HEAT RELEASE RATE Updates

2019 June Materials Meeting
Cologne, Germany

Materials Working Group

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June, 2019

AGENDA – HR2

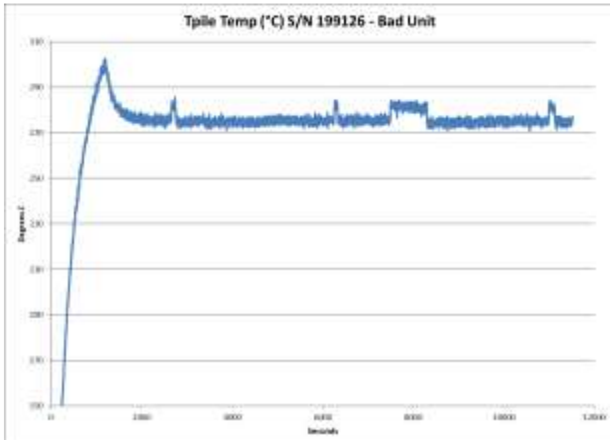
- Background
- T'Pile step change issue (Airflow)
- Calibration (Zero / Span method)
- Voltage control system / TRL 5 activity
- Placeholder document update
- O_2 insitu probe update (oxygen depletion)
- Next

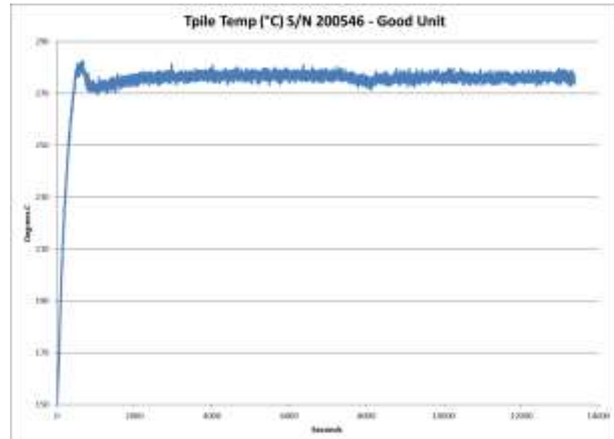
Background

- Initiative: Too improve OSU (HR2 development)
- Goal: Improve Repeatability / Reproducibility
- Objective: Standardized / Simple and easy
- Where are we at today?
  - Continuing forward with the HR2 current configuration of a non-cooled exhaust
  - Working the Calibration change discussed previous meeting
  - Continuing TRL 5 / 6 test activity

HR2 Mass Flow Meter Update

Random step change observed in thermopile

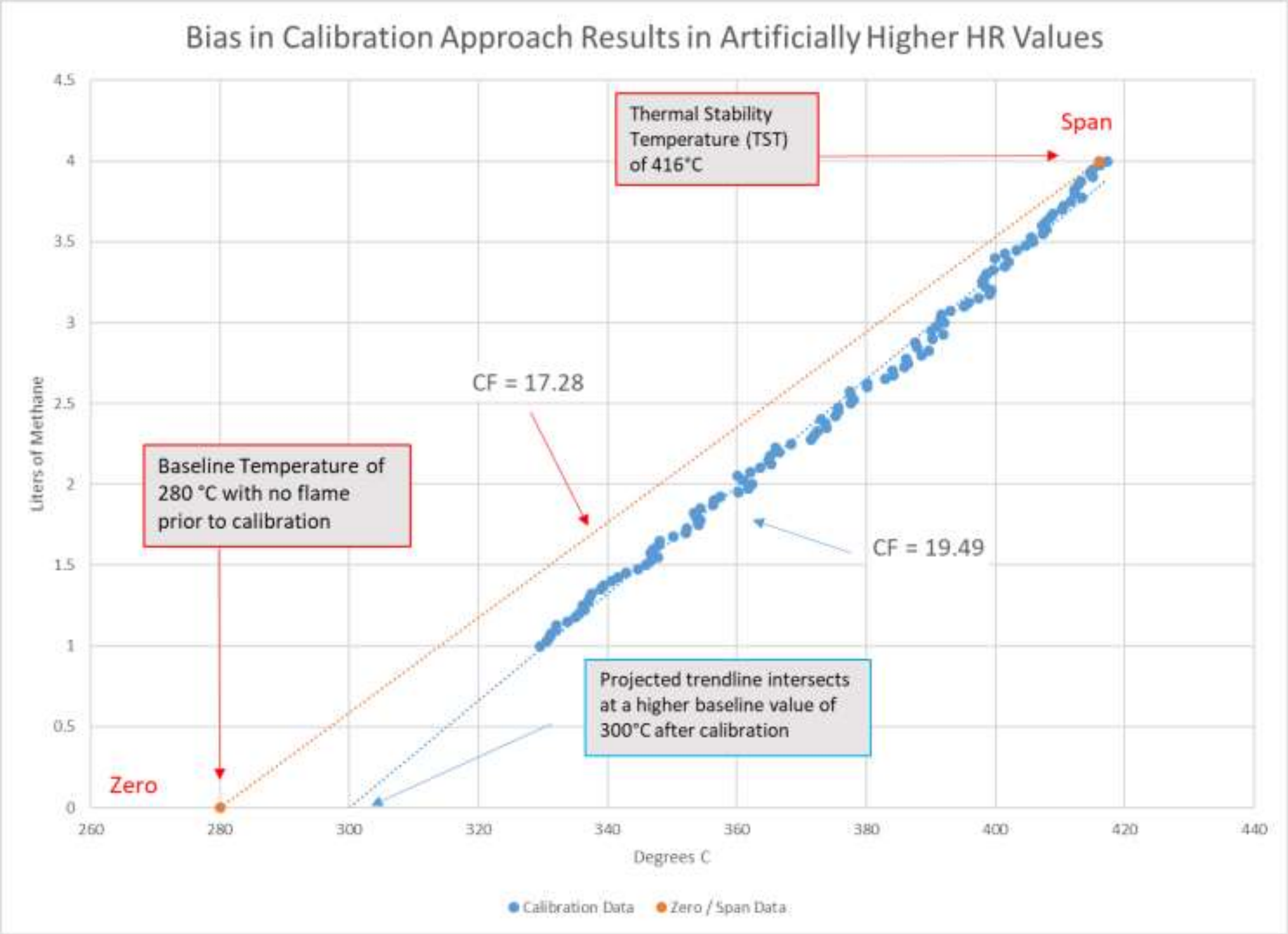




Evaluation and Repair:

Customer reported uneven flow rates with occasional spikes. Sierra technician was not able to duplicate this condition with a long-term test. A full set of data was taken and the meter was found near to spec. After discussing with the customer, Sierra is committed to changing out valve parts, circuit board and sensor as needed, as a precaution. The customer should run the controller in their application to confirm correct operation.

HR2 Status



Bias in Calibration Approach Results in Artificially Higher HR Values
Thermal Stability Temperature (TST) of 416°C
Span
CF = 17.28
CF = 19.49
Baseline Temperature of 280 °C with no flame prior to calibration
Projected trendline intersects at a higher baseline value of 300°C after calibration
Zero
Liters of Methane
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
260
280
300
320
340
360
380
400
420
440
Degrees C
Calibration Data
Zero / Span Data

Calculating Theoretical Heat Release Rate

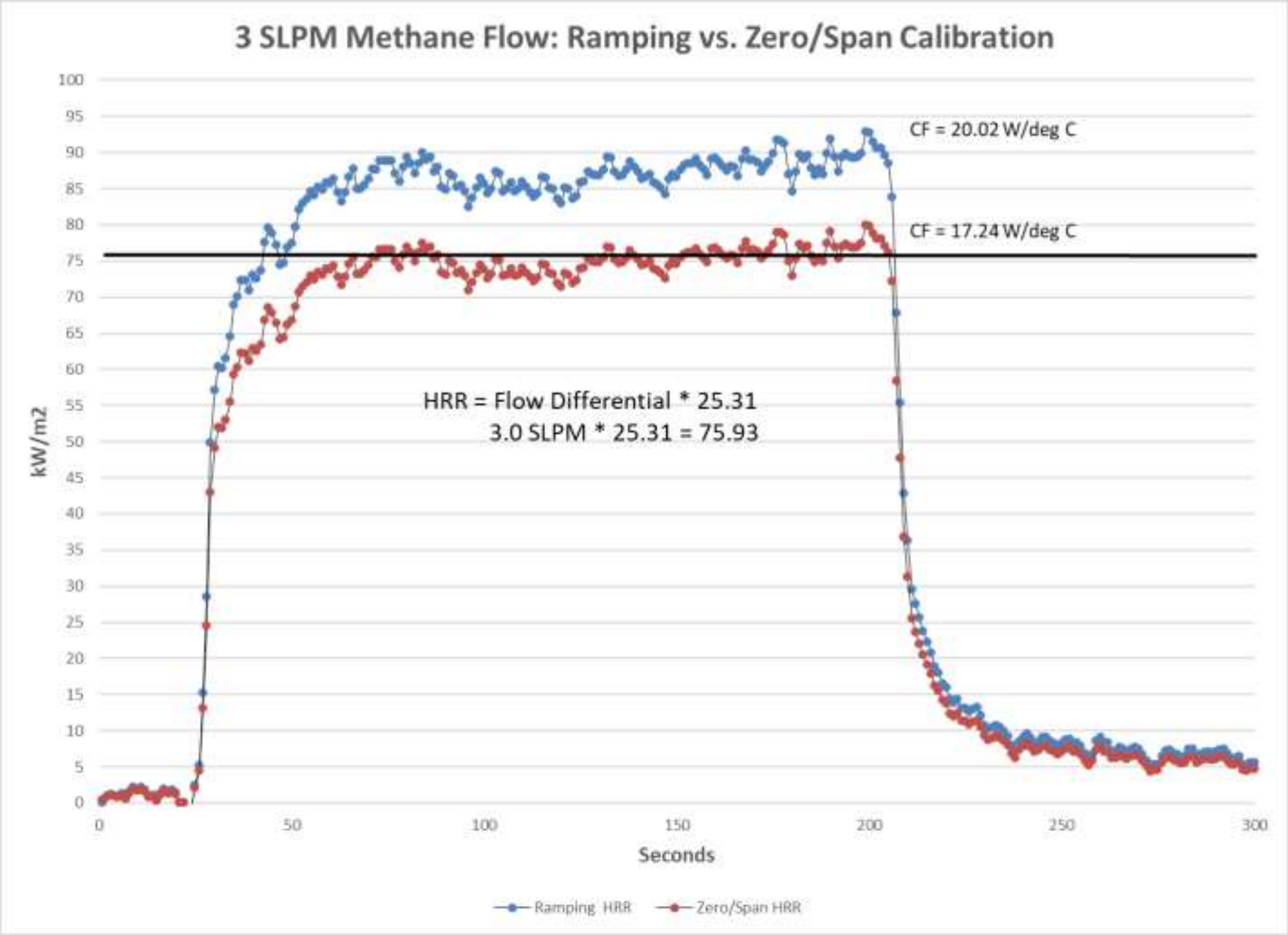
- $$\text{CF} = \frac{(210.8 - 22)}{(22.41 * 0.01433 * 1000)} * \frac{\Delta \text{L}}{\Delta °\text{C}}$$

- $$\frac{\text{CF}\ (\frac{\text{kW}}{°\text{C}})}{\frac{\Delta \text{L}}{\Delta °\text{C}}} = 0.5879\ \frac{\text{kW}}{\text{L}}$$

- $$\text{Theoretical HRR} = \frac{0.5879\,\frac{\text{kW}}{\text{L}}}{0.02323\ \text{m}^2} = 25.31\,\frac{\frac{\text{kW}}{\text{L}}}{\text{m}^2}$$

- $$\text{Theoretical HRR} = \Delta\ \text{Flow (L)} * 25.31\,\frac{\frac{\text{kW}}{\text{L}}}{\text{m}^2} = \frac{\text{kW}}{\text{m}^2}$$

Calculating Theoretical Heat Release Rate



HR2 Calibration

Zero / Span calibration

- Confirm heat flux / Remove calibration assembly / Close all doors
- Start Calibration program
- ZERO: 4 minute hold then average T'pile last 20 seconds
- Light burner @ <u>3 SLPM</u>
- SPAN: 4 minute hold then average T'pile last 20 seconds

HR2 Calibration

Zero / Span calibration

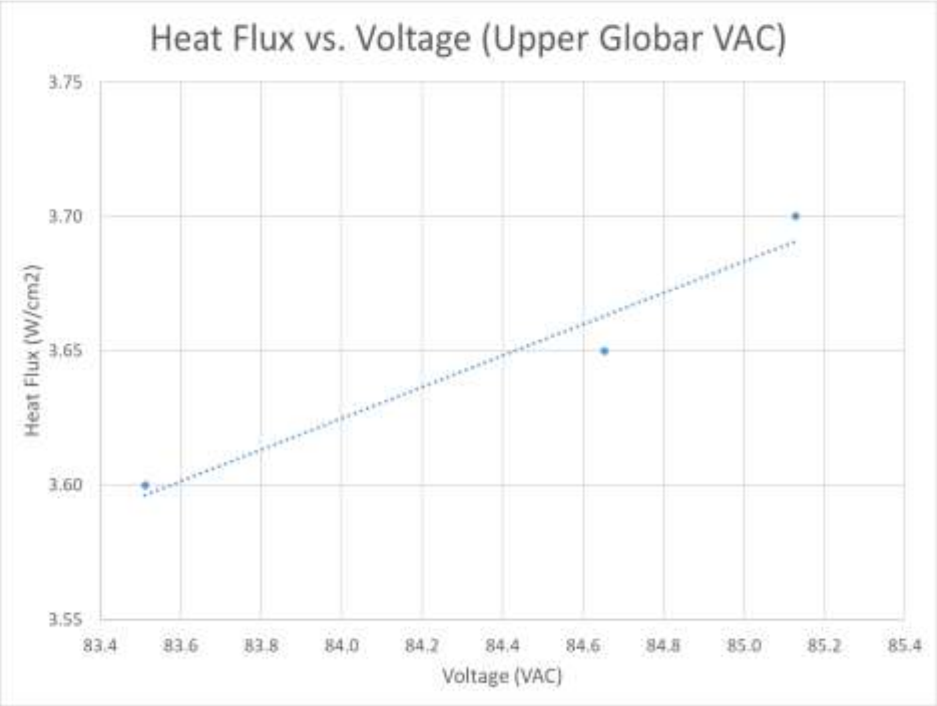
- Thermal Stability Temperature (TST) criteria changed since we are only flowing 3 SLPM Methane:

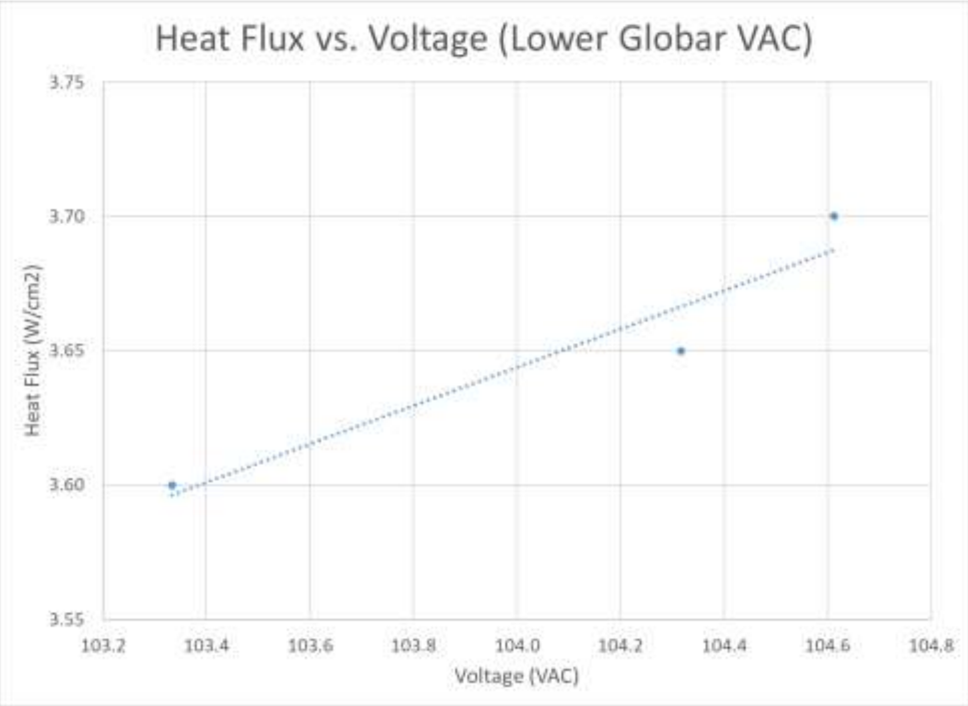
Old: 420 +/- 20 Degrees C / New: 380 +/- 15 Degrees C

- Ramping down of gas flow removed
- Calculate Zero / Span slope & new calibration factor
- Calibration factor range criteria change:

Old: 18 +/- 2 W/deg C / New: 17 +/- 2 W/deg C

Globar Voltage





Min/Max = 1.6 VAC Delta

Min/Max = 1.3 VAC Delta

HR2 Voltage Control System

4/29-30/2019

- ME1200-1 Power Control Upgrade Kit installed in HR2 unit (Marlin Engineering)
- The following equipment/features were included:
  - New Power Transducers (2)
  - New Voltage Transducers (2)
  - New DAQ Board
  - All associated wiring needed to install the above components
  - New software version to allow control and monitoring of power settings
- Work completed prior to TRL testing

HR2 Placeholder document update

Stability

- The term "stable," as it relates to heat-flux density and chamber equilibrium, is calculated using a moving average and expressed in terms of percent standard deviation over a defined period of time. Typically, stable conditions can be achieved between 60 and 90 minutes after heating has begun.

Heat flux (60-second moving average)

- Heat-flux gauge (HFG) millivolt signal that varies less than **(from 2 to 1.0%)** standard deviation during the last 60 seconds and having a calculated heat-flux density that is within range (see section A4.6).

Chamber equilibrium (15-minute moving average)

- Thermopile temperature signal that varies less than **(from 2 to 1.0%)** standard deviation during the last 15 minutes commencing no sooner than 30 minutes after turning the heating elements on.

HR2 Placeholder document update

Radiation Source

- A power supply capable of producing 12 kVA has been shown to be satisfactory. The radiation source must be adequately protected from variations in the power supply. A device for monitoring the voltage and current through each globar during testing must be provided. Line voltage fluctuations to the globars shall not exceed **(from 1.5% to +/- 1.0%).**

- The thermopile temperature is calculated as the temperature differential (ΔT) between the air entering and leaving the chamber. Each of the five hot zone thermocouple inputs is recorded and the average value is determined. The reference junction temperature is then subtracted from the average hot zone temperature to calculate the temperature rise of the thermopile signal. Annual calibration of each thermocouple and temperature input (DAQ) is required. Accuracy must be within ± 1% of **(from 420 to 380°C).**

Determination of the Calibration Factor (Kh) and procedures

HR2 Placeholder document update

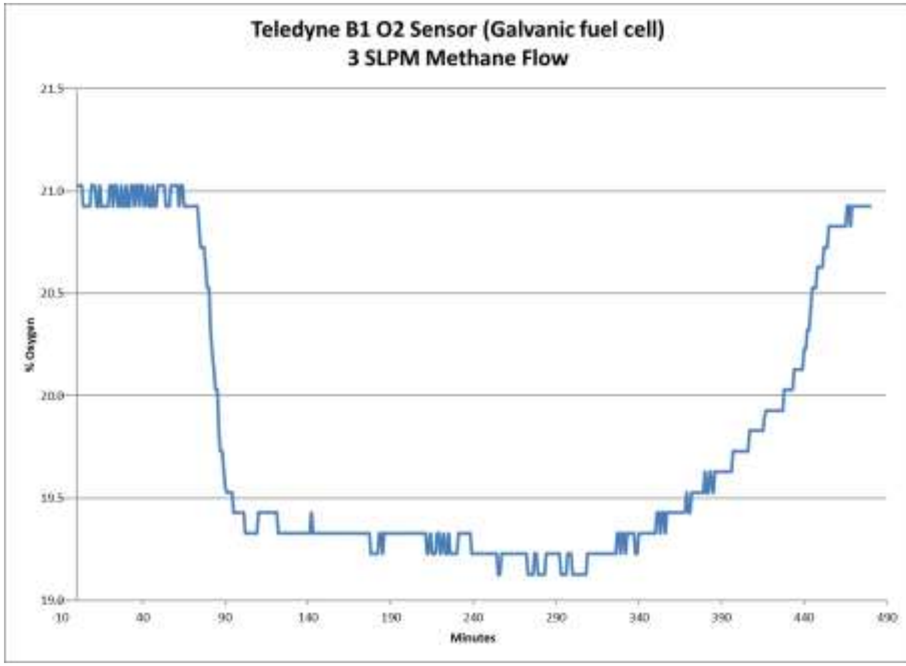
Nominal operating parameters/ranges

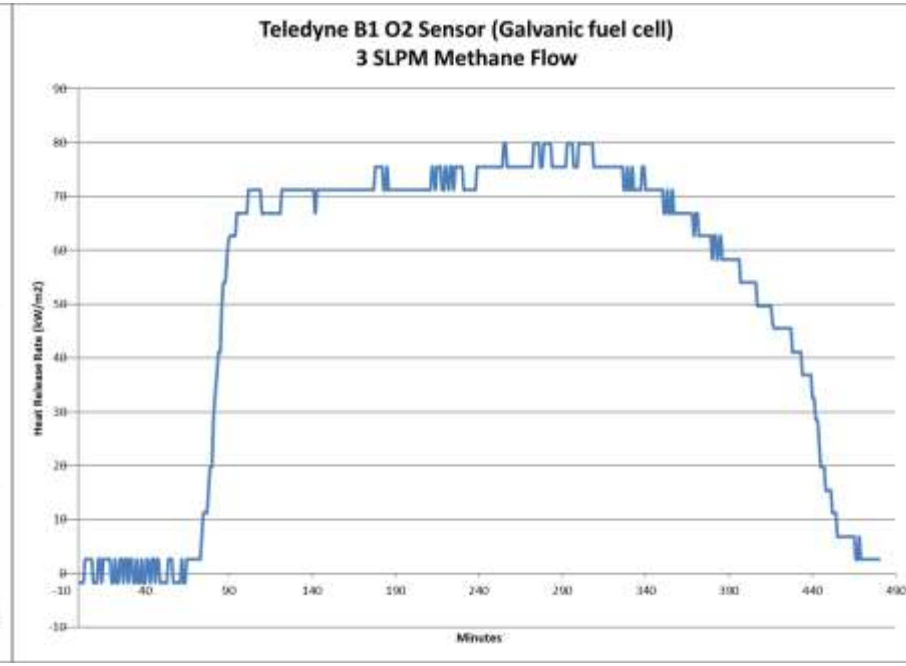
PARAMETER	DESCRIPTION	MIN.	NOMINAL.	MAX.
Inlet Airflow Rate	SCFM	19.6	20	20.4
Inlet Air Temperature	°C	21.1	22.5	23.9
Inlet Air Relative Humidity	% RH	-	-	≤ 65
Heat Flux (W/cm^2)	Center	3.60	3.65	3.70
	Each Corner (4)	3.55	3.65	3.75
Average Baseline Exhaust Gas Temperature	No Flame (°C)	270	280	290
Calibration Factor Range	**L/°C**	**0.0255**	**0.0289**	**0.0323**
	W/°C	**15.00**	**17.00**	**19.00**
	W/m^2/°C	**0.646**	**0.732**	**0.818**
	3 SLPM ΔT (°C)	**92.8**	**103.7**	**117.6**
Interspace Pressure	inH2O	0.40	0.55	0.70
Lower Plenum Pressure	inH2O	11.0	12.5	14.0
Methane Gas Supply Pressure	PSIG	18	20	22
Main Air Supply Pressure	PSIG	18	20	22
Mixing Air Supply Pressure	PSIG	18	20	22
Thermal Stability Temperature (TST)	**20 sec average (°C)**	**365**	**380**	**395**
Specimen Conditioning	Temperature (°C)	18	21	24
	Relative Humidity (%)	45	55	65
Upper Pilot Gas Flow	Air (SLPM)	0.98	1.00	1.02
	Methane (SLPM)	1.47	1.50	1.53
Lower Pilot Gas Flow	Air (mL/min)	0.65	0.70	0.75
	Methane (mL/min)	115	120	125

HR2 Oxygen Depletion R&D

- Teledyne B1 O2 Sensor (Galvanic Fuel Cell Type)
- SM-AFR Wideband Sensor Kit

HR2 Oxygen Depletion R&D





- Teledyne B1 O2 Sensor – Very poor resolution
- SM-AFR Wideband Sensor Kit – Could not read any % O2 change

NEXT

- Complete TRL activities as needed
- Continue observing calibration data over time
- Continue new prototype heater development for globar replacement
- Task group participant input requested

Questions?