South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

39th AAAR Annual Conference

A Comprehensive Test Standard for Indoor Air Quality Low-Cost $PM_{2.5}$ Sensors: ASTM D8405-21

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Indoor Air and $PM_{2.5}$

- Only ambient $PM_{2.5}$ air quality standards exist
- Many sources of $PM_{2.5}$ in indoor and occupational environments
  - Cooking
  - Smoking
  - Incense/candle burning
  - Dust resuspension
  - Machining/sanding/welding/spray-painting
- We spend ~90% of our time indoors

Low-Cost $PM_{2.5}$ Sensors

- Well-suited for indoor and consumer applications
  - Low cost (~$100-1,000 USD range)
  - Low power
  - Low noise
  - Optical scattering measurement; high time resolution
  - Compact form factor
  - Range of aesthetic choices and interfaces
  - Some are smart-home integrable
- Can provide feedback for indoor space ventilation or filtration actions
- Data quality can be a challenge

- History of laboratory chamber test protocols used for $PM_{2.5}$ sensor performance
  - Only discussing protocols carried out by testing entities, not one-time protocols in academic/research studies
  - 2016 – South Coast AQMD AQ-SPEC laboratory evaluation protocol
  - 2017 – UK Environment Agency Monitoring Certification Scheme (MCERTS)
  - 2018 – RESET® Certification
  - 2021 – US EPA $PM_{2.5}$ sensor performance testing protocol
  - **2021 – ASTM D8405-21 Standard Test Method for $PM_{2.5}$ Sensors or Sensor Units Used in Indoor Air Applications** (less than 1 month old!)

Scope of Test Method

- $PM_{2.5}$ sensors and sensor systems
- Indoor applications
- Continuously powered
- Data history logged or retrievable
- Non-regulatory, security, law enforcement, or forensic purposes

Limitations

- Particle composition effects
  - Indoor particle types diverse
  - A single inorganic salt type
  - A single organic polymeric type
- Optical scattering technique and ~0.3 µm diameter limit
  - Some reference monitors
  - Nearly all low-cost $PM_{2.5}$ sensors

Chamber and Supporting Test Equipment

- Large enough so that triplicate sensor cross-sectional areas do not exceed 15% of any chamber face area
- Stainless steel, airtight
- Temperature control 20-50°C
- RH control 40-80%
- Moisture and particle-free air (ISO 8573-1 class 2.4.1 air, HEPA-filtered)
- Well-mixed, homogeneous

$PM_{2.5}$ Reference Monitor and PM Generators and Materials

- Reference monitor
  - EPA Class III FEM for $PM_{2.5}$
  - Must also report PM_{10}
  - 1-minute or faster reporting interval
  - Report particle size distributions; supplementary monitor permitted for this purpose
- Particle generator(s)
  - Produce particles from 50nm-10µm
- Materials
  - NaCl
  - SRM 1690 1 µm PSL
  - Arizona Test Dust ISO 12103-1 Grade A-4 Coarse

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Phase 1: Initial Concentration Ramp

- 6 $PM_{2.5}$ concentration steps from 0 to 300 µg/m^3
- Response to power loss also conducted
- Inorganic and organic particle type tested

Phase 2: Effect of T and RH

- 2 temperature conditions (20 and 30°C)
- 1 optional high temperature condition of 50°C
- 3 RH conditions (40-80%)
- 2 $PM_{2.5}$ concentrations
- 12 total T/RH/$PM_{2.5}$ combinations required (plus 6 optional combinations)

Phase 3: Interferent Testing

- Use of Arizona Test Dust as interfering coarse PM
- 4 coarse PM concentration conditions from 10-150 µg/m^3

Phase 4: Temperature Cycling

- Simulates a year's worth of cyclical environmental stress
- 143 temperature cycles from 10°C to 50°C, and back

Phase 5: Final Concentration Ramp

- Repeat of Phase 1
- Measures drift
- Minimum of 15 days must have elapsed since Phase 1
- Only inorganic particle type

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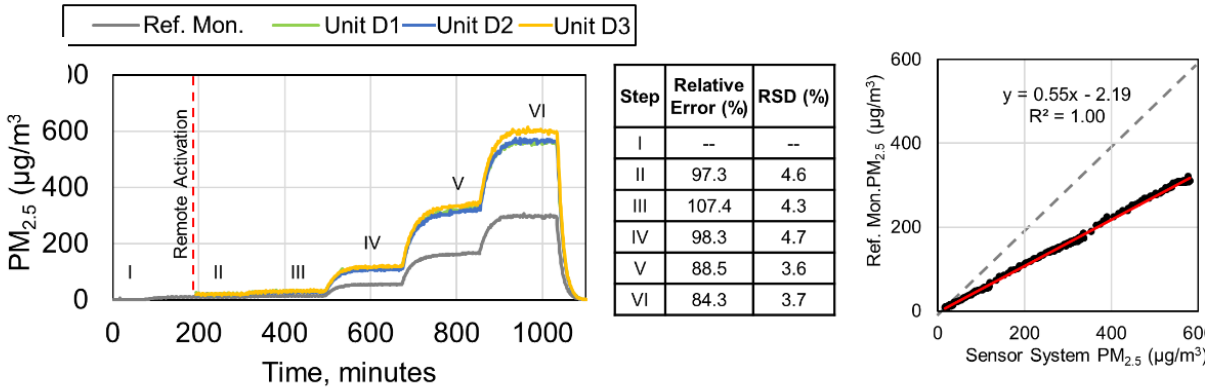
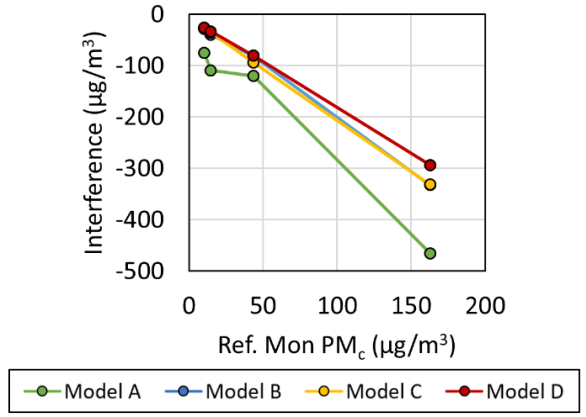
Phase 1 – Initial Concentration Ramp

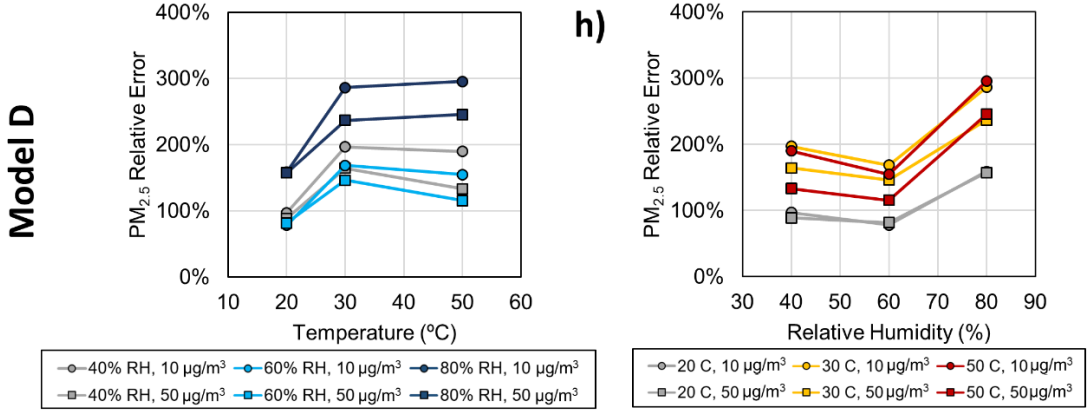


Step	Relative Error (%)	RSD (%)
I	--	--
II	97.3	4.6
III	107.4	4.3
IV	98.3	4.7
V	88.5	3.6
VI	84.3	3.7

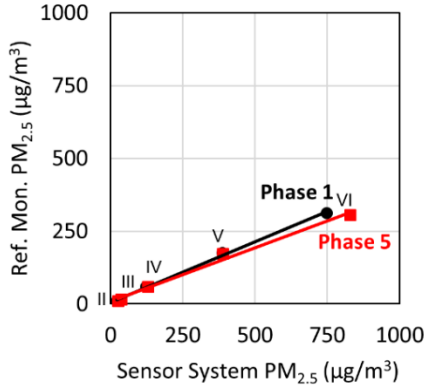
Phase 3 – Interferent Testing



Phase 2 – Effect of T and RH



Phase 5 – Final Concentration Ramp



Aspect	AQ-SPEC (2016)	MCERTS (2017)	RESET® (2018)	EPA (2021)	ASTM (2021)
PM Material	KCl	--	Cigarettes, mosq. coils	Not specified	NaCl, PSL, ATD
$PM_{2.5}$ Ref. Mon.	EPA FEM Class III	--	TSI DustTrak II	EPA FEM	EPA FEM Class III
Duration	~10 days	--	14 days	At least 60 days	At least 15 days
Concentrations	10-300 µg/m^3	--	15-250 µg/m^3	10-250 µg/m^3	0-300 µg/m^3
Linearity	X		Unclear	X	X
Bias	X		X	X	X
Precision	X		X	X	X
T/RH Effects	X			X	X
PM Size Effects					X
Aging/Drift				X	X
Data Recovery	X		X	X	X
Power Loss					X
Perf. Targets		X	X	Outdoor only	

- Future Developments
  - AQ-SPEC to start $PM_{2.5}$ sensor testing using ASTM D8405-21 standard test method
  - New AQ-SPEC test chamber (see AAAR talk by my colleague David Herman)
  - Home Ventilating Institute (HVI) Certification using this method
  - ASTM indoor CO_2 sensor standard test method under development!

Contact AQ-SPEC

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Contact the Speakers

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