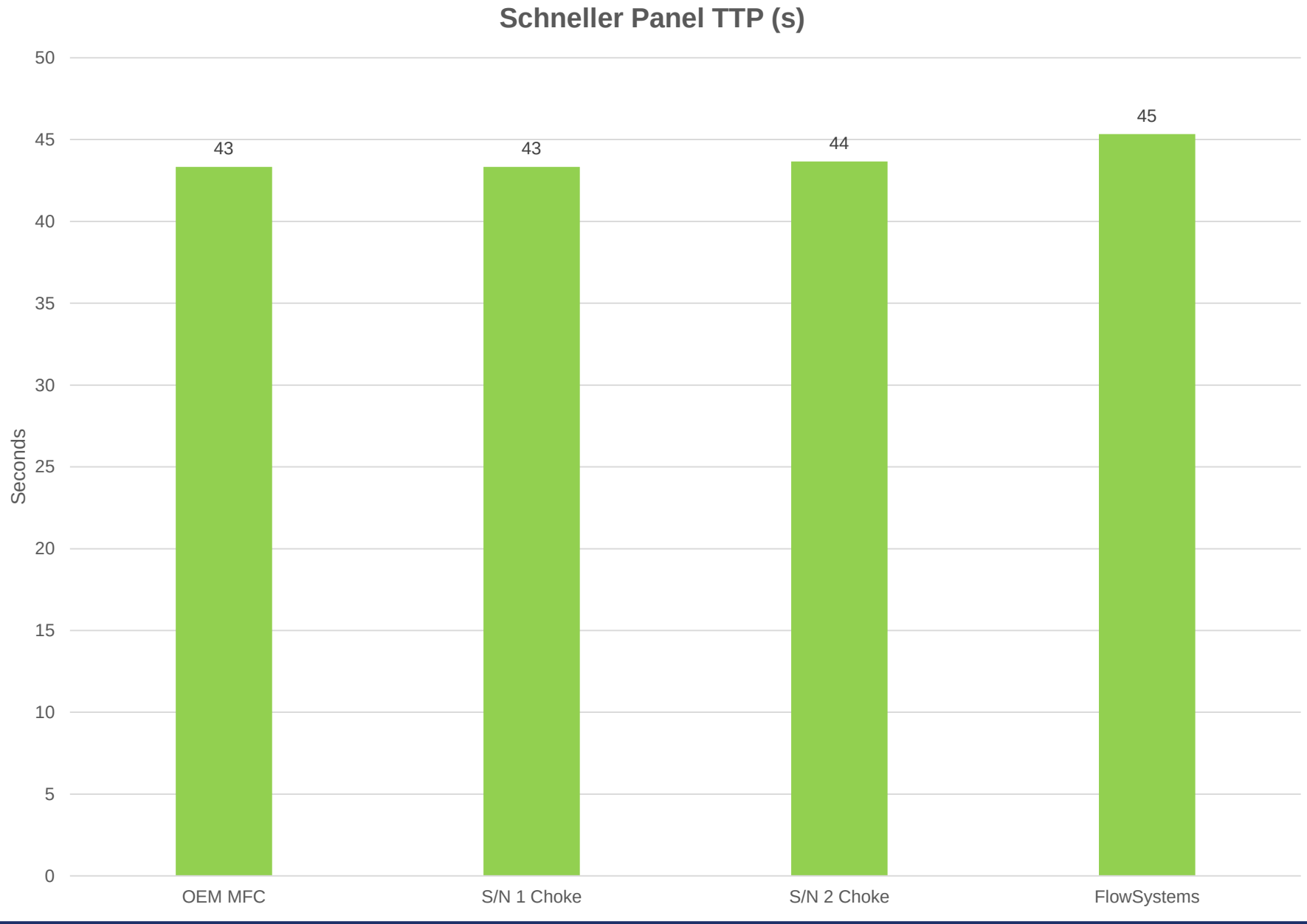

Calibration Factor (W/°C)
19
18
17
16
15
14
13
12
W / °C
Avg. 17.39
Avg. 17.16
Avg. 17.05
17.61
17.51
17.21
17.23
16.98
17.17
17.26
17.21
16.97
17.04
16.97
17.21
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
High Flow
Nominal Flow
Low Flow

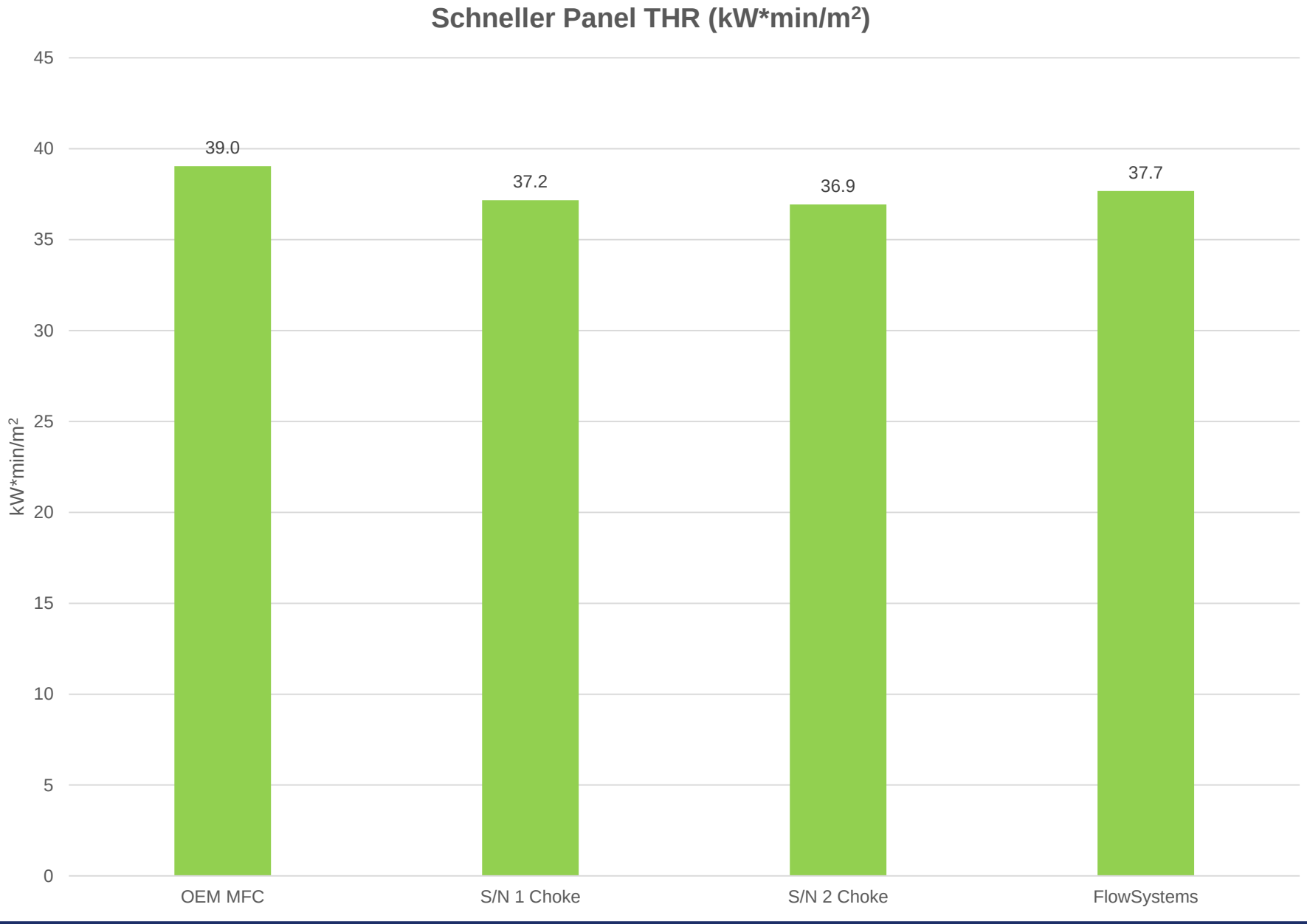

Lower Plenum Pressure (INWC)
Avg. 13.69
Avg. 13.18
Avg. 12.60
INWC
16
14
12
10
8
6
4
13.7
13.7
13.7
13.7
13.1
13.3
13.1
13.2
12.6
12.5
12.6
12.7
OEM
S/N 1
S/N 2
Flow Systems
High Flow
OEM
S/N 1
S/N 2
Flow Systems
Nominal Flow
OEM
S/N 1
S/N 2
Flow Systems
Low Flow


Interspace Pressure (INWC)
INWC
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.4
OEM
S/N 1
S/N 2
Flow Systems
High Flow
Nominal Flow
Low Flow


CDI Mass Flow Meter (SCFM)
Avg. 20.61
Avg. 20.23
Avg. 19.84
SCFM
24
22
20
18
16
14
12
10
21.2
20.3
20.3
20.5
20.9
20.0
19.9
20.2
20.4
19.6
19.6
19.7
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
OEM
S/N 1
S/N 2
Flow Systems
High Flow
Nominal Flow
Low Flow


Schneller Panel PHRR (kW/m²)
60
50
40
30
20
10
0
kW/m²
51.2
49.9
51.3
49.9
OEM MFC
S/N 1 Choke
S/N 2 Choke
FlowSystems


Schneller Panel TTP (s)
Seconds
50
45
40
35
30
25
20
15
10
5
0
43
43
44
45
OEM MFC
S/N 1 Choke
S/N 2 Choke
FlowSystems


Schneller Panel THR (kW*min/m²)
45
40
35
30
25
20
15
10
5
0
kW*min/m²
39.0
37.2
36.9
37.7
OEM MFC
S/N 1 Choke
S/N 2 Choke
FlowSystems

Summary Discussion

Schneller Test Panel (3 run average)

Device	OEM MFC	Fox #1	Fox #2	Flow Systems
PHRR(kW/m^2)	51.2	49.9	51.3	49.9
TTP (sec.)	43	43	44	45
THR (kW*min/m$^{2)}$	39.0	37.2	36.9	37.7

	Average	STDEV	% STDEV (COV)
PHRR(kW/m^2)	50.6	0.78	1.5%
TTP (sec.)	44	0.96	2.2%
THR (kW*min/m$^{2)}$	37.7	0.93	2.5%

Summary Discussion

- The average values for Thermal Stability Temperature (°C), Calibration Factor (W/°C), Baseline (°C) and Delta T (°C) were calculated and compared between the four devices @ three ranges of air flow in the Deatak HR2.
- Data shows very good correlation between all four configurations for both sonic choke manufacturers and the OEM MFC.
- Confidence was gained conducting this experimentation regarding ability to replace the MFC with the more economical sonic choke devices using at least two manufacturers.

Questions May Be Directed To:

Michael Burns

Aerospace Engineering Technician

FAA Fire Safety R&D Team, ANG E212

Phone (609) 485-4985

Fax (609) 485-5158

Email: mike.burns@faa.gov