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

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FAATC
Atlantic City, NJ
USA

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AGENDA

- Background
- Laser equipment / Installation
- Smoke Release Rate (SRR) and Cumulative Smoke Release (CSR) Determination
- Data and Summary of Findings

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 recommended that smoke levels continue to be monitored in some manner (NPRM/SNPRM).
- This presentation details 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 traditional NBS Smoke Density Chamber

HR2 Smoke Monitoring

- In addition to the widely accepted NBS methodology for measuring smoke levels, the OSU heat release rate test apparatus once had this capability as well.
  - *ASTM Report, "Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using a Thermopile Method" (E906/E906M – 17)*
- This report describes the procedures and equipment used in the apparatus.
- The configuration utilized a collimated light source and photocell affixed above the exhaust chimney of the OSU.
- Light source and receiver are positioned 2" above the exhaust opening and 5.25" separation.

HR2/NBS Smoke Monitoring Research

Heat Release Rate Test Apparatus
October 2023

HR2 Smoke Monitoring

- The following slide illustrates the differences between the NBS and heat release rate (HRR) test methods.
- Although each of the methods expose the test samples to both radiant heat and piloted ignition, it is important to note the difference in:
  - Heat flux
  - Sample size
  - Airflow parameters (vented vs. sealed)

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)

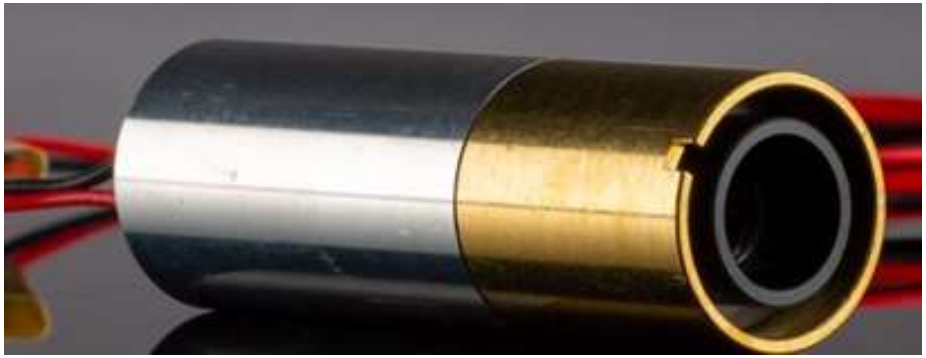
HR2 Smoke Monitoring

Laser equipment info:

- Coherent Powermax USB Laser / Thermopile Power 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



Coherent Sensor (left) and Laser Diode (right)

HR2 Smoke Monitoring

- The thermopile power sensor operates by absorbing and converting incident laser radiation into heat, which then flows into a heat sink.
- The temperature difference between the absorber and heat sink is converted into an electrical signal by a thermocouple junction.
- The output of the sensor (W) is proportional to the amount of laser light received by the sensor.

HR2 Smoke Monitoring

- As particles enter the laser light path, the light is reflected, refracted, or absorbed, reducing the amount of light received by the sensor.
- The percent light transmittance is determined as the difference between the sensor baseline (clear air) and the test measurement, when an obscuration may be present in the light path, reducing the sensor output signal below the baseline.

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

HR2 Smoke Monitoring (E906)

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

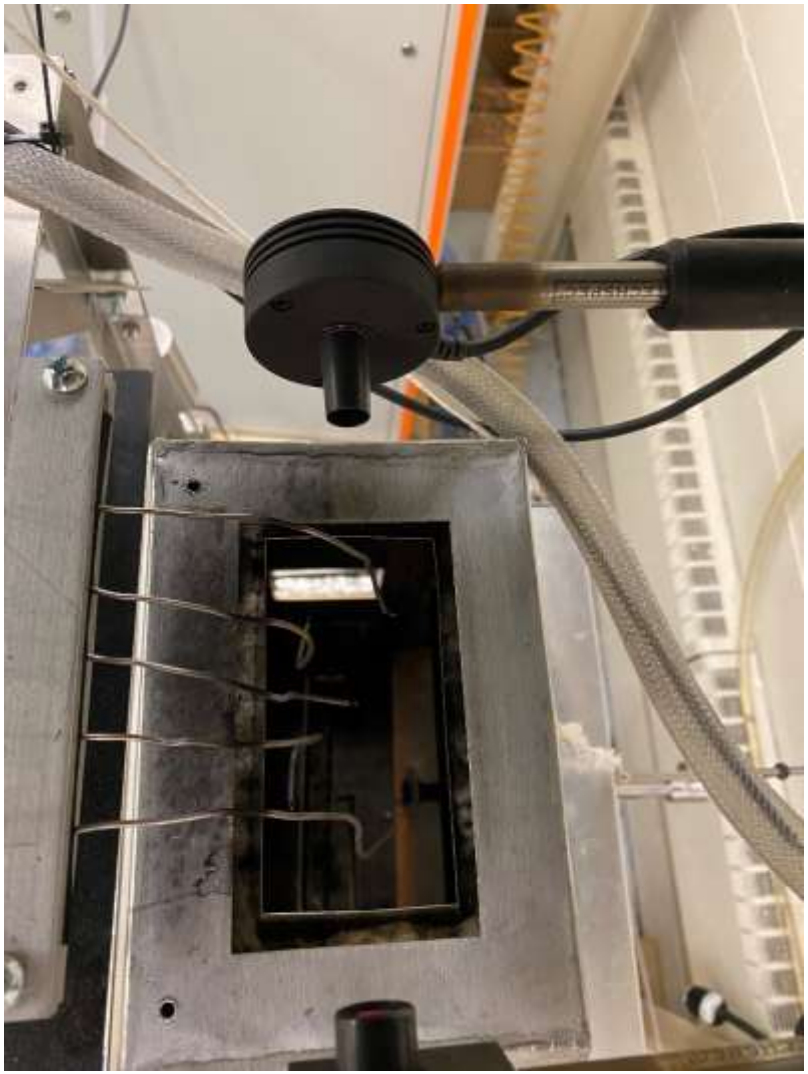
HR2 Ds Calculation: $\text{SMOKE Release Rate} = \text{SRR} = \frac{D}{kLA} \cdot \left(\frac{V_o}{t} \right)$

where:

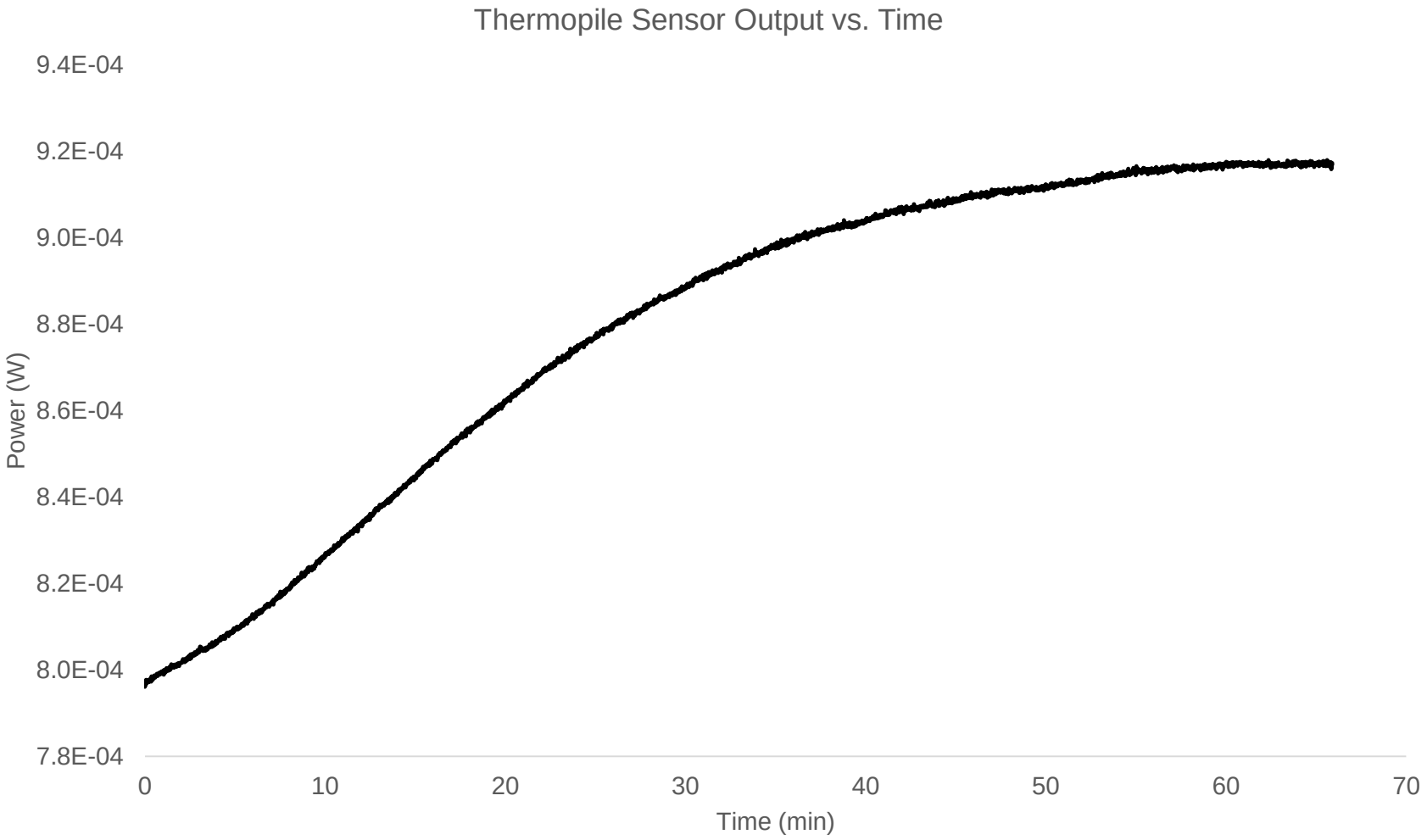
k = absorption coefficient = 1.0 m^2/SMOKE,
D = optical density (absorbance) = log (100/%T),
L = light path = 0.134 m (stack width),
A = exposed surface area of specimen, m^2,
$\frac{V_o}{t}$ = flow rate of air leaving apparatus, m^3/min,
$\frac{V_o}{t} = \frac{V_i}{t} \times \frac{T_o}{T_i}$,
$\frac{V_i}{t}$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

HR2 Exhaust Stream



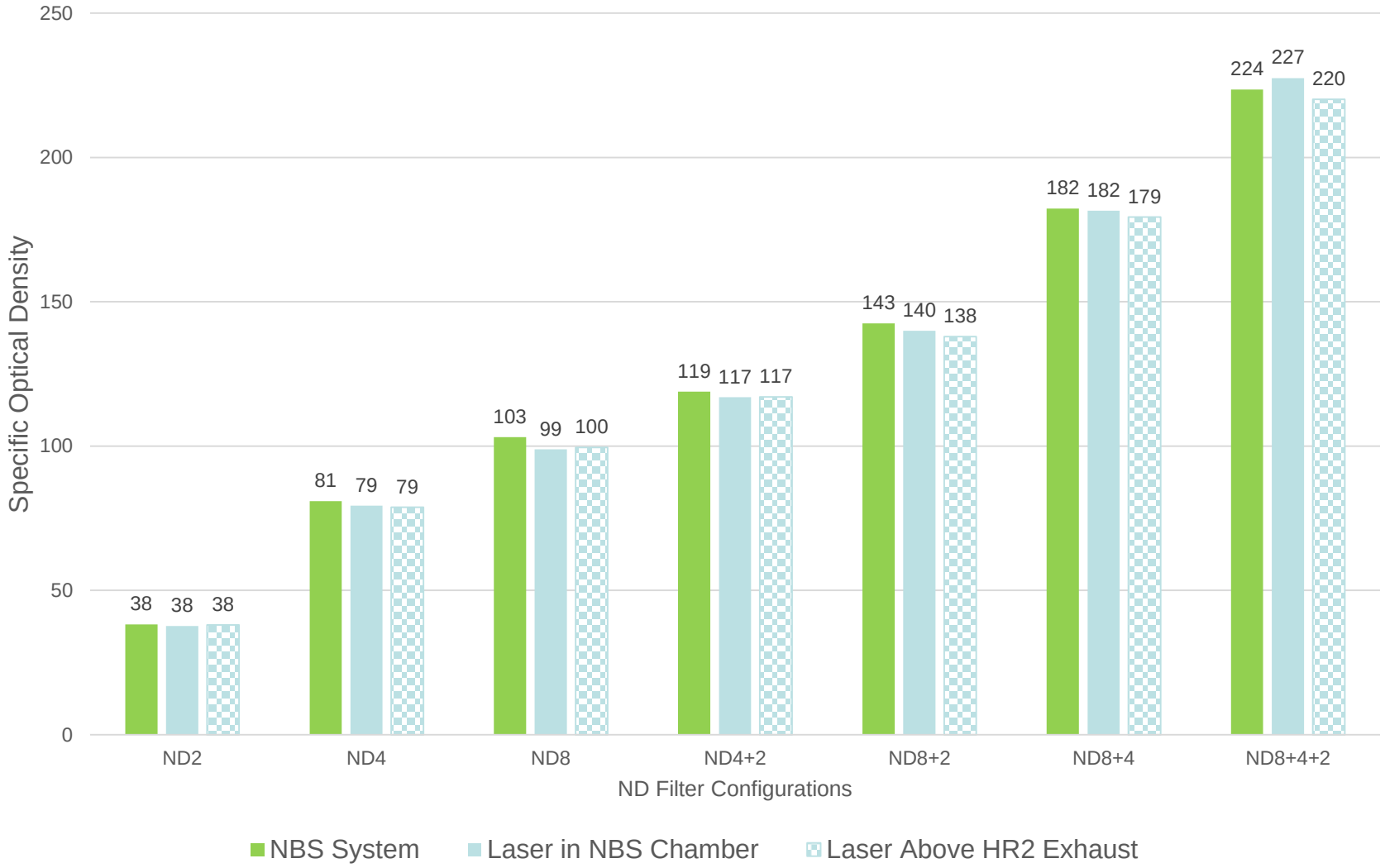
HR2 Smoke Monitoring



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

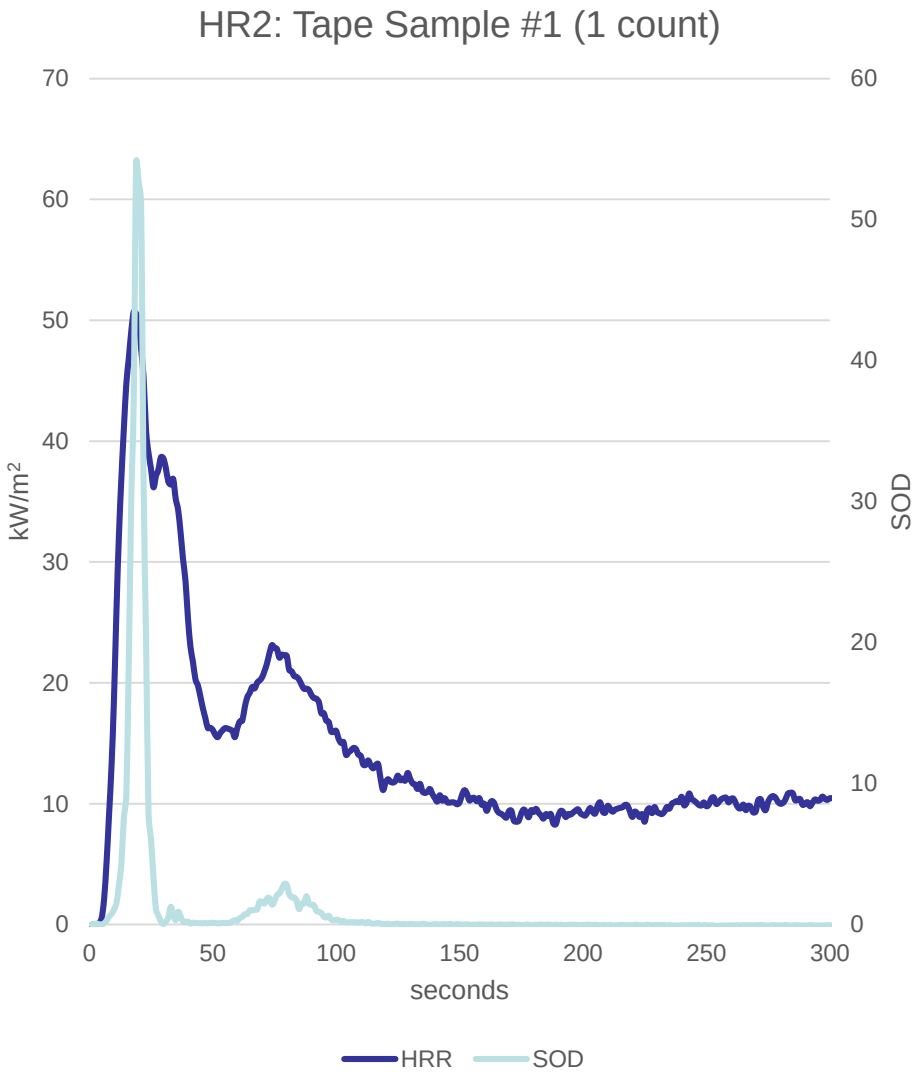


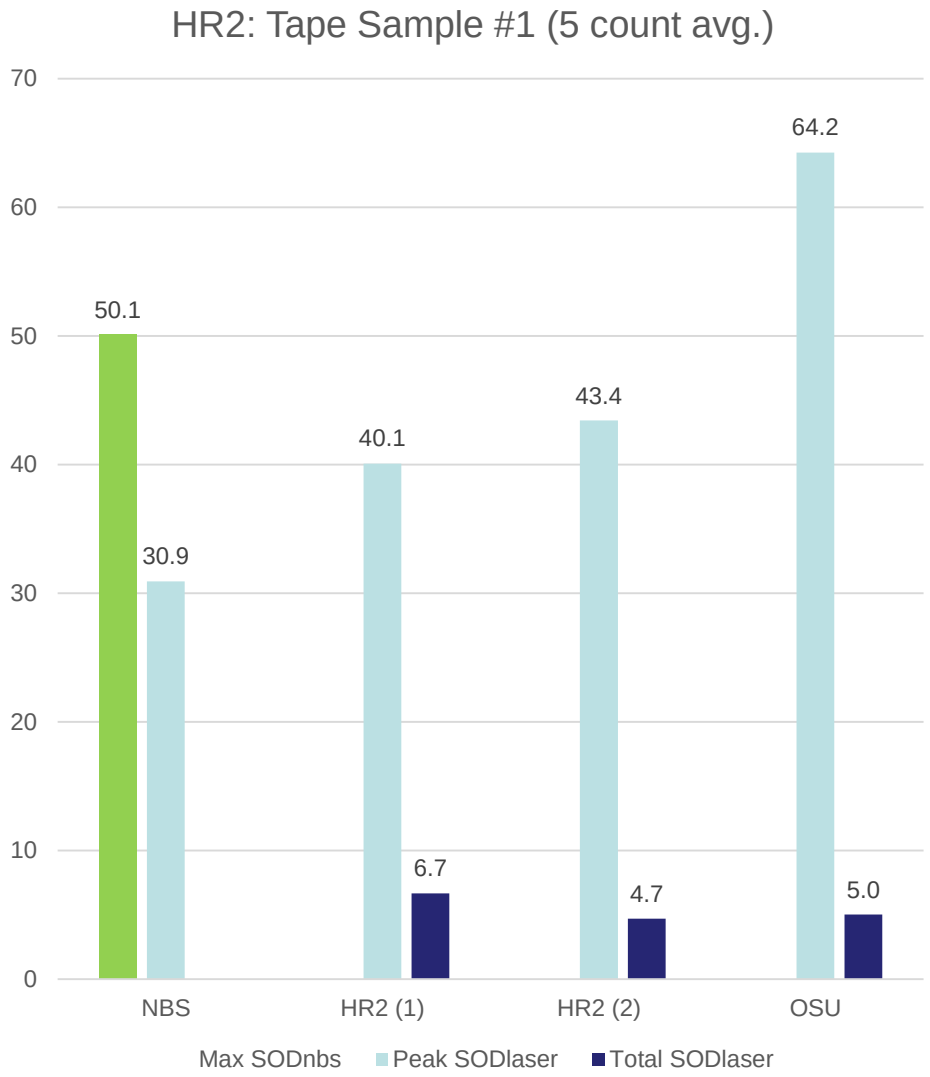
HR2 Smoke Monitoring

Three types of material tested (5 each):

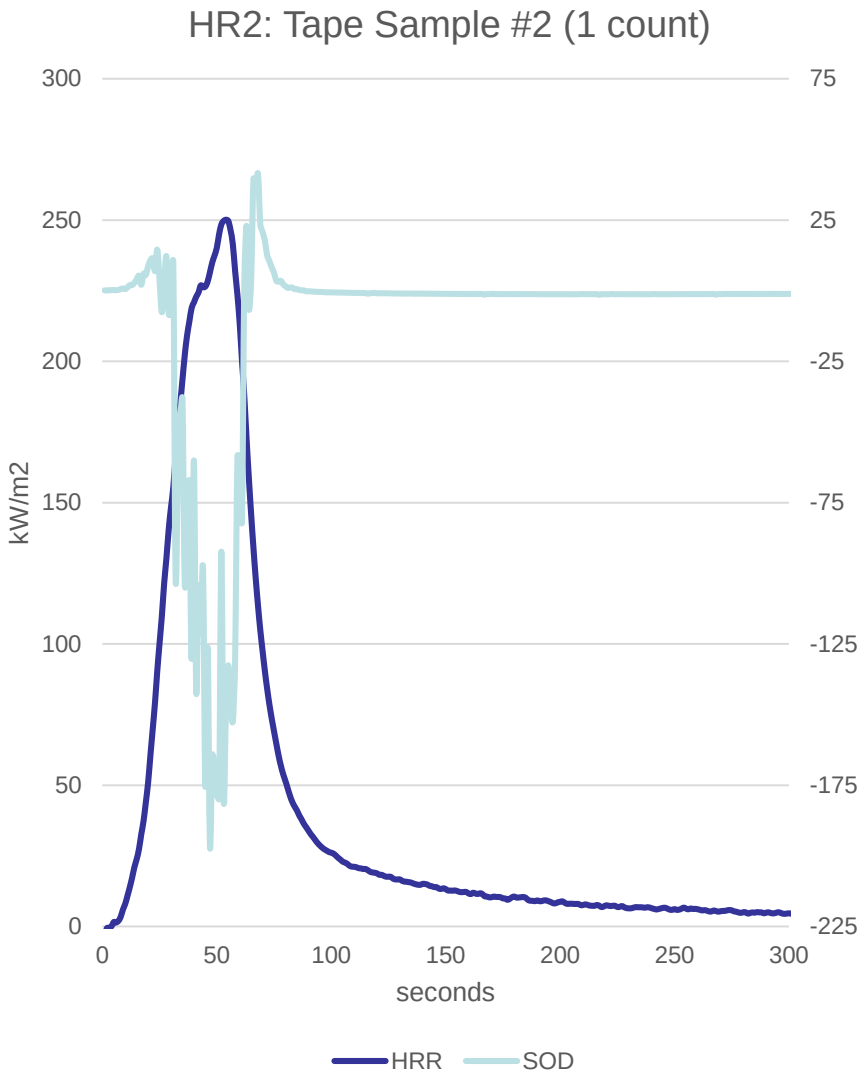
1. Honeycomb panel with decorative (0.25” Thickness)
2. 3m, Type 950, Double-sided tape (6 layers) on 0.030” aluminum (no backing)
3. Polyester, Double-sided tape (6 layers) on 0.030” aluminum (with backing left on each layer)

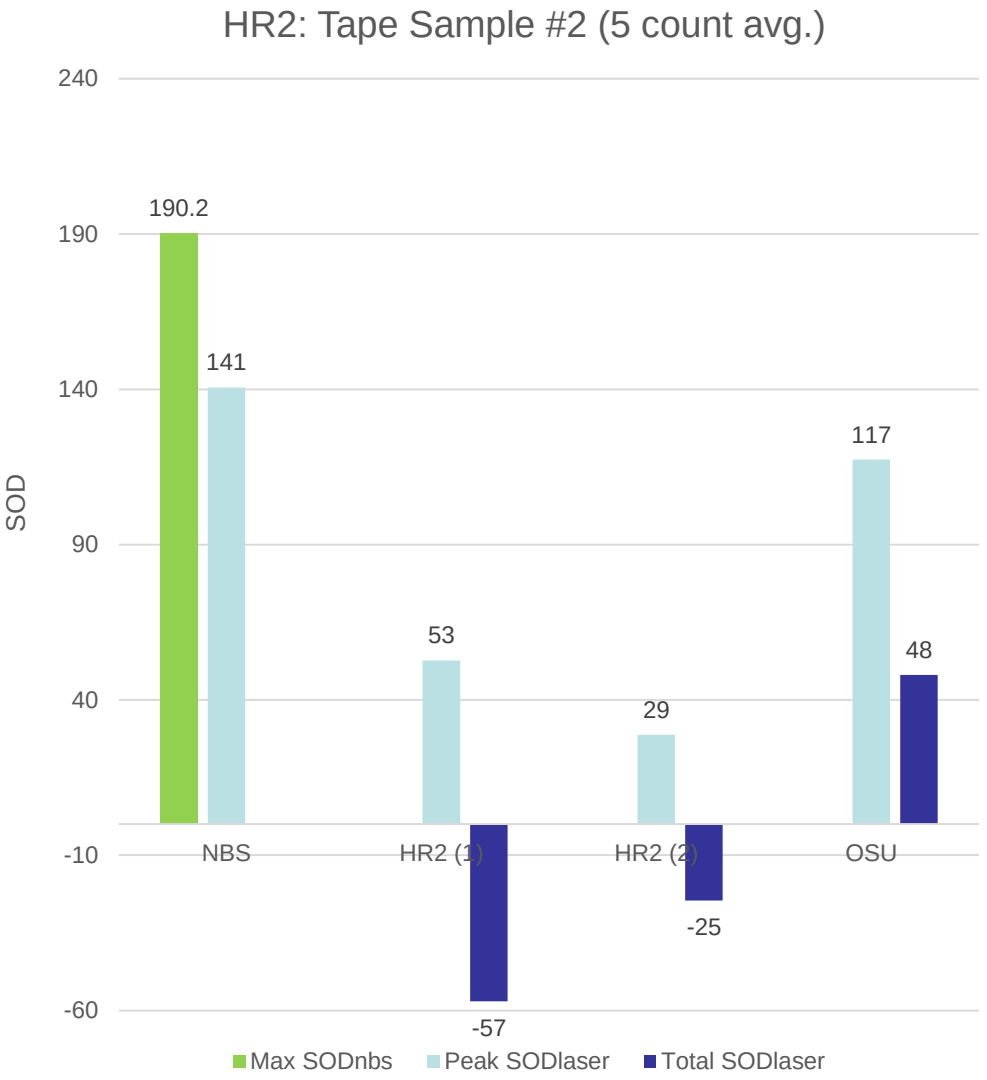
Measurement of Smoke in HR2





Measurement of Smoke in HR2





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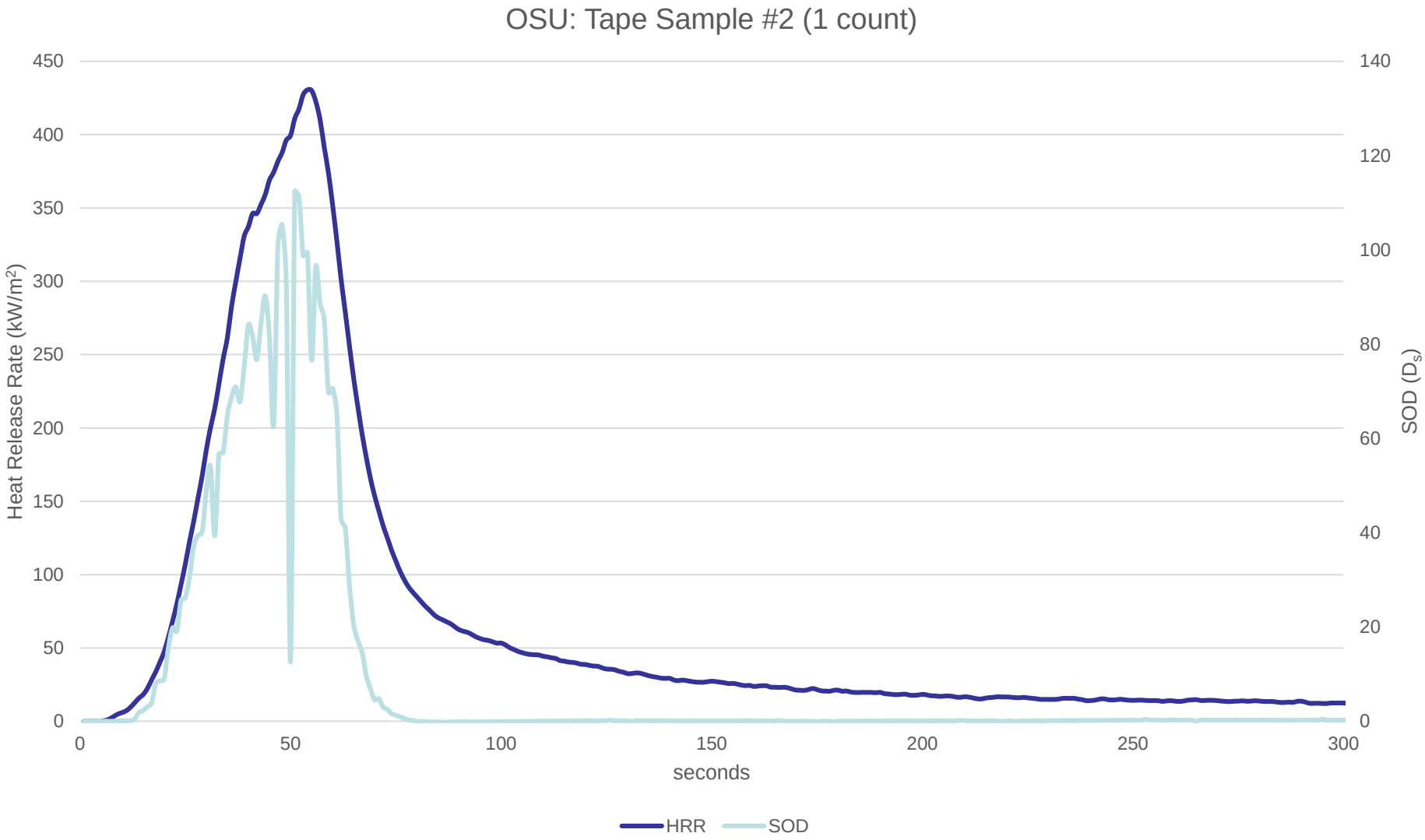
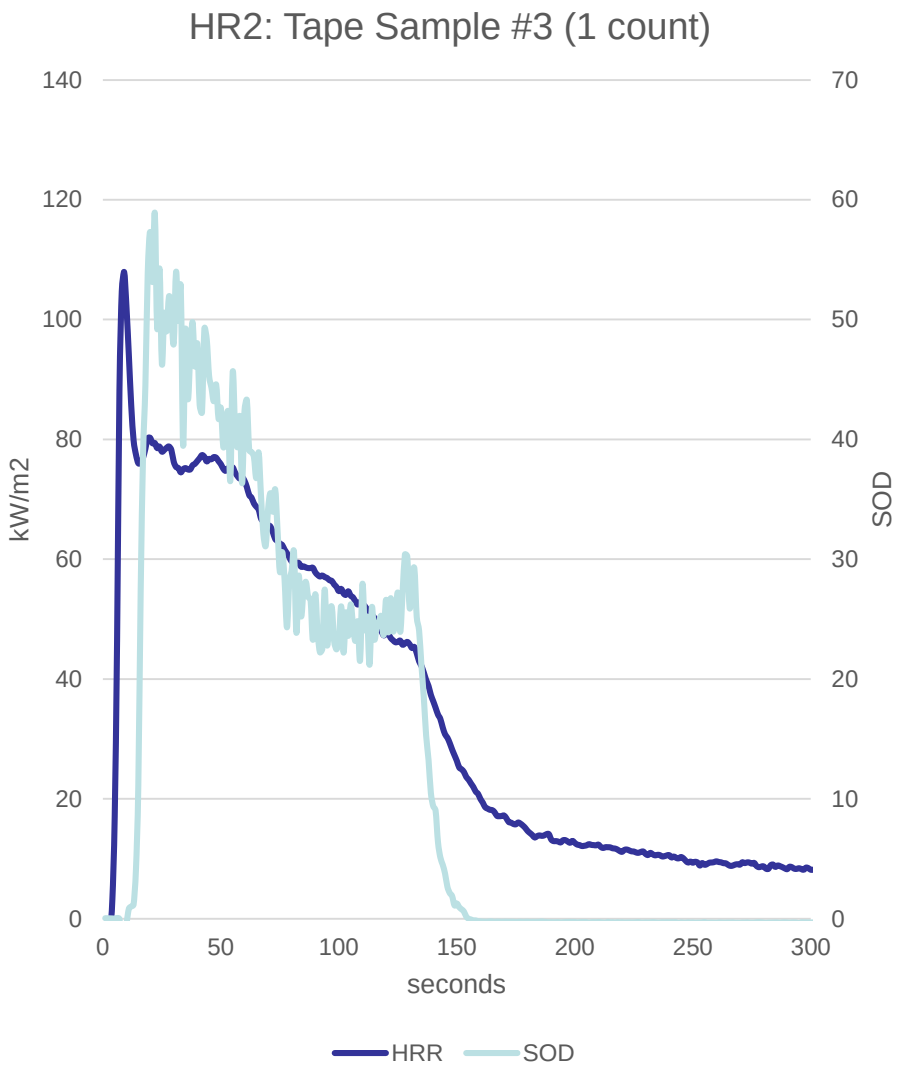
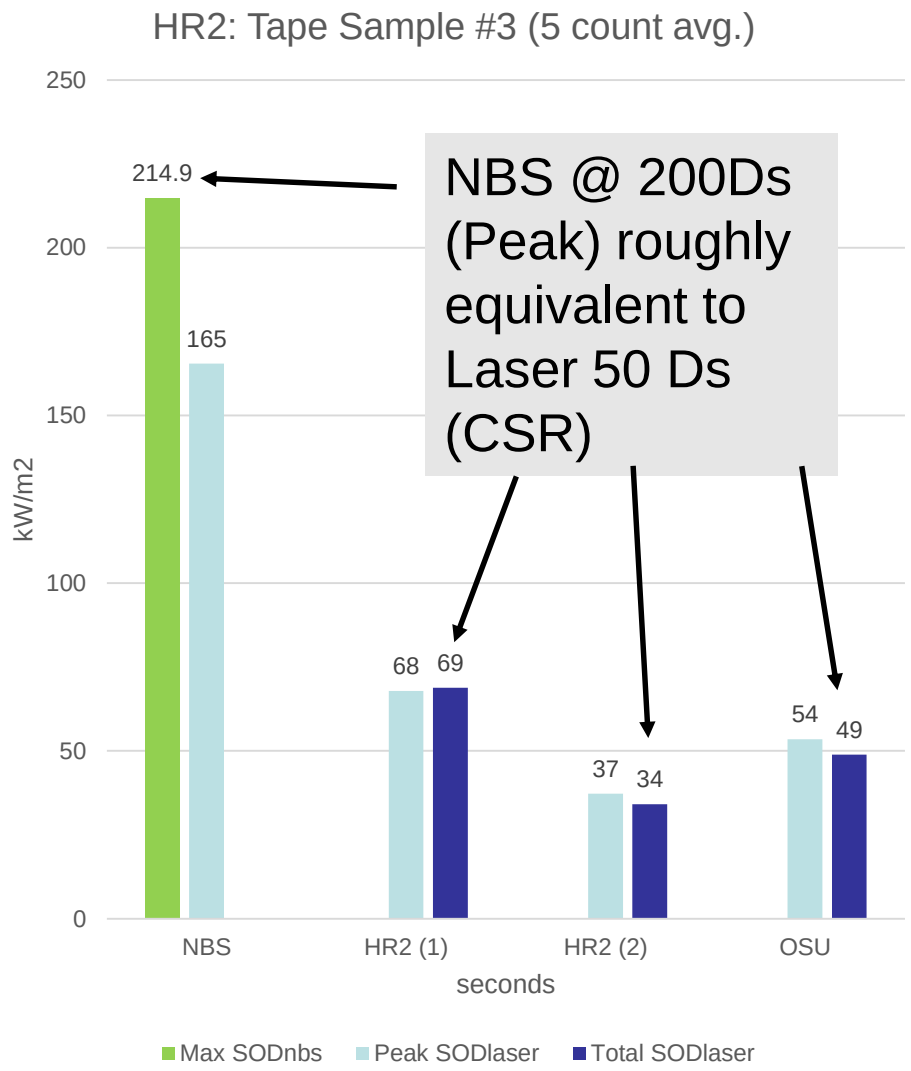


Measurement of Smoke in HR2





Measurement of CSR in NBS / HR2

Material	NBS Photometric			NBS Laser/Sensor		
	Average	Standard Deviation	Relative Standard Deviation	Average	Standard Deviation	Relative Standard Deviation
1	50.1	5.45	10.9%	30.92	3.74	12.1%
2	214.86	19.60	9.1%	165.44	17.71	10.7%
3	190.16	18.03	9.5%	140.61	14.02	10.0%

Material	HR2 Laser/Sensor		
	Average	Standard Deviation	Relative Standard Deviation
1	6.7	1.5	22.9%
2	68.8	2.8	4.0%
3	N/A	N/A	N/A

SUMMARY OF FINDINGS

- Laser/sensor was affected by the elevated temperatures at the HR2 exhaust opening, providing an increase in sensor output. This was compensated for by allowing the HR2 to reach a stable operating temperature prior to setting the sensor baseline power-output.
- Visible flame in exhaust stream amplified signal output
- Good ND filter correlation
- Laser/Receiver separation (> 5.25” to prevent soot contamination)
- CSR values of 50 Ds approximate NBS fail criteria for this test series

SUMMARY OF FINDINGS

- Although the CSR for material 2 was unable to be determined, it can be seen that based on materials 1 and 3, the CSR as measured in the HR2 trends in the same manner as the NBS photometric Ds and the NBS laser/sensor Ds.
- This gives confidence that the laser/sensor measurement system in the HR2 can provide a quantitative assessment of the smoke output of a material.
- System can be used to monitor material performance over time to verify that a material smoke output is consistent with those traditionally used.

Questions?