Revised Rate of Heat Release Test Method & Smoke Monitoring (HR2)

October, 2022
Triennial Conference
Atlantic City, NJ
USA

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AGENDA

- HRR test method
- Background for revision
- Modifications
- Smoke monitoring research
- Next

Heat Release Rate Test Method

- Required by Federal Aviation Administration (1988)
- Qualify large surface area interior materials for use in commercial passenger aircraft
  - Ceilings
  - Stow bins
  - Sidewalls
  - Partitions
- Federal Register 14 CFR parts 25 and 121
  - Description
  - Use
  - Calibration
  - Pass / Fail criteria

Revised Heat Release Rate Test Method

Goal: Simplify and Streamline

- Multi-laboratory studies in which the same material was tested at different locations indicate reproducibility of test results can be improved.
- Many factors can contribute to poor agreement between test laboratories.
- This presentation describes a detailed revision of the test apparatus conducted by the International Aircraft Materials Fire Test Forum (IAMFTF) to better standardize components, procedures and calibration of equipment for this test method.

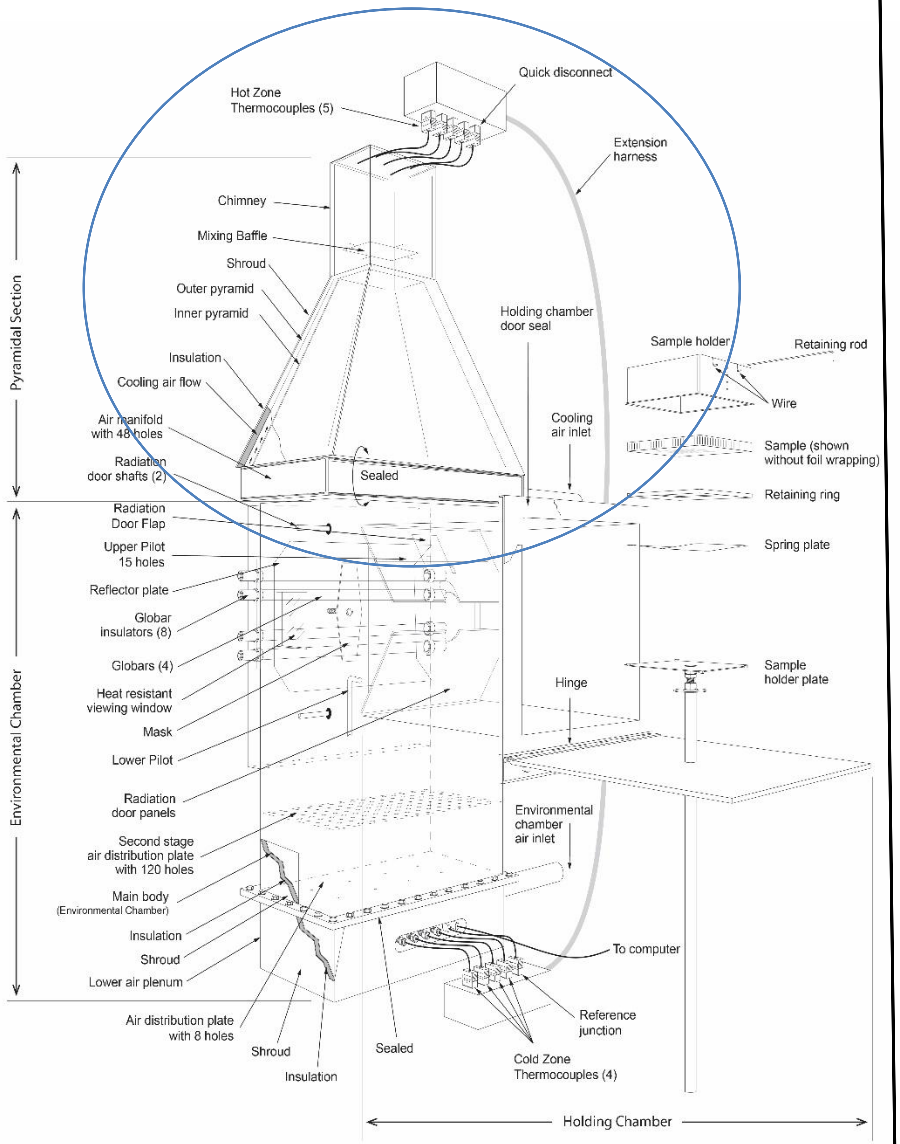
Areas Of Focus

- Airflow
  - Dual flow to single flow
  - Defined air quality (%RH) and control (MFC)
  - Higher exhaust gas temperatures (non-cooled exhaust)
- Standardized Construction
  - Component metal thickness & tolerances table
  - Overlap criteria specified
  - Insulation - Thermal conductivity, density and material criteria specified
  - Carbon graphite gasket material

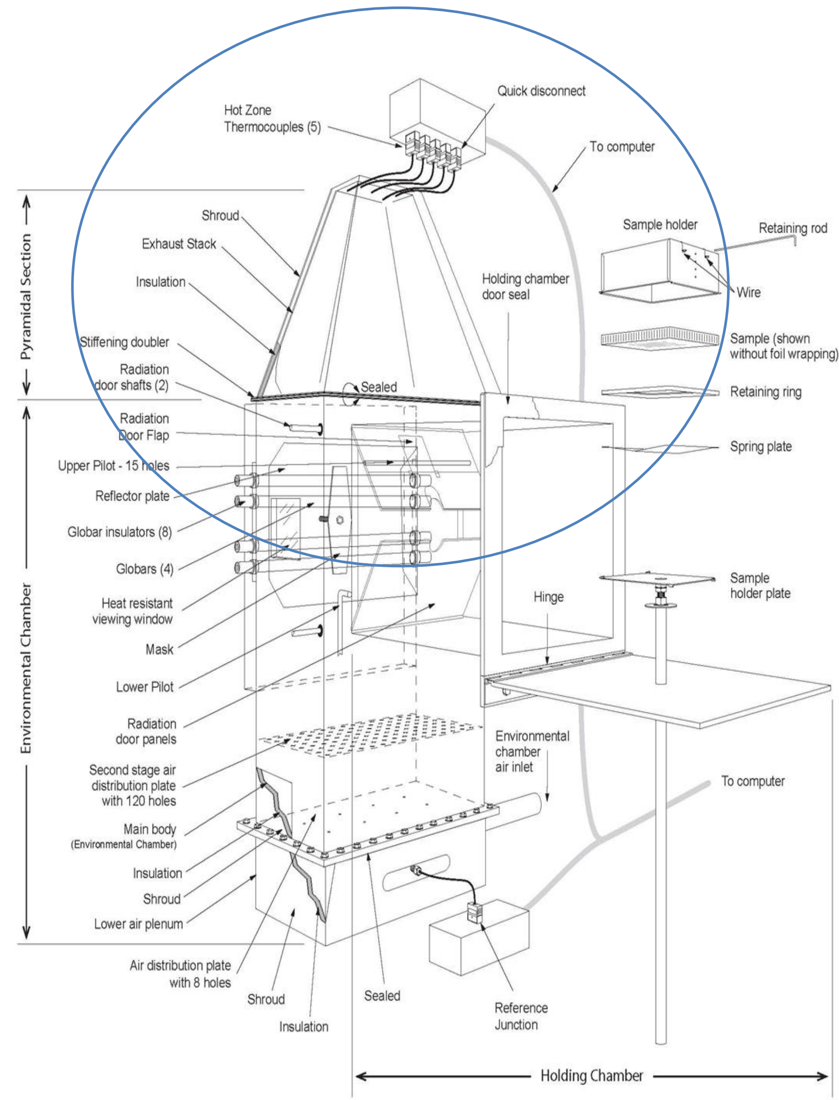
Areas Of Focus

- Software DAQ criteria
- Initiated power control requirements
- Improved calibration method
  - Zero / Span
- Equipment
  - Manufactured TC’s
  - Schmidt-Boelter heat flux gauges
  - Gas flow control using MFC’s
- Detailed operation & procedures

Airflow – Single Flow Design

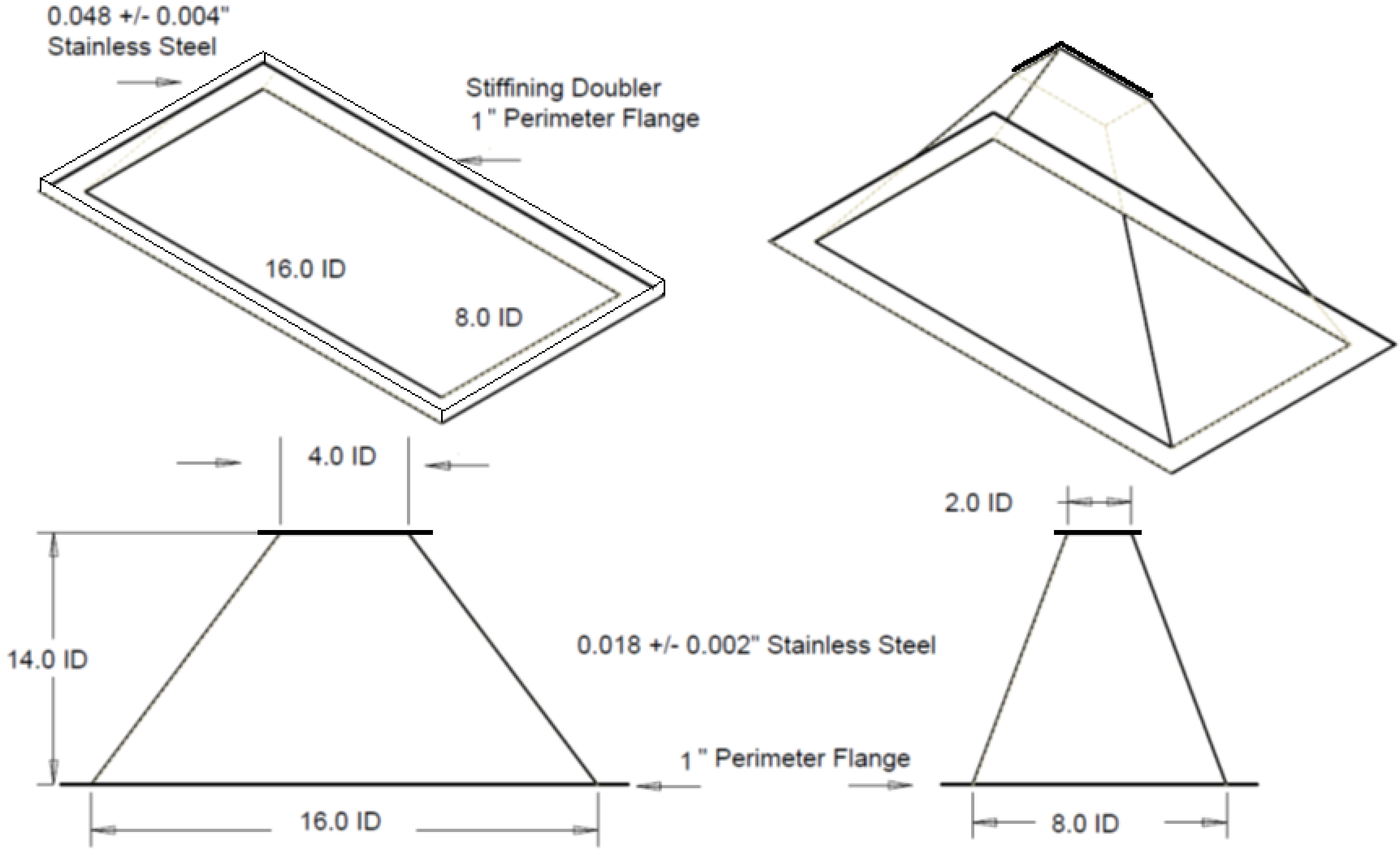


OSU: Orifice Meter, Natural 3:1 Airflow Split



HR2: Mass Flow Controlled

HR2 Exhaust Assembly



Standardized Construction

- Exhaust stack mounting
  - #10-32 x ¾” bolts / washers / nuts (28)
  - Stiffening doubler and gasket (carbon graphite)
  - Insulation (mineral wool)
  - 0.036 +/- 0.003 Aluminum covering
  - No substitutions permitted

- Main body
  - Dimensions
  - Observation window
  - Inner radiation doors
  - Rear globar pan
  - Reflector plate
  - Diamond plate shaft
  - Upper pilot / Calibration burner
  - Second Stage Plate
    - Hole pattern (centered in chamber)
    - Perimeter sealed
    - Removable

Standardized Construction

- Holding chamber
  - Dimensions
  - Outer door
  - Preheat sample position

- Specimen holder / components
  - Dimensions
  - Retaining ring
  - Spring plate
  - Retaining rod
  - Drip pan

- HFG Mounting
  - Corner HFG position defined
  - Refractory board (thickness, density, HFG flush mount)

Standardized Thermopile / Globars

- Thermopile System
  - New Exposed Bead type thermocouples
    - 5 hot zone; 1 cold zone
  - 24 gauge, solid conductor, thermocouple grade wire
  - Quick disconnects
  - Cold junction centrally located in lower plenum
  - Independent monitoring of all TC's (calculate ΔT)
  - Annual calibration of each thermocouple and temperature input is required. Accuracy must be within ± 1% of 380°C
  - Distilled water spray (cleaning)

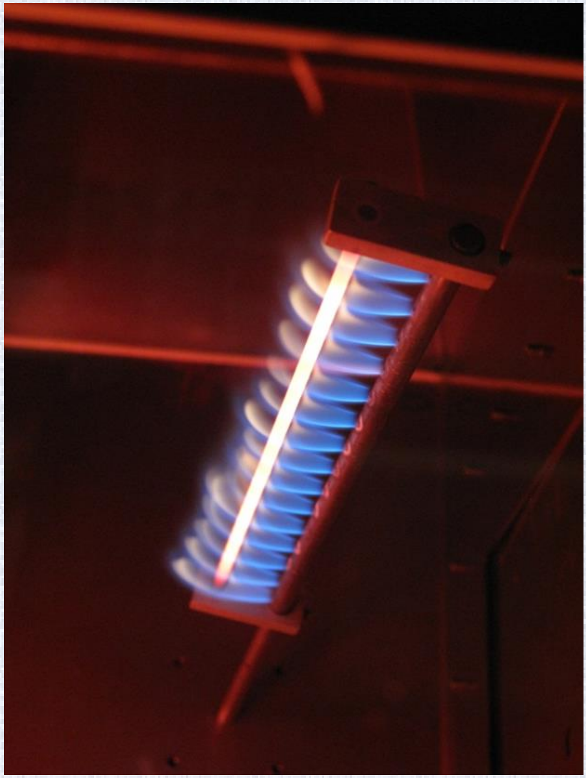
- Globars
  - Construction: CHZ, length, diameter, resistance
  - Power control requirements of upper / lower globars
  - Voltage fluctuation tolerance ± 1% (throughout day)

New: Upper Pilot Hot Surface Igniter (HSI)

- A 0.125 ± 0.005 inch diameter ceramic rod 8.0 ± 0.0625 inches in length is positioned directly in the flames of the upper pilot burner.

- The rod is continuously heated by the flamelets acting as a hot surface igniter to auto-ignite any upper pilot flames should they go out.

- The distance from the centerline of the burner tube to the centerline of the HSI rod is 0.75 ± 0.125 inch.



New Procedures: Heat Flux

- HFG Type: Replaced Gardon with Schmidt-Boelter

- HFG Guidance: Paint / Care / Mounting

- New insitu method (Center)
  - 3.65 ± 0.05 W/cm^2 ($3.50 \pm 5\%$ W/cm^2)

- New uniformity tolerance (4-Corners)
  - 3.65 +/- 0.10 W/cm^2

New Procedures: Heat Flux

Stability criteria

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

Heat flux (60 second moving average)
Heat flux gauge millivolt signal that varies less than 1.0% standard deviation over the last 60 seconds and having a calculated heat flux density that is within range.

Chamber equilibrium (15 minute moving average)
Thermopile millivolt signal that varies less than 1.0% standard deviation over the last 15 minutes commencing no sooner than 30 minutes after turning the heating elements on.

Changes as result of DOE Testing (~2016)

- Chamber airflow:
  From: 20.0 ± 5% (19.0 – 21.0 SCFM)
  To: 20.0 ± 2% (19.6 – 20.4 SCFM)
- Upper pilot methane flow:
  From: 1.50 ± 13.3% (1.30 – 1.70 SLPM)
  To: 1.50 ± 2% (1.47 – 1.53 SLPM)
- Upper pilot air flow:
  From: 1.0 ± 20% (0.80 – 1.20 SLPM)
  To: 1.0 ± 5% (0.95 – 1.05 SLPM)
- Replaced the panel mounted air flow meter (for upper pilot mixing air) with a MFC

Calibration

Goals:

- Achieve better repeatability between successive calibrations
- Achieve good reproducibility between machines
- Reduce time req'd to complete the calibration process
- Reduced use of Methane gas
- Make it easier

Calibration

- Replaced wet test meter / mercury manometer with MFC

- Upper pilot burner Methane MFC
  - Thermal-based
  - 0.25 inch inlet/outlet fittings
  - Calibrated annually with NIST traceability
  - Calibrated for Methane gas
  - Accuracy: 1% Full Scale
  - STP 0ºC at 760 mmHg
  - Signal output to data acquisition system

- Dual purpose burner (upper)
  - Calibration burner (replaces calibration T-burner)
  - Upper pilot burner during testing - 1.5 SLPM Methane / 1.0 SLPM Air

Note: Mixing air MFC has same specifications (calibrated for air)

Calibration (Zero/Span)

- Calibration method changes
  - HFG assembly removed, system to stabilize 4 minutes averaging final 20 second thermopile (doors closed; no flame)
  - Set flow to 3 SLPM for 4 minutes averaging final 20 second thermopile
  - Thermal stability thermopile temperature range must be achieved (380 +/- 15°C)
  - Methane flow and thermopile signal are recorded
  - A slope is generated to calculate the calibration factor K_h (W/°C)
- Calibration pass / fail criteria
  - The slope is used to determine the calibration factor using:

$$K_h = \frac{(210.8\ -\ 22.0)\ kCal}{mole} * \frac{mole\ (CH_4\ STP)}{22.41} * \frac{WATT\ min}{0.01433\ kCal} * \frac{(F_1 - F_0)}{(°C_1 - °C_0)}\ W/°C$$

  - Calibration factor must be 17 ± 2 W/°C
- Applied Calibration Factor (K_H)

$$K_H = \frac{(K_{h1} + Kh_2 + Kh_3 + Kh_4 + Kh_5)}{5}\ W/°C$$

Calibration Requirements and Frequency

- Equipment (Annual calibration required)
  - Heat flux gauges (center & corner)
  - Data acquisition system/display devices
  - Thermocouples (hot zone & cold zone)
  - Main air supply MFC
  - Methane / Mixing air MFC
  - Sample conditioning equipment
- Procedures
  - System heat flux (daily)
    - Center and 4-corner uniformity
  - Thermopile gas calibration (weekly)

Future work

- Additional unit buildups for reproducibility testing (TRL 6)
- New radiant heater design R&D
- Internal alignment fairing R&D
- Plan TRL7 activities (range)

HR2/NBS Smoke Monitoring Research

HR2 Smoke Monitoring

- All materials, parts, and components that must meet the HRR test requirements are also required to pass the smoke emissions test in accordance with current § 25.853(d).
- FAA recently proposed removing the requirement for testing of smoke emissions.
- FAA anticipates that some of the smoke emission testing would continue to take place.
- The purpose of this study is to evaluate an optional alternative method of monitoring smoke characteristics of materials using laser technology mounted in the HR2 Heat Release Rate Apparatus and compare results with the NBS Smoke Density Chamber

HR2 Smoke Monitoring

	NSB Smoke Density Chamber	HR2 Heat Release Rate Apparatus
Heat Flux	2.5 W/cm^2	3.5 W/cm^2
Air Flow	None (sealed box)	20 SCFM (vented)
Sample Size	3" x 3"	6" x 6"
Light Detection	Photomultiplier Tube	Laser / Receiver
Light path Length	36"	5.25"
Test Duration	4 minute	5 minute
Data Evaluation	Peak Ds	Peak Ds Rate & Total Ds
Pilot Burners	6 (lower)	1 (lower) 15 (upper)

HR2 Smoke Monitoring

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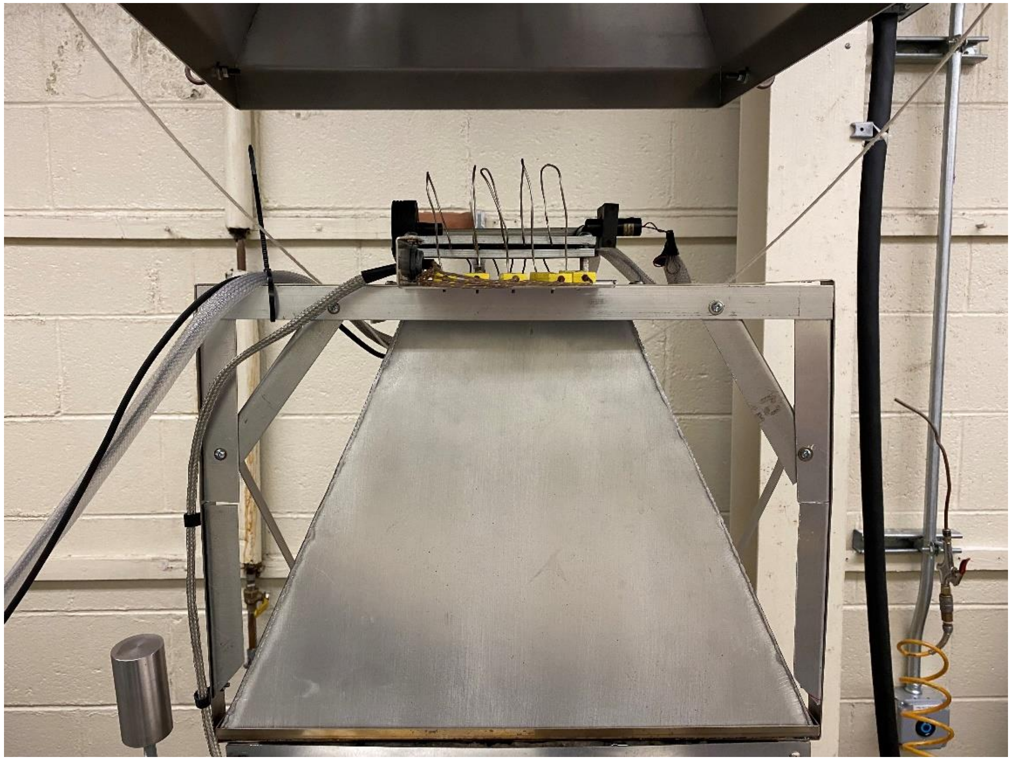


HR2 Exhaust Stream

HR2 Smoke Monitoring

Laser equipment info:

- Coherent Powermax USB Laser / Sensor
- Continuous wave (CW) laser module or Visible Laser Module (VLM)
- Power required: +3.5 vdc to +5vdc
  - ❖ Zero / Span
- Common Applications:

- Alignment and Positioning	- Bar Code Readers
- Robot Control	- Target Designation
- Entertainment (Laser Gaming)	- Security

HR2 Smoke Monitoring

The Visible Light Spectrum:

Color	Wavelength (nm)
Red	625 – 740
	(Coherent Laser equipment @ 670 nm)
Orange	590 – 625
Yellow	565 – 590

HR2 Smoke Monitoring (E906)

<u>NBS specific optical density (Ds) Calculation</u> = LOG10 (100 / % Light Transmission) * 132

<u>HR2 Ds Calculation:</u>

$$\text{SMOKE Release Rate} = \text{SRR} = \frac{D}{kLA} \cdot \left(\frac{V_o}{t} \right)$$

where:

k	=	absorption coefficient = 1.0 m^2/SMOKE,
D	=	optical density (absorbance) = log (100/%T),
L	=	light path = 0.134 m (stack width),
A	=	exposed surface area of specimen, m^2,
$\frac{V_o}{t}$	=	flow rate of air leaving apparatus, m^3/min,
$\frac{V_o}{t}$	=	$\frac{V_i}{t} \times \frac{T_o}{T_i}$,
$\frac{V_i}{t}$	=	flow rate of air entering apparatus, m^3/min, and
T_i, T_o	=	absolute temperature of air in and out of apparatus, respectively.

HR2 Smoke Monitoring

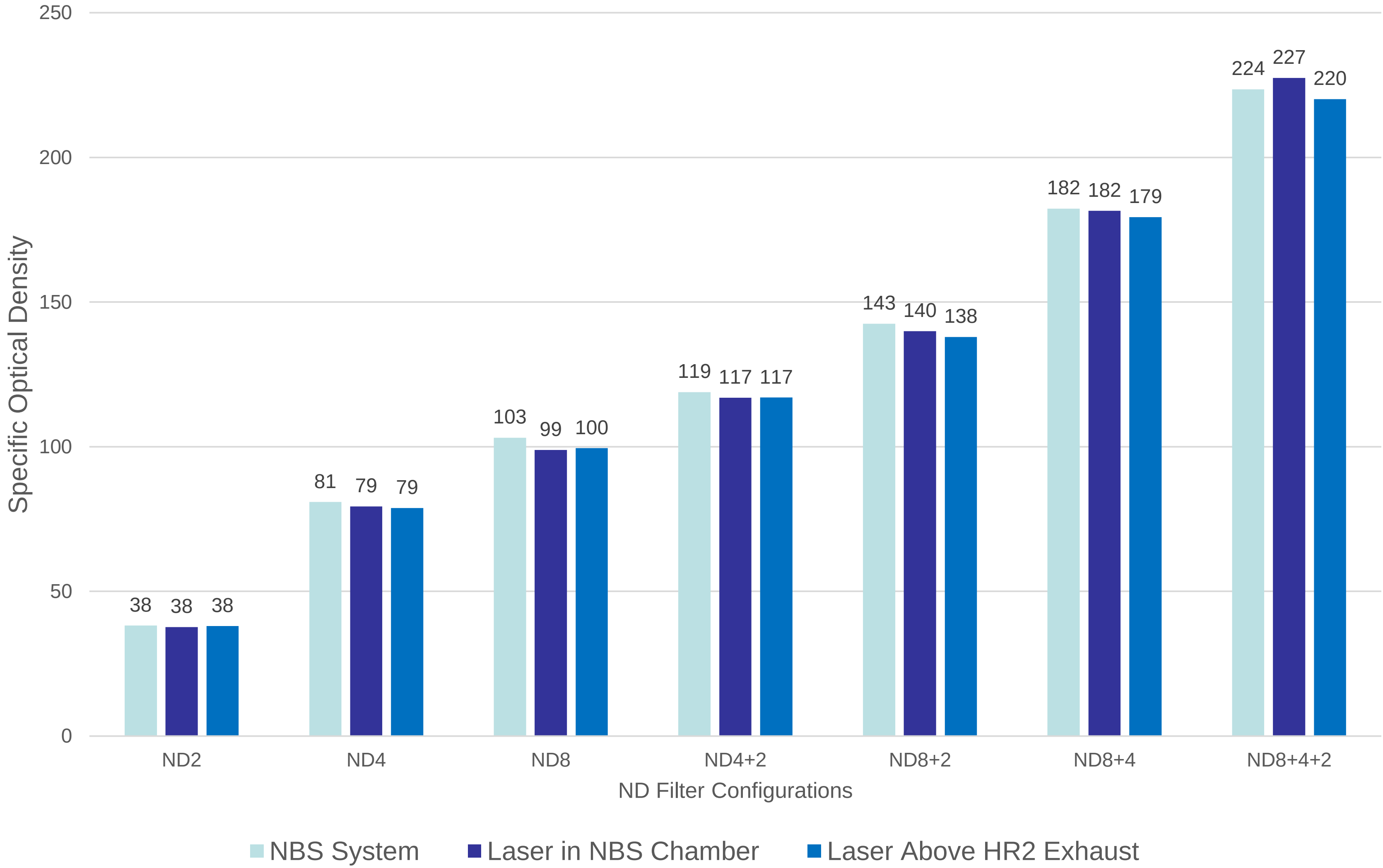
Three types of material tested (5 each):

- Honeycomb panel with decorative (0.25" Thickness)
- 3m, Type 950, Double-sided tape (6 layers) on 0.030" aluminum (no backing)
- Polyester, Double-sided tape (6 layers) on 0.030" aluminum (with backing left on each layer)

Measurement of Smoke in HR2

Stock Number	Edmund Optics OD Filters
54731	FILTER ND MTD 0.3OD 58X0.75
54737	FILTER ND MTD 0.6OD 58X0.75
54743	FILTER ND MTD 0.9OD 58X0.75

Neutral Density Filter Data using NBS Photomultiplier System and Laser/Receiver



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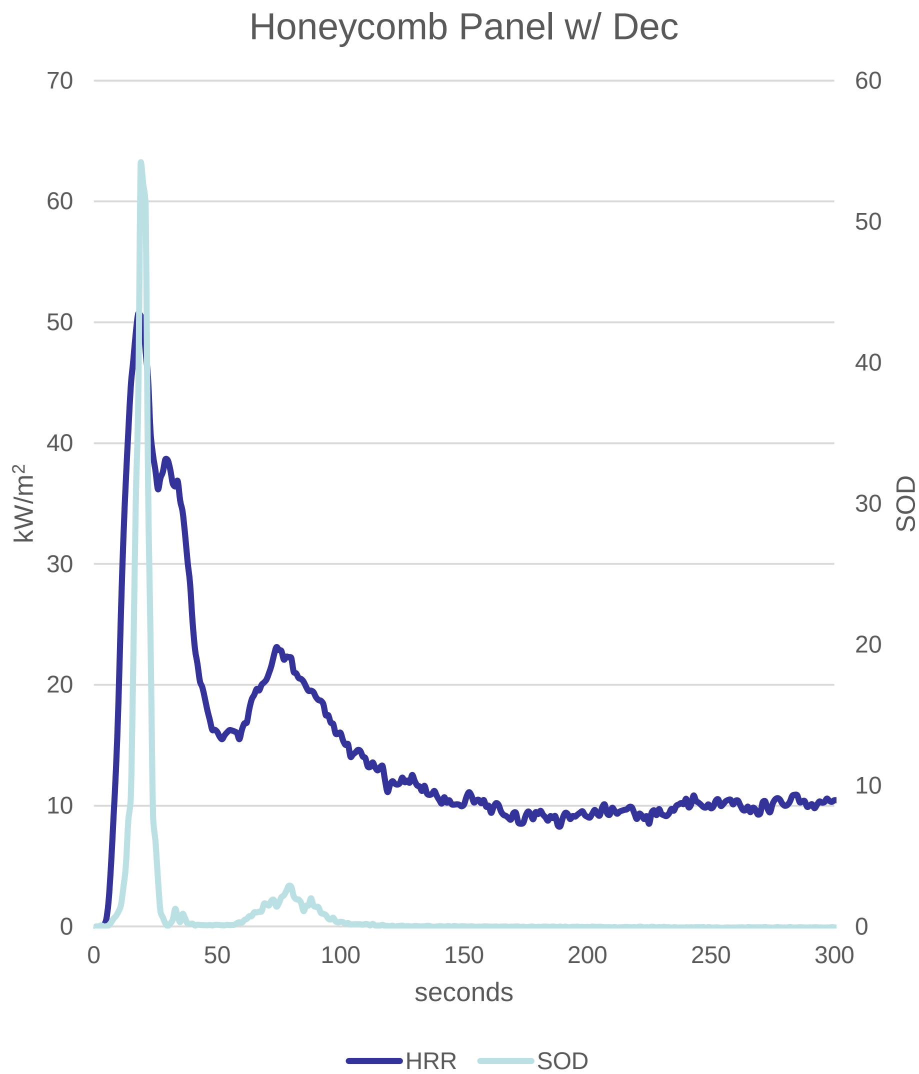

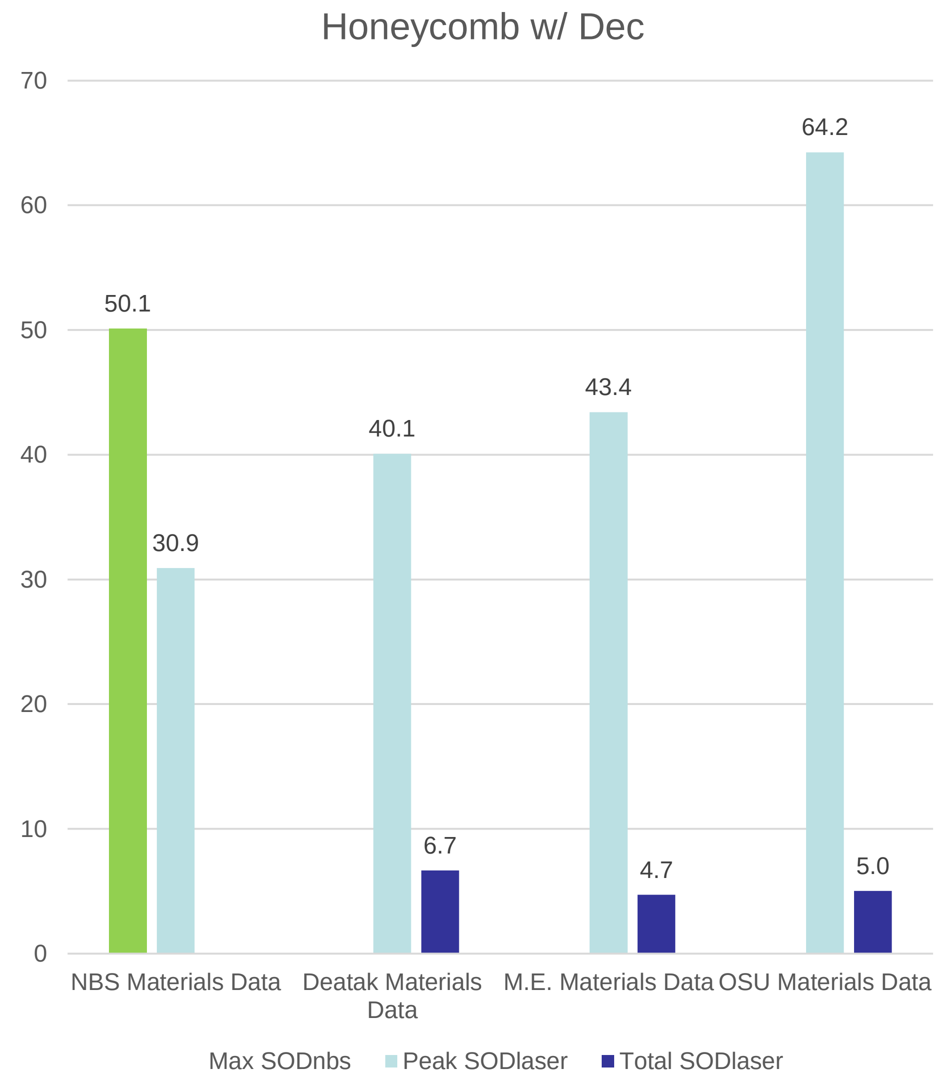

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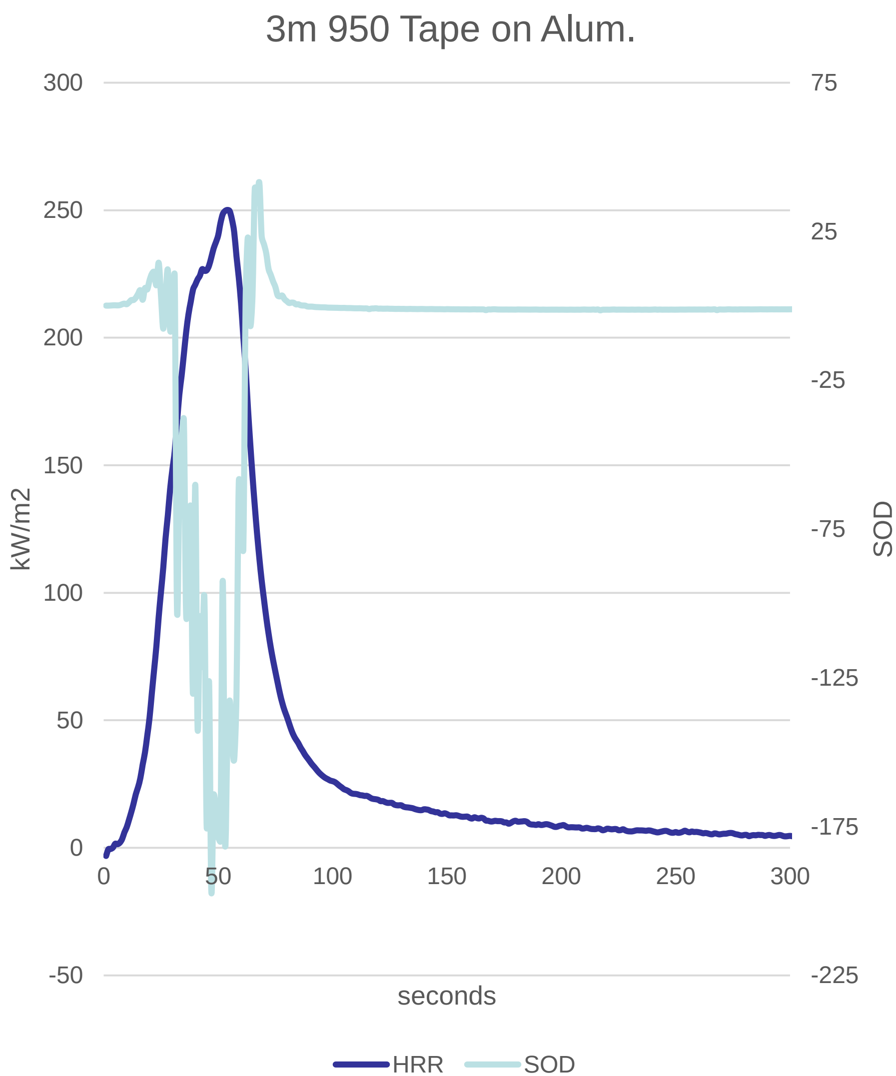

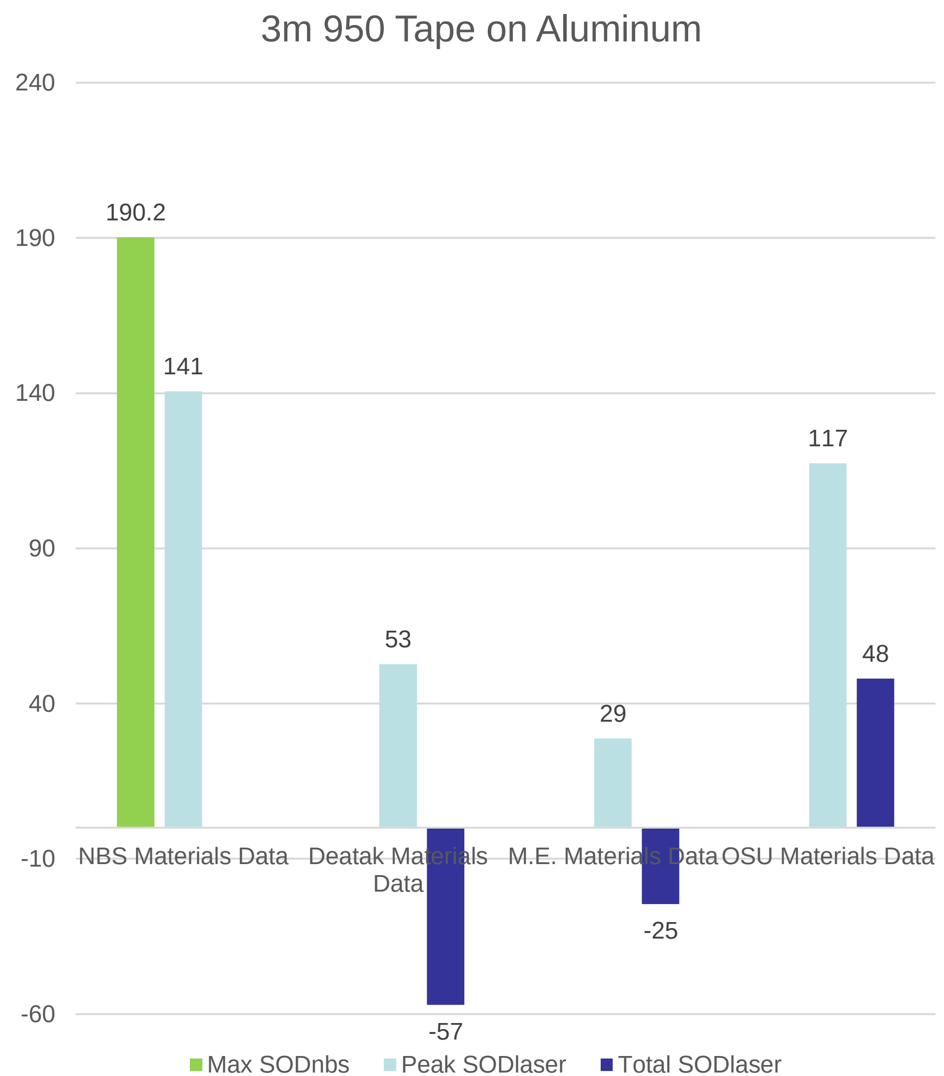

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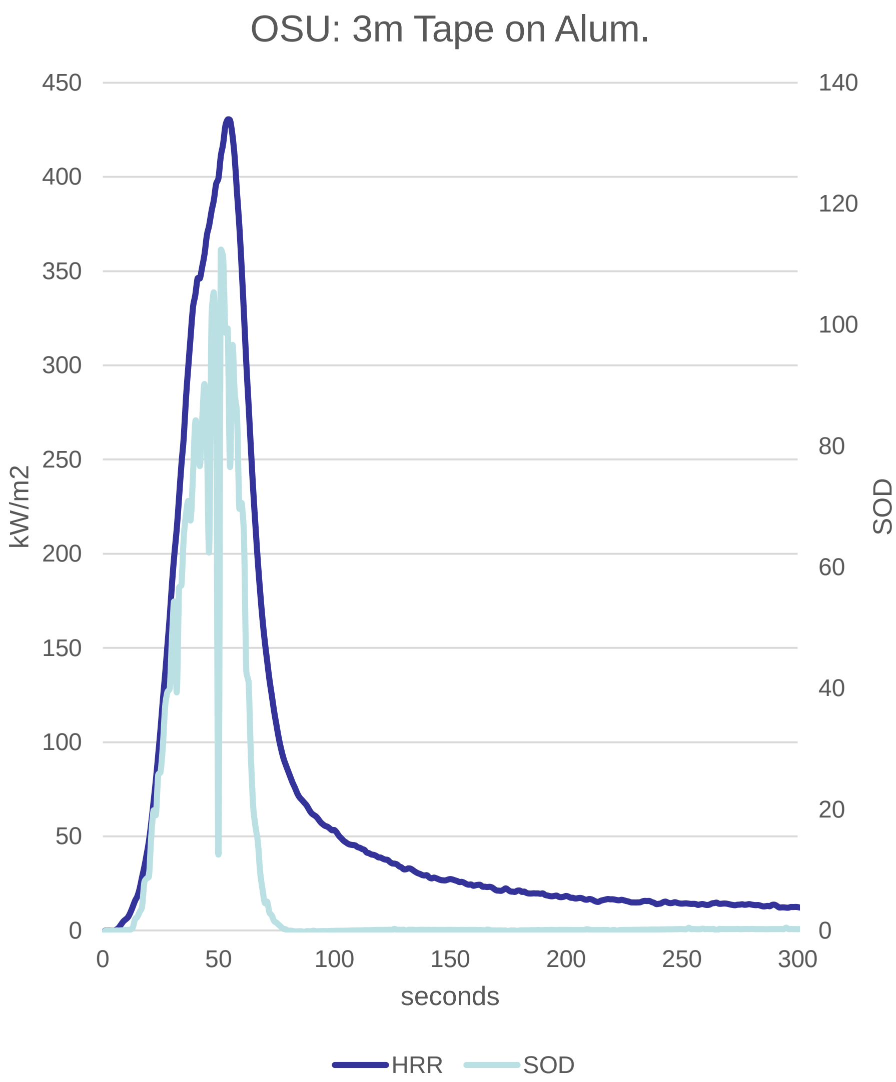

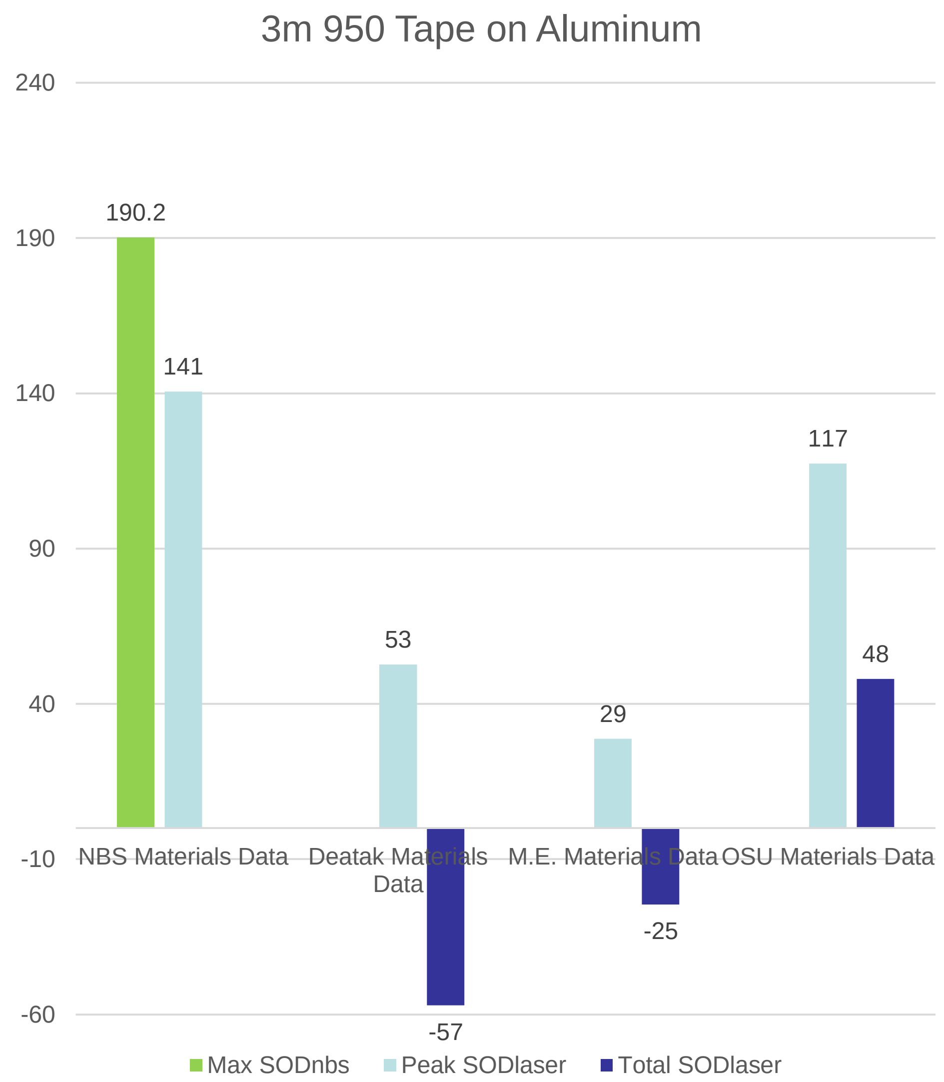

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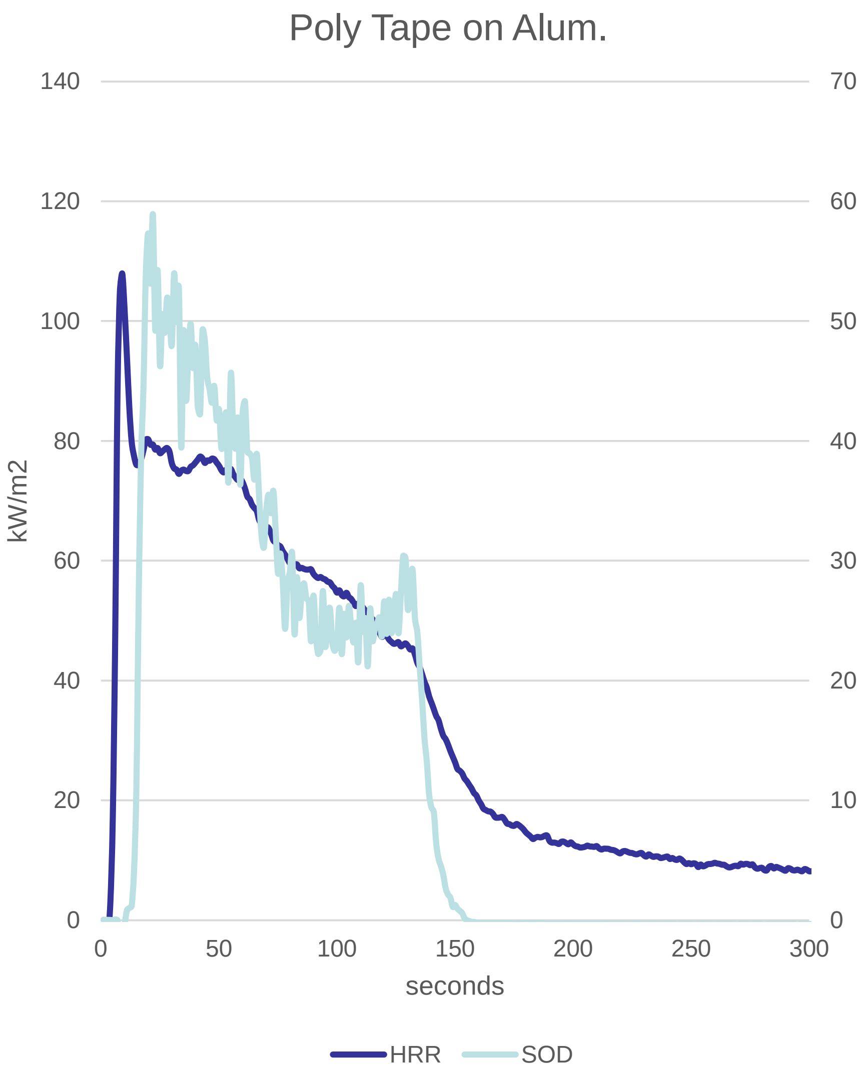

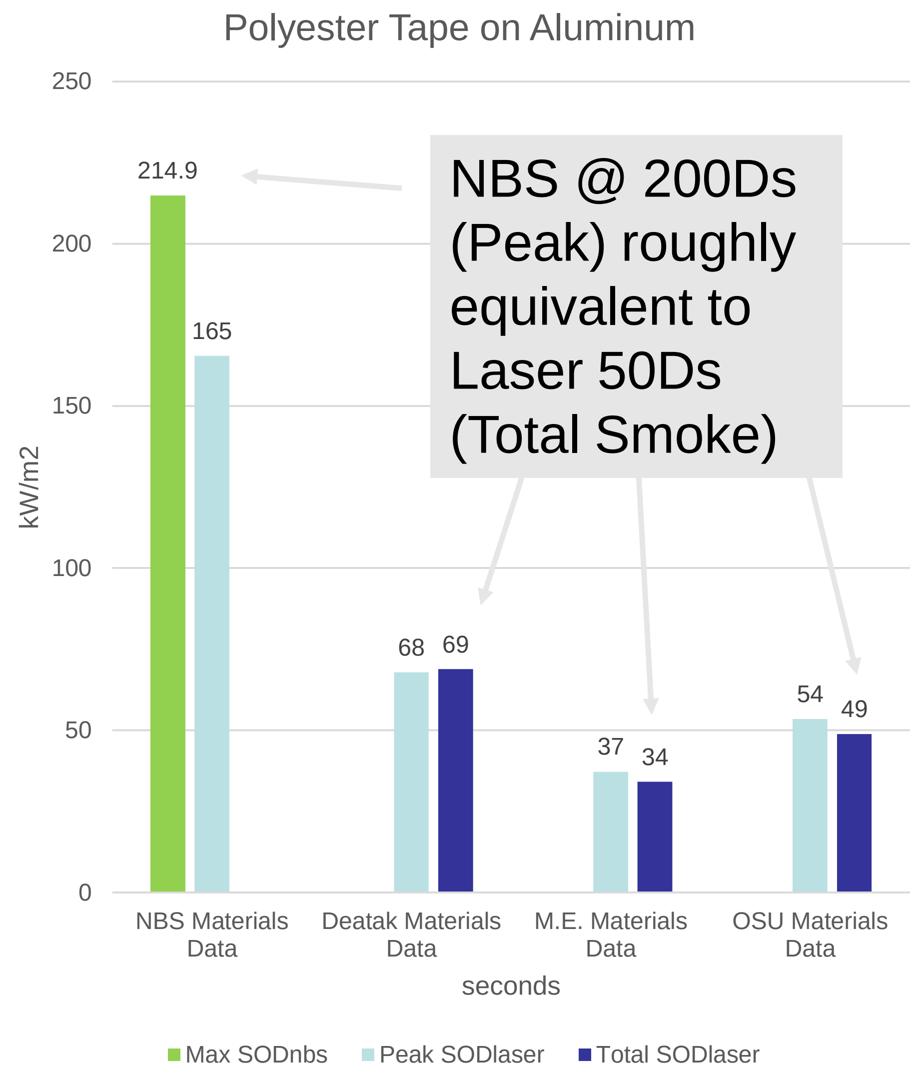

SUMMARY OF FINDINGS

The following is a summary of the significant findings based on the limited tests performed during this study:

- Open flame in exhaust stream impacted laser signal
- Laser/Receiver separation (> 5.25” to prevent soot contamination)
- Good ND filter correlation
- Total smoke values of 50 Ds may approximate NBS fail criteria
- Additional testing (Break out discussions)

Questions?