Wood Heating PM Method Precision Testing

Virtual Workshop Discussion:

Evaluation of TEOM & IDC PM Measurement Precision

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Recognition of IDC Measurement Methods

- All protocols and PM measurement methods used in this study were developed by Northeast States for Coordinated Air Use Management (NESCAUM) and are property of the New York State Energy Research and Development Authority (NYSERDA) and are credited here. Written permission was obtained for use specifically for this research.
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Cordwood-Fired Hydronic Heating Appliances: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Thermostatically Controlled Automatic-Feed Hydronic Heating Appliances: Measurement of Particulate Matter (PM), Carbon Monoxide (CO) Emissions and Heating Efficiency
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Thermostatically Controlled Central Warm Air Appliances: Measurement of Particulate Matter (PM), Carbon Monoxide (CO) Emissions and Heating Efficiency
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Wood-Fired Stoves Using Cordwood: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency
  - NYSERDA Integrated Duty Cycle Test Method for Certification of Automatic-Feed Stoves: Measurement of Particulate Matter (PM) and Carbon Monoxide (CO) Emissions and Heating Efficiency

Wood Stove PM Measurement - Current

- 2015 Rulemaking adapted
  - ASTM Measurement Method and Operating Protocols
    - Measurement = How PM is collected and measured
    - Operating protocols = How appliance is fueled and operated during test
  - ISO Third Party Certification for model lines
- Based on EPA legacy Method 28 “burn rates” for operating
  - Filter based PM measurement
  - Weighted average of burn categories used for compliance result

2020 Round Table Meeting

- 30+ Industry, State and EPA staff met in RTP
  - Discussed Integrated Duty Cycle operation versus existing ASTM “burn rate” operation.
  - EPA announced we would pursue vetting of the IDC compliance approach including the use of TEOMs for measurement of PM
- TEOMs are capable of real-time PM measurement
  - Provides for a better understanding of PM emissions profile
  - More sensitive than filter-based approaches

Test Method Evaluation

- Evaluation of TEOM sampling for PM – Precision study
  - Being conducted at EPA with Office of Research & Development (ORD) partnership
- Evaluation of Wood-Fired Stoves Using Cordwood Integrated Duty Cycle method – Precision study
  - Two separate test labs, each with side-by-side identical appliances
  - Goal is to understand test variability and performance
- Evaluation of similar IDC methods at two test labs for:
  - Pellet heaters
  - Hydronic heaters (pellet and cordwood)
  - Forced air furnaces

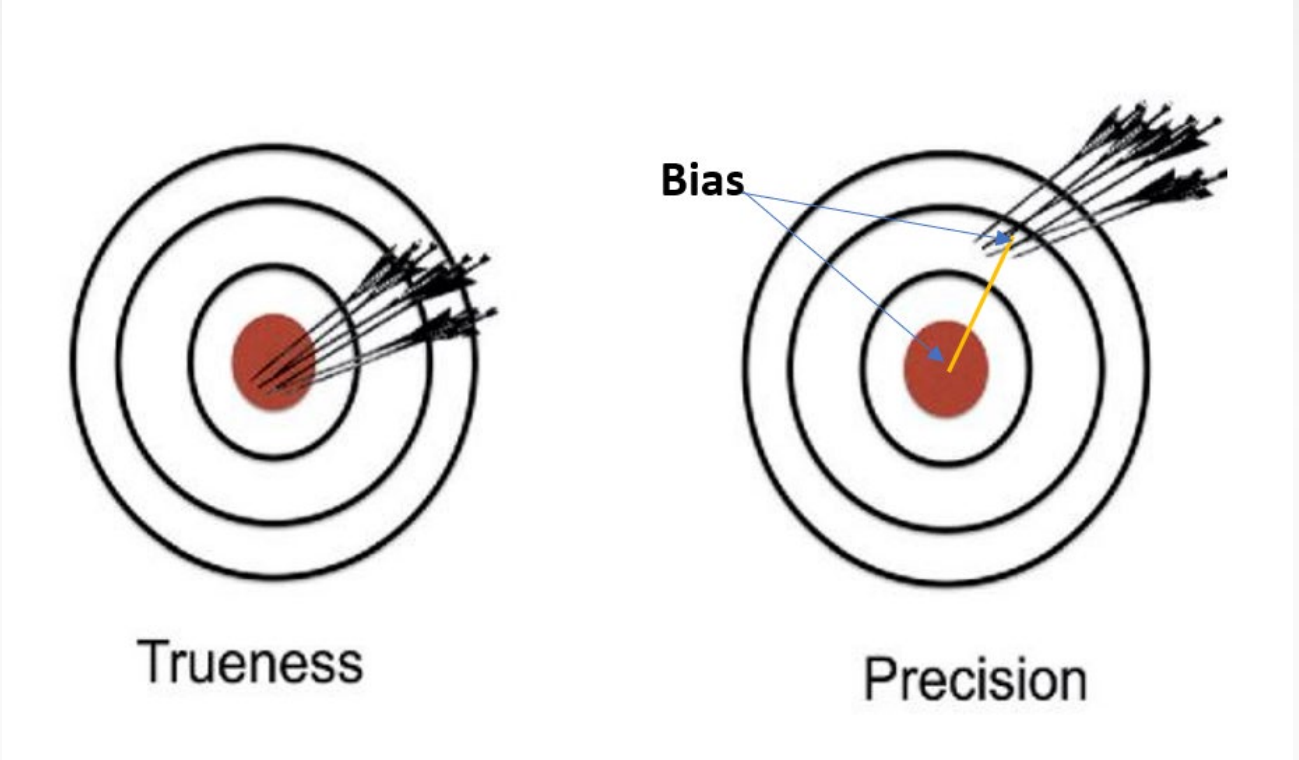
Accuracy / Bias / Precision

- **Accuracy:** The closeness of agreement between a test result and an accepted reference value ("truth").
- **Bias:** The difference between the expectation of the test results and an accepted reference value.
- **Precision:** The closeness of agreement between independent test results obtained under stipulated conditions.

*ASTM International. (2020). ASTM E177-20, Standard Practice for the use of the terms Precision and Bias in ASTM test methods.

Accuracy / Bias / Precision Visual

- Accuracy /Trueness cannot be assessed as there is no reference standard particulate source for wood smoke. Therefore, Bias also cannot be assessed.
- This makes precision very important to characterize, as it is the only information we can reliably collect about the test methodology.



Repeatability & Reproducibility Definitions

- **Repeatability Conditions:** Conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time.
- **Reproducibility Conditions:** Conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment.

*ASTM International. (2020). ASTM E177-20, Standard Practice for the use of the terms Precision and Bias in ASTM test methods.

ORD PM Measurement Precision Testing

- Precision test in one lab setting is known as “Repeatability”
  - What spread of test results might we expect with replicates?
- ORD lab burned hardwood pellets in a pellet heater.
- Paired Dichot TEOMs (two channels per TEOM device)
- 21 test runs for statistical evaluation using ASTM E691
  - Calculate standard deviation for each TEOM
  - Calculate repeatability standard deviation for the pairs

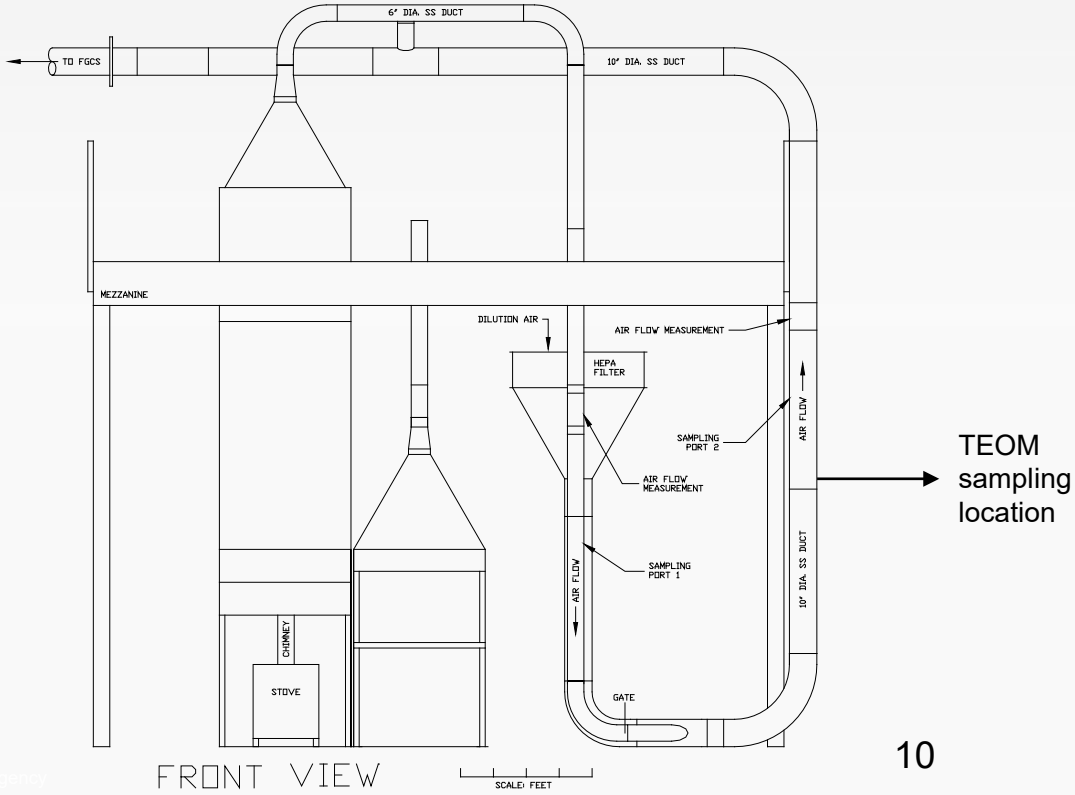
$$s_r = \sqrt{\sum_{1}^{p} d^2/(p-1)}$$

$$s_r = \sqrt{\sum_{1}^{p} s^2/p}$$

ORD TEOM Sampling Configuration

Two 1405 Dichot TEOMs

Dilution Tunnel Schematic



ORD PM Measurement Ruggedness Testing

- **Ruggedness:** Insensitivity of a test method to departures from specified test or environmental conditions.
- **Ruggedness test:** A planned experiment in which environmental factors or test conditions are deliberately varied in order to evaluate the effects of such variation.
  - TEOM PM measurement method will be evaluated for ruggedness by varying TEOM operating parameters, sampling conditions, and probe materials.
    - These ruggedness test results will help determine the sensitivity of the TEOM PM measurement method.

*ASTM International. (2021). ASTM E1169-21 Standard Practice for Conducting Ruggedness Tests.

ORD TEOM Precision & Ruggedness Testing

Precision Testing Matrix

High fire steady state
- 7 paired tests

Medium fire steady state
- 7 paired tests

Low fire steady state
- 7 paired tests

Total precision tests
- 21 paired tests on each TEOM
  - TEOM 1 - 42 runs total (2 channels)
  - TEOM 2 - 42 runs total (2 channels)

Ruggedness Testing Matrix

Medium fire steady state	Medium fire steady state	Medium fire steady state	Medium fire steady state	Low fire steady state
• Increase sample rate on TEOM • Decrease sample rate on TEOM	• Increase TEOM filter temperature • Decrease TEOM filter temperature	• Brush probe & sample line TEOM #1 • Brush probe & sample line TEOM #1 and TEOM #2	• Probe material A • Probe material B	• Reduce % loading parameter required to trigger a filter change

Total number of tests = 27

- All precision testing and ruggedness testing is being performed using an EPA Step-2 certified pellet heater.

IDC Precision - Repeatability

- IDC Repeatability matrix:
  - Wood heater cordwood method
  - 3 appliance models, pairs of each, replicate tests on 2 different fuels
    - Non-catalytic, hybrid, and catalytic controls.
    - Douglas fir and maple fuel (West), maple and birch fuel (East)
    - Separate TEOM used for testing each of the paired appliances
- 52 IDC test runs – 26 pairs of tests, 13 pairs per fuel

IDC Precision - Reproducibility

- Douglas fir and maple in Western lab
- Maple and birch in Eastern lab
- 3 wood heater appliance types, different sizes and controls
  - 52 IDC tests, 3 different stoves (26 paired tests, 13 for each fuel)
  - Precision /Repeatability based on single lab results
  - Reproducibility based on evaluation of both data sets
- 104 IDC test runs total (both east & west labs)

IDC Precision – Test Breakdown

- Douglas fir, maple and birch fuels used

- Non-catalytic stove: 1 pair, 2 fuels, 3 runs, 2 labs = 24 tests
- Catalytic stove: 1 pair, 2 fuels, 3 runs, 2 labs = 24 tests
- Hybrid stove: 1 pair, 2 fuels, 7 runs, 2 labs = 56 tests

- 52 tests with maple, 26 with Douglas fir, 26 with birch

IDC Planned Future Evaluation

- Hydronic heaters (pellet and cordwood)
  - 3 models, 2 tested in pairs, two laboratories
- Forced air furnaces
  - Two models, tested in pairs, two laboratories
- Pellet heaters
  - Two models, tested in pairs, two laboratories
- Ruggedness testing for each IDC protocol

What is the point of these studies?

- New test methods mean a new definition of PM measurement
- This requires new PM standards setting /rulemaking
- New emissions limits for each appliance type
- New test method then used for compliance at any lab
  - Must know emissions limit is reasonable and that method precision supports compliance measurement at different labs.
  - Precision test data underpins method understanding and regulatory use.

Current Timeline

IDC Methods Testing Timeline

Current Phase

- IDC cordwood wood-heater testing completed at West coast lab. East coast lab work to begin soon.
- ORD TEOM precision & ruggedness testing to be completed by September 2022 (precision portion complete).
- IDC hydronic heater (pellet & cordwood) testing starting soon and to be completed by December 2022.
- IDC forced air furnace testing and pellet heater testing (ORD) to be completed by December 2023.

Rulemaking Timeline

- New methods proposed for public comment following precision testing.
- New rulemaking and emissions limits follow method finalization.
- Estimated completion by the end of the calendar of 2026.

All Evaluation Information in EPA's Docket

- Raw data, SOPs, QAPPs, IDC Protocols, IDC fuel calculators, final data and reports will be made available in EPA's docket for public access.
  - Link
    - https://www.regulations.gov/docket/EPA-HQ-OAR-2016-0130

Questions?


Thank you very much
for your time today!
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