HEAT RELEASE RATE Updates

2019 March Materials Meeting
Savannah, GA USA

Materials Working Group
Michael Burns, FAA Tech Center
March, 2019
AGENDA

• Background
• Bypass Flow in Heat Release Rate Apparatus
• HR2 / OSU Temperature Data
• HR2 Calibration / Calibration repeatability
• Recommendation for Voltage Monitors
• New Prototype Heater Development Update
• Next
Background

• Initiative: Too improve OSU (HR2 development)
• Goal: Improve Repeatability / Reproducibility
• Objective: Makes things simple, easy and standardized
• Where are we at today?
  o Concerns were raised over the exhaust section of the HR2 (non-cooled as compared to the OSU)
  o Is the HR2 hotter or produce higher HR values than OSU?
  o More data was requested by task group members as a way of moving forward
Bypass Cooling Effect in Heat Release Rate Apparatus

Cooled Exhaust

(Inserted 5 TC’s here)

Non-Cooled Exhaust
Dual and Single Flow Configuration

OSU Configuration
Chamber Flow: 21.3 SCFM
Bypass Cooling Flow: 63.7 SCFM
Total Flow: 85 SCFM

OSU Configuration (simulating HR2)
Chamber Flow: 21.3 SCFM
Bypass Cooling Flow: None
Total Flow: 21.3 SCFM
OSU Metal Temperatures (no flame)

Wall Temperatures: Single and Dual Flow

<table>
<thead>
<tr>
<th>Location</th>
<th>Single Flow</th>
<th>3_1 ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding Chamber</td>
<td>145</td>
<td>141</td>
</tr>
<tr>
<td>Cooling Manifold Left</td>
<td>437</td>
<td>187</td>
</tr>
<tr>
<td>Cooling Manifold Right</td>
<td>333</td>
<td>106</td>
</tr>
<tr>
<td>Inner Cone Left</td>
<td>695</td>
<td>245</td>
</tr>
<tr>
<td>Inner Cone Rear</td>
<td>688</td>
<td>215</td>
</tr>
<tr>
<td>Outer Cone Left</td>
<td>595</td>
<td>159</td>
</tr>
<tr>
<td>Outer Cone Rear</td>
<td>566</td>
<td>140</td>
</tr>
</tbody>
</table>
OSU Internal Temperatures
OSU Exhaust Gas Temperatures

Average Exhaust Gas Temperature (OSU 3:1 Ratio is Inner Cone EGT)

- No Pilot Burners:
  - OSU 3:1 ratio: 499°F
  - HR2: 574°F
  - OSU Single Flow: 568°F

- With Pilot Burners:
  - OSU 3:1 ratio: 611°F
  - HR2: 678°F
  - OSU Single Flow: 721°F

- 4 SLPM:
  - OSU 3:1 ratio: 781°F
  - HR2: 815°F
  - OSU Single Flow: 781°F
HR2 / OSU Power Data

AC Voltage

OSU

Upper Golbar Volts: 69.3
Lower Golbar Volts: 77.0

HR2

Upper Golbar Volts: 69.3
Lower Golbar Volts: 92.6
HR2 / OSU Power Data

![Amperage Chart]

- **OSU**:
  - Upper Golbar Amps: 22.9
  - Lower Golbar Amps: 30.6

- **HR2**:
  - Upper Golbar Amps: 22.8
  - Lower Golbar Amps: 29.8

Legend:
- Blue: Upper Golbar Amps
- Orange: Lower Golbar Amps
Ramp Down Calibration Profile (6 Total Minutes)

- ΔT
- Flow

Thermal Stability Temperature: 420 ± 20 °C (20 seconds average)

0.025 L/second ramp down rate over 120 seconds

Must start 4 SLPM preheat within 10 seconds of lighting the burner and closing the doors
HR2 Ramp Down Calibration

Calibration Repeatability Testing
Avg: 19.72 / % Stdev: 1.8
HR2 Status

Bias in Calibration Approach Results in Artificially Higher HR Values

- Thermal Stability Temperature (TST) of 416°C
- Baseline Temperature of 280 °C with no flame prior to calibration
- Projected trendline intersects at a higher baseline value of 300°C after calibration

CF = 17.28

CF = 19.49
Calculating Theoretical Heat Release Rate

- \[ CF = \frac{(210.8 - 22)}{(22.41 \times 0.01433 \times 1000)} \times \frac{\Delta L}{\Delta mV} = \frac{kW}{mV} \]

\[ CF \left( \frac{kW}{mV} \right) = 0.589714 = \frac{kW}{L} \]

- Theoretical HRR = \[ \frac{0.587914 \frac{kW}{L}}{0.02323 \ m^2} = 25.31 = \frac{kW}{L \ m^2} \]

- Theoretical HRR = Flow delta(L) * 25.31 \[ \frac{kW}{L \ m^2} = \frac{kW}{m^2} \]
Calculating Theoretical Heat Release Rate

\[ HRR = \text{Flow Differential} \times 25.31 \]

\[ 3.0 \text{ SLPM} \times 25.31 = 75.93 \]
Schneller Panel Test Data

**Heat Release Rate Test Apparatus**
March 2019
Honeycomb Panel w/ White Dec

Heat Release Rate Test Apparatus
March 2019
Ultem 9085
HR2 Calibration

Research new zero/span calibration approach

• 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 @ 3 SLPM

• SPAN: 4 minute hold then average T’pile last 20 seconds
HR2 Calibration

- Thermal Stability Temperature (TST) Criteria will change since we are only flowing 3 SLPM Methane
  
    Old: 420 +/- 20 Degrees C / New: 380 +/- 15 Degrees C

- Calibration complete (Ramping down of gas flow removed)

- Calculate Zero / Span slope & new calibration factor

- Calibration Factor Range Criteria will change
  
    Old: 18 +/- 2 W/deg C / New: 17 +/- 2 W/deg C

* Possibly incorporate a 90% thermal response time criteria
Globar Voltage Monitors?

- Not too many labs monitor globar voltage or current throughout the day
- TC installed DP20 voltage monitors (x2) on OSU & HR2
- Easy to install
- Maintain confidence in power even after HFG’s are removed just prior to testing
Globar Voltage Monitors?

Min/Max = 1.6 VAC Delta

Min/Max = 1.3 VAC Delta
HR2 Status

New Prototype Heater Development

- Dimensions: 10” W x 10” H x 2” D
- Zones: 3 (Upper / Center / Lower)
- Flush mounted glass with rear wall (sealed)
  - Removed from air stream (internally)
- Replaces the following components:
  - Globar pan (Globar end penetrations), Diamond-shaped Mask & Rear Reflector Plate
HR2 Status

New Prototype Heater Development
NEXT

- Continue working calibration R&D as needed
- Continue new prototype heater development for globar replacement
- Complete TRL activities
- Task group participant input requested
Questions?

KEEP CALM
BECAUSE
IT'S ALMOST HAPPY HOUR