Worldwide Pollution Control Association

W P C A

Ameren Seminar

August 19–20, 2008

Effingham, IL

Vist our website at www.wpca.info

Fine Particulate Issues

Presented by
Scott Evans
Clean Air Engineering

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Topics

What is particulate?

How is it regulated?

How is it measured?

Method comparison data

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What is Particulate?

(Part One)

US EPA defines particulate matter as:

"... all finely divided solid or liquid material, other than uncombined water, emitted to the ambient air as measured by applicable reference methods, or an equivalent or alternative method, specified in this chapter, or by a test method specified in an approved State implementation plan."

40 CFR 51.100(qq)

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PM Definitions

PRIMARY PARTICULATE MATTER (PM): Particles that enter the atmosphere as a direct emission from a stack or an open source. It is comprised of two components: Filterable PM (FPM) and Condensable PM (CPM).

FILTERABLE PM: Particles that are directly emitted by a source as a solid or liquid at stack or release conditions and captured on the filter of a stack test train.

CONDENSIBLE PM: Material that is vapor phase at stack conditions, but which condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack.

SECONDARY PM: Particles that form through chemical reactions in the ambient air well after dilution and condensation have occurred. Secondary PM is usually formed at some distance downwind from the source.

Source: US EPA Emission Inventory Guidance 2003

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PM 2.5 Implementation Rule

Secondary Fine PM Precursors

- SO_2
- VOC
- NOx
- NH_4

SO_2 and NOx are default precursors. States may choose to exempt NOx and/or add VOC and NH_4

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PM is defined by the method used to measure it.

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How is PM Regulated?

The National Ambient Air Quality Standards (NAAQS) determine what kinds of particulate are regulated and indirectly determine emission limits

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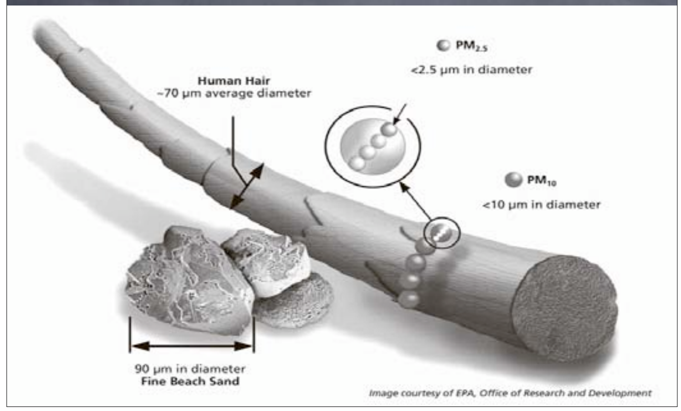
Size Matters



A Brief History of PM NAAQS

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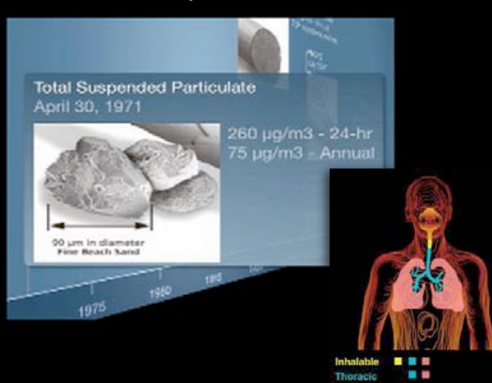

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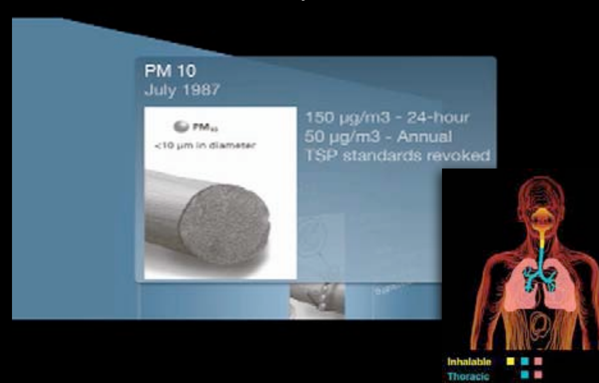
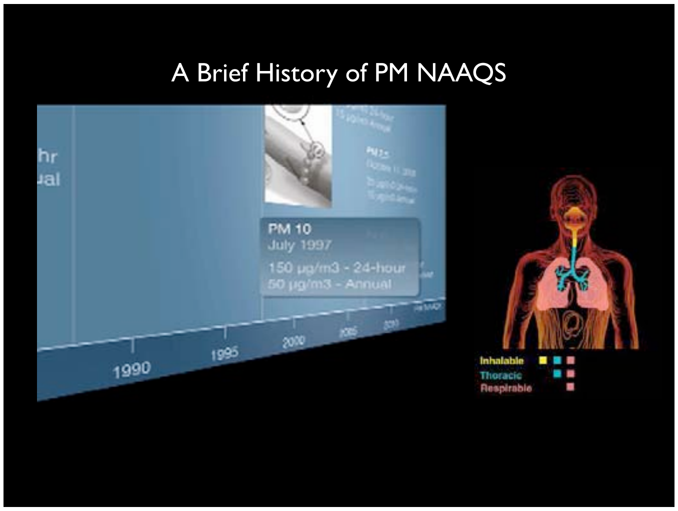
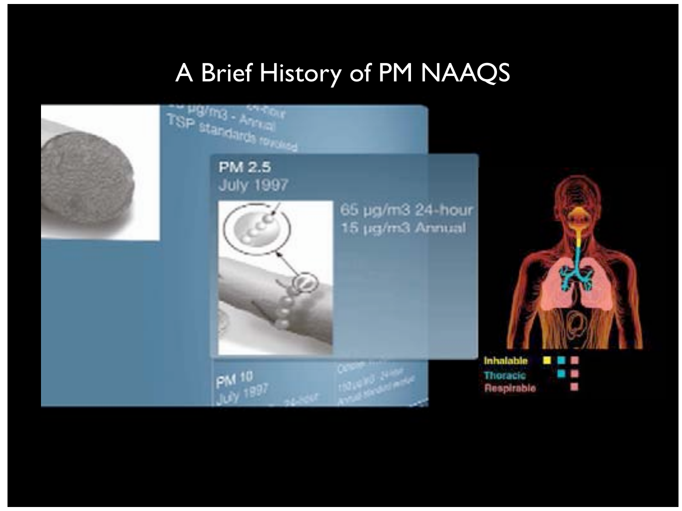



A Brief History of PM NAAQS
PM 10
July 1997
150 µg/m3 - 24-hour
50 µg/m3 - Annual
1990
1995
2000
2005
2010
Inhalable
Thoracic
Respirable


A Brief History of PM NAAQS
TSP standards revoked
PM 2.5
July 1997
65 µg/m3 24-hour
15 µg/m3 Annual
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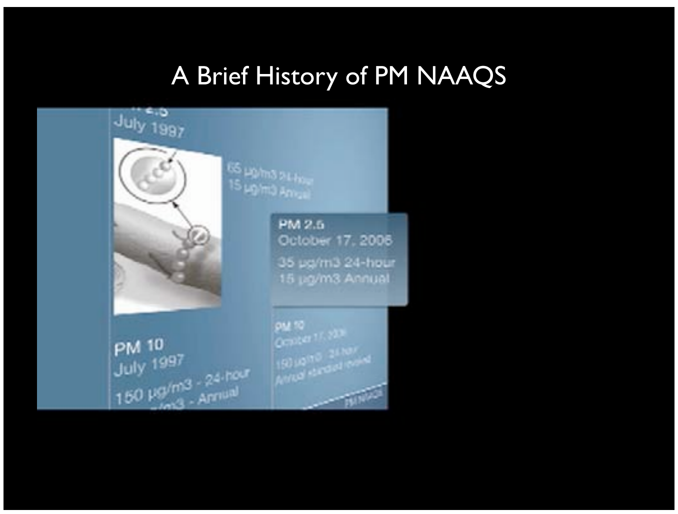
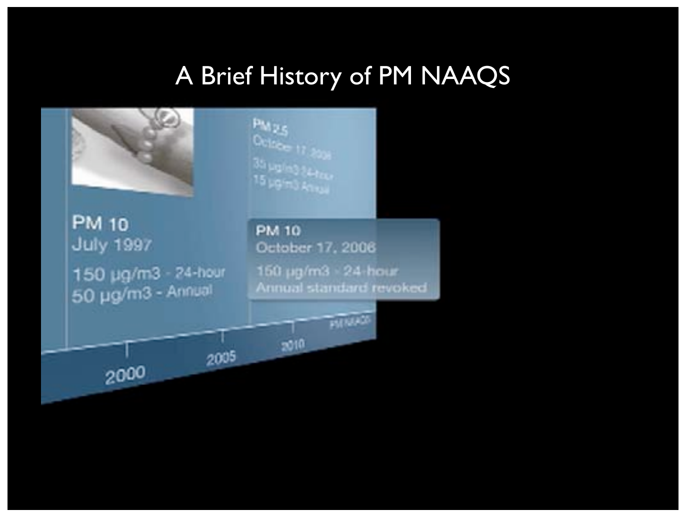
Inhalable
Thoracic
Respirable


A Brief History of PM NAAQS
July 1997
65 µg/m3 24-hour
15 µg/m3 Annual
PM 2.5
October 17, 2006
35 µg/m3 24-hour
15 µg/m3 Annual
PM 10
July 1997
150 µg/m3 - 24-hour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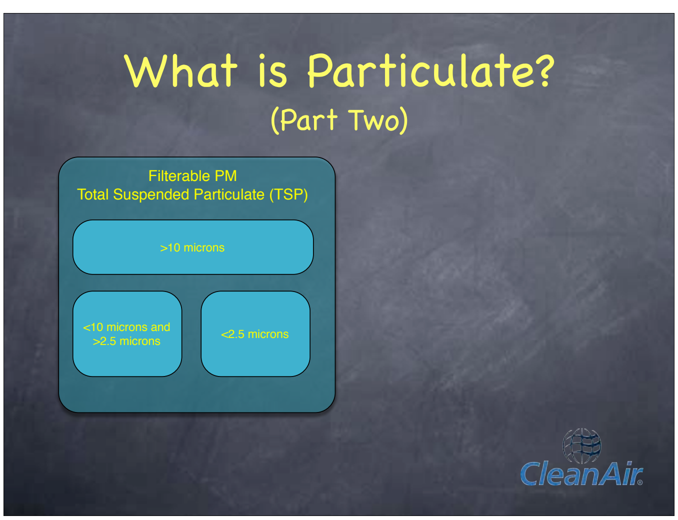
What is Particulate?
(Part Two)
Filterable PM
Total Suspended Particulate (TSP)
>10 microns
<10 microns and >2.5 microns
<2.5 microns
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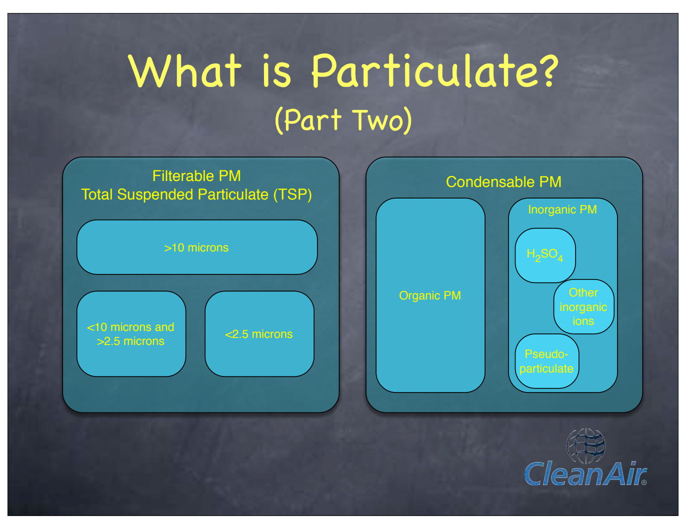
What is Particulate?
(Part Two)
Filterable PM
Total Suspended Particulate (TSP)
>10 microns
<10 microns and >2.5 microns
<2.5 microns
Condensable PM
Organic PM
Inorganic PM
H_2SO_4
Other inorganic ions
Pseudo-particulate
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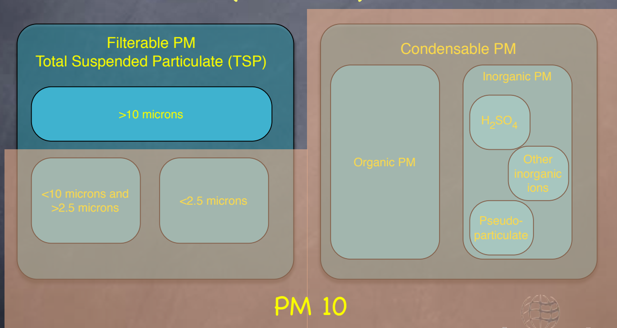
What is Particulate?

(Part Two)



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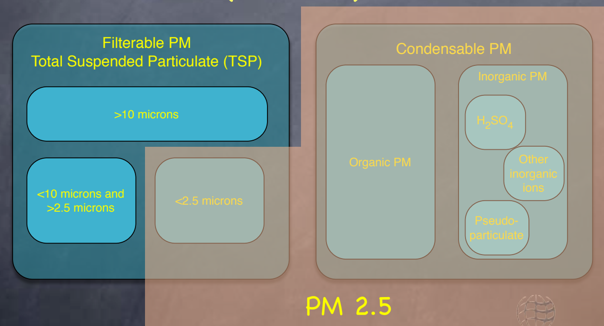
(Part Two)



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PM 2.5 Implementation Rule - NSR/PSD

- Regulates both Primary and Secondary emissions
- Condensables need not be considered until test method promulgated or 2011
- Major source threshold consistent with other polluants -- 100/250 tons per year
- NSR significance threshold - 10 tons
- Trading available including interpollutant trading
- States must address PM 2.5 in minor source NSR

Federal Register: May 16, 2008

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How is PM Measured?

- Filterable methods: 5, 5B, 5F, 17, 201A, OTM-27 (CTM-040)
- Condensable methods: 202, OTM-28 (20x), CTM-039
  - EPA developed Method 202 to determine CPM. Method 202 involves the analysis of the sample train impinger solution.
  - Impinger methods for CPM are subject to substantial artifacts that do not occur naturally in atmospheric conditions.

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Combination of PM Methods

Typical Permit Language

Whenever compliance emission testing is required, US EPA Method 5 or 5B including back-half (Method 202) shall be used to demonstrate compliance or an alternate method approved in writing by the Department, shall be used.

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EPA Method 5

- Measures Total Suspended Particulate
- Any compounds in a vapor phase at 250 °F will not be measured.

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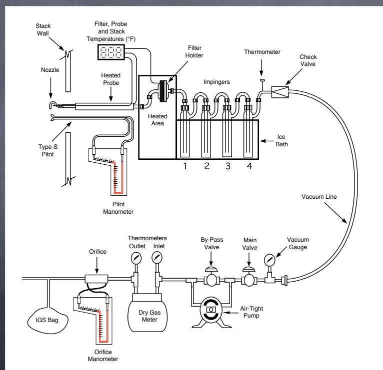
Method 5 Sampling Train



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Isokinetic Sampling

Pulling the stack gas through the nozzle at the same velocity it is moving through the stack

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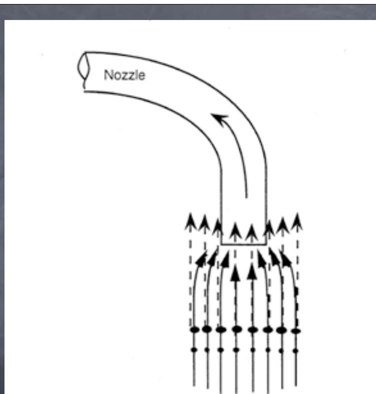
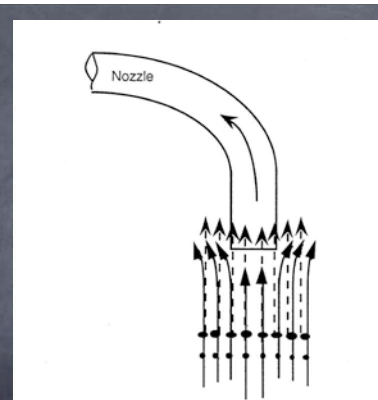
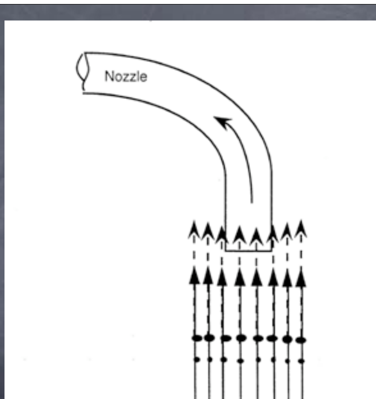


Over-isokinetic (>100%)
Low PM bias



Under-isokinetic (<100%)
High PM Bias



Isokinetic (100%)
No PM Bias

For PM 10 and especially for PM 2.5, isokinetic testing doesn't matter

Glassware

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Glassware

CleanAir

Glassware

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Variations on a Theme

- Method 5B - Non-sulfuric acid PM
  - Probe and filter at 320 °F
  - Filter desiccated at 320 °F
- Method 5F - Non-sulfate PM
  - Probe and filter at 320 °F
  - Sulfate analysis by IC, stablized with NH_4OH and subtracted

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The Death of Method 5?

A formal declaration would clarify EPA's policy stance that TSP is not a regulated pollutant for purposes of new source review permit requirements, but the clarification will not necessarily mean that states will no longer be able to use TSP as a particulate measurement, Scott Mathias of the Office of Air Quality Planning & Standards said at an Oct. 3 AAQTF meeting in Indianapolis.

EPA is also working on guidance for states that may use TSP to measure PM from various sources to persuade them not to use TSP as a valid measurement, Mathias said.

"I suspect we will make a very strong pitch to states that there is no sense in regulating anything that is not included in the Clean Air Act," Mathias said. He added that it is a "priority" because measuring "total PM" is confusing in light of different standards over the years, and a clarification by EPA is necessary.

Source: Clean Air Report, Oct. 18, 2007

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Measuring Fine PM

- Method 201 A for PM 10
- OTM 27 (CTM-040) for PM 2.5
- Both measure ONLY filterable PM
- Both use in-stack cyclone to remove large particulate

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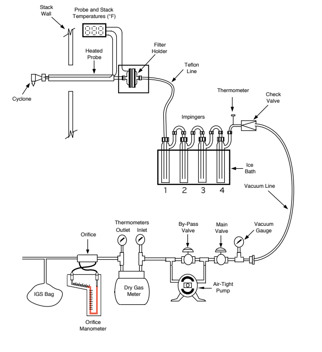
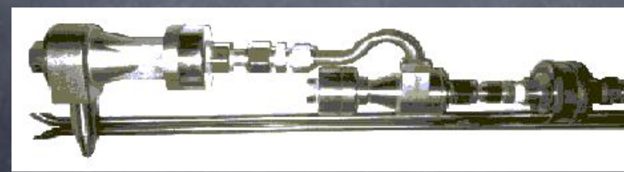
Method 201A



M201A, Cat w/BH, OSF

OTM 27 Dual Cyclone



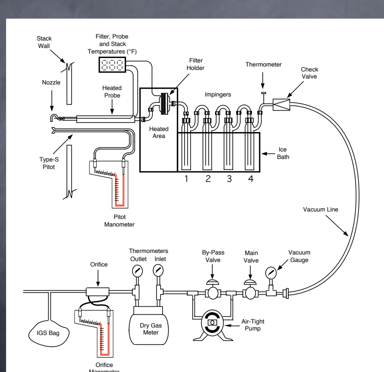
Measuring Condensables

- Originally developed Method 202
- M202 problematic due to "pseudo-particulates" or artifacts
- Various approaches tried
  - Dilution (CTM-039)
  - Dry Impinger (OTM 28 or M20x)
- No solutions finalized

Method 202

- Uses back-half of Method 5/17 method train
- Inorganic and organic fractions
- Nitrogen purge to remove dissolved SO_2
- Allows correction for HCl in the presence of NH_4

Method 202



The Problem with M202

6 Options

144 variations

The Problem with M202

- Dissolved SO_2 reacts to form sulfites and bi-sulfite artifacts which are counted as CPM

$$SO_2 \rightarrow H_2SO_3^{-} \rightarrow H_2SO_4$$

- Free NH_4 enhances this effect and increases artifact formation. HCl measured as CPM.
- Post-test N_2 purge not as effective as once thought -- effectiveness related to concentration of SO_2 and pH

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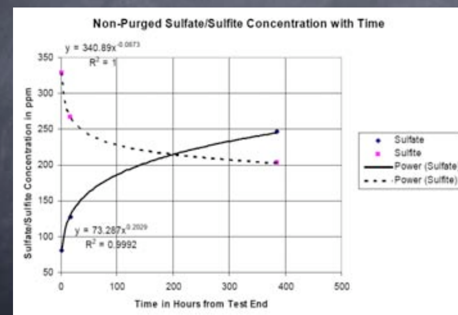
Transformation of $SO_3^{=}$ to $SO_4^{=}$ over time



EPA 2005

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Approaches to Bias Correction

Filterable Fraction

\+ Back-half Inorganic Fraction

\+ Back-half Organic Fraction

– SO_4 analysis of impingers

\+ SO_3 from Controlled Condensation

= Total Particulate

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The Dry Impinger Approach

- No options
- Uses lessons learned from SO_3 methods
- Removes liquids from impingers
- Uses ambient (85 °F) temperature condenser in place of chilled impinger as main cooling mechanism
- Now EPA's preferred approach
- Method in final phase of validation.

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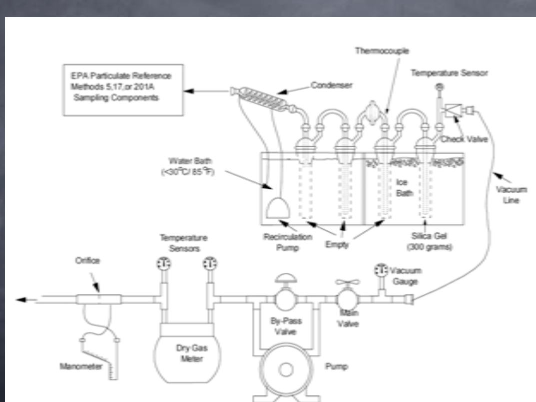
Method 20x



Dilution Approach

- EPA CTM-039
- ASTM Workgroup WK8124
- Recommended in Final EPA PM Guidance
- Now on back burner due to relative simplicity of dry impinger approach.

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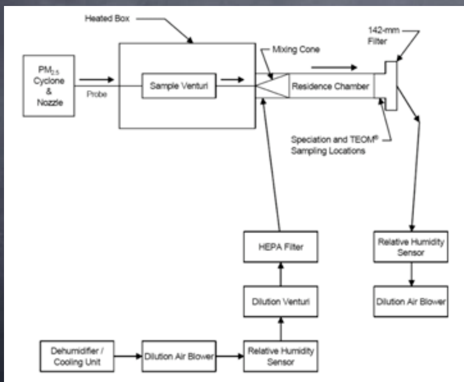
CTM-039



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And Don't Forget...

- Mass emission calculations (lb/hr, lb/Mlb coke burned) require flow measurements.
- EPA Methods include
  - Method 2 - Velocity and Volumetric Flow
  - Method 2F - Non-Axial Flow
  - Method 2G - Wall Adjustment Factors

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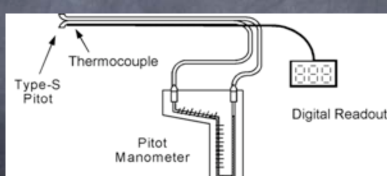
EPA Method 2

In this method a standard Staucheibe (S-type) pitot tube is used to determine the velocity pressure by measuring gas flow as a unidirectional vector



Common Stack Velocity Sampling Apparatus (EPA Method 2)

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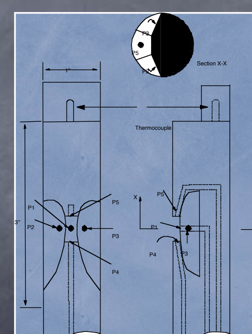
Method 2F Equipment

- Five-holed (pressure taps P1-P5) prism shaped probe tip with thermocouple
- A centrally located tap, P1, measures the stagnation pressure while two lateral taps, P2 and P3, measure the static pressure. The yaw angle is determined by rotating the probe until the difference between the two lateral holes is zero
- Once the yaw angle is determined two static pressure taps are combined, and the velocity pressure is measured as P1-(P2+P3) on a digital manometer



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Advantages of 2F & 2G

5% to 15% Lower Flow

=

5% to 15% Lower Mass Emissions

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Method Comparison Data

Results from ESP

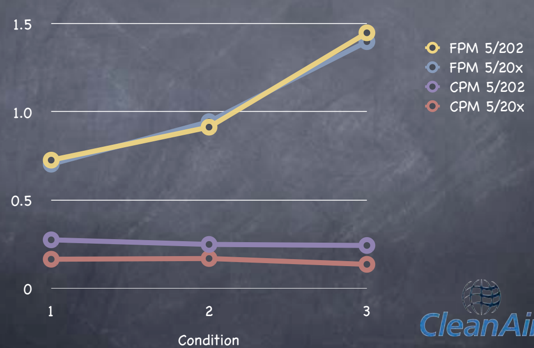
- Compared four methods...
  - Method 5/202
  - Method 5/20x
  - Method 5F
  - Method 201A
- Under three conditions...
  - Fully functioning ESP
  - Both bays functional - one bus de-energized in each
  - One bay isolated - one bus de-energized

Test Results

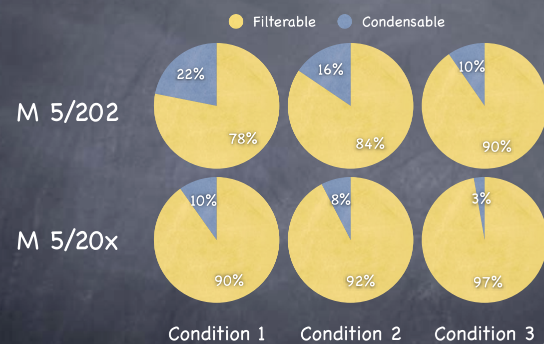
Condition ->	1	2	3
5/202	F: 0.728 C: 0.276 T: 1.004	F: 0.915 C: 0.250 T: 1.166	F: 1.45 C: 0.244 T: 1.69
5/20x	F: 0.705 C: 0.166 T: 0.871	F: 0.946 C: 0.170 T: 1.116	F: 1.40 C: <DL T: 1.40
5F	NSP: 0.663	NSP: 0.933	NSP: 1.30
201A	PM_{10}: 0.783 Total: 0.803	PM_{10}: 0.760 Total: 0.766	PM_{10}: 1.059 Total: 1.110

M5/202 vs M5/20x

ESP

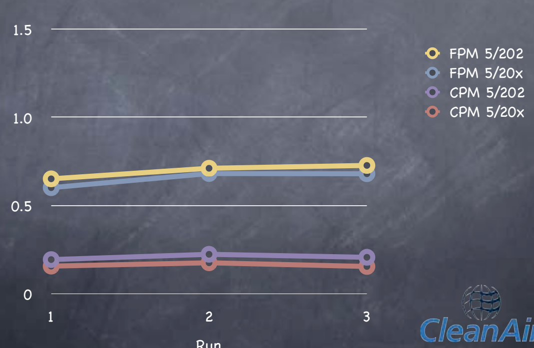


FPM/CPM Fractions



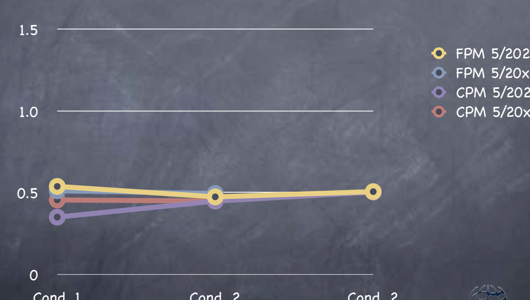
M5/202 vs M5/20x

Baghouse

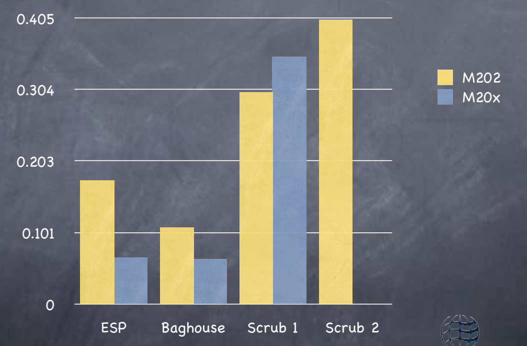


M5/202 vs M5/20x

Wet Scrubber

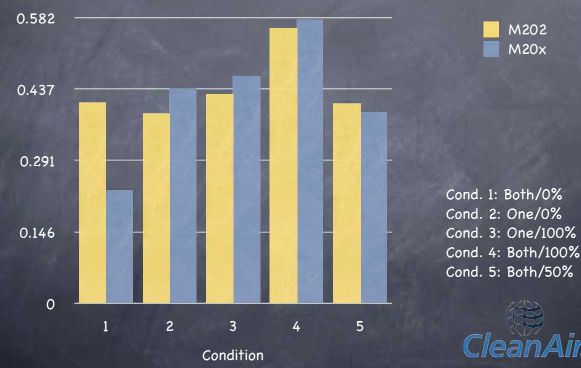


M202 vs M20x Condensables



M202 vs M20x Condensables

ESP w/NH_4



So What Does All This Data Really Mean?

- How likely is it that we will demonstrate on-going compliance?
- Is there really a difference between M202 and M20x?
- Is it more advantageous to use M5F in place of M5?

Condensable Particulate Measurement Uncertainty

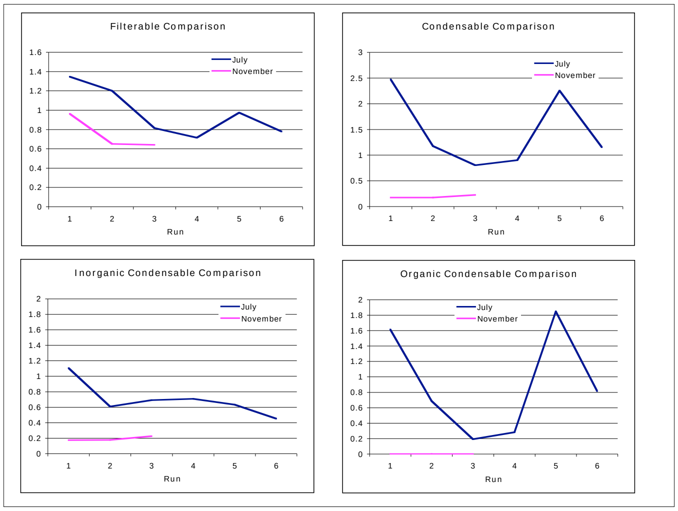
Data	Condition 1		Condition 2		Condition 3	
	M5/202	M5/20x	M5/202	M5/20x	M5/202	M5/20x
Run 1	0.260	0.174	0.204	0.152	0.257	0.137
Run 2	0.261	0.180	0.268	0.170	0.238	0.137
Run 3	0.307	0.144	0.232	0.188	0.238	0.136
Run 4			0.296			
SD	0.0269	0.0193	0.0403	0.0180	0.0110	0.0006
AVG	0.2760	0.1661	0.2500	0.1699	0.2443	0.1367
RSD	9.73%	11.59%	16.13%	10.57%	4.49%	0.41%
N	3	3	4	3	3	3
SE	0.016	0.011	0.020	0.010	0.006	0.000
RSE	5.62%	6.69%	8.07%	6.10%	2.59%	0.24%
P	95%	95%	95%	95%	95%	95%
TINV	4.303	4.303	3.182	4.303	4.303	4.303
CI +	0.343	0.214	0.314	0.214	0.272	0.138
AVG	0.276	0.166	0.250	0.170	0.244	0.137
CI -	0.209	0.118	0.186	0.125	0.217	0.135
Diff	Significant		Significant		Significant	
TB +	0.482	0.314	0.457	0.307	0.328	0.141
TB+ All	0.457		0.394		0.411	

Total Particulate Measurement Uncertainty

Data	Condition 1		Condition 2		Condition 3	
	M5/202	M5/20x	M5/202	M5/20x	M5/202	M5/20x
Run 1	0.945	0.846	0.997	1.027	1.672	1.657
Run 2	0.871	0.745	1.037	0.989	1.463	1.503
Run 3	0.897	0.722	1.133	1.033	1.644	1.443
Run 4			1.096			
SD	0.0375	0.0660	0.0605	0.0239	0.1135	0.1105
AVG	0.9043	0.7710	1.0658	1.0163	1.5930	1.5344
RSD	4.15%	8.56%	5.68%	2.36%	7.12%	7.20%
N	3	3	4	3	3	3
SE	0.022	0.038	0.030	0.014	0.066	0.064
RSE	2.40%	4.94%	2.84%	1.36%	4.11%	4.16%
P	95%	95%	95%	95%	95%	95%
TINV	4.303	4.303	3.182	4.303	4.303	4.303
CI +	0.998	0.935	1.162	1.076	1.875	1.809
AVG	0.904	0.771	1.066	1.016	1.593	1.534
CI -	0.811	0.607	0.969	0.957	1.311	1.260
Diff	Not Significant		Not Significant		Not Significant	
TB +	1.192	1.276	1.377	1.200	2.462	2.380
TB+ All	1.162		1.222		1.954	

Tips For Evaluating PM Stack Test Data

- Familiarize yourself with the test method
- Watch the test -- Ask questions
- Look at run-to-run variation
- Look for unexplained trends in the data
- Graph it!
- Check equipment calibration



Accredited Stack Testers

- Stack Testing Accreditation Council (STAC)
- www.betterdata.org
- Conformance to ASTM D7036
- Required by EPA for electric utilities

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