

**ThermoFisher**  
S C I E N T I F I C

*The world leader in serving science*

# FEM Approved PM<sub>2.5</sub> Continuous Samplers

**TEOM 1405-DF**  
**TEOM 1400ab with 8500C FDMS**  
**SHARP (5030)**  
**FH62C14-DHS Beta Monitor**

# Presentation Summary

- Thermo Scientific PM<sub>2.5</sub> FEM Test Program
- Thermo Scientific FH62C14-DHS Beta Monitor
- Thermo Scientific Synchronized Hybrid Ambient Real-time Particulate Monitor (SHARP) (5030)
- Thermo Scientific TEOM 1400ab with 8500C FDMS
- Thermo Scientific TEOM 1405-DF Dichotomous Sampler with FDMS



# FEM PM2.5 Test Program Results

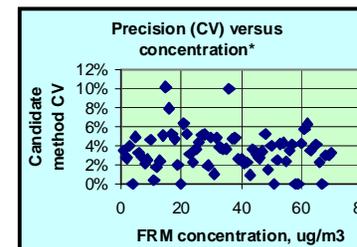
- High Degree of Precision Between Candidate Monitors
- Excellent Correlation with Reference Sampler Results
  
- There are Differences Between the FRM and Continuous Monitors
  - FRM is a design based method
  - Potential FRM sample loss during sampling process (semi-volatile compounds)
  - FEM Continuous Monitors are Performance Based
  
- Variety of Approaches can be used to Account for Differences
  - Following EPA test guidelines
  - Empirical equation based on data
  - $FEM\ MC = a * MC^b$

# TEOM 1405-DF FEM Results - Bakersfield

Applicant:	Thermo Fisher Scientific
Candidate method:	TEOM 1405-DF Dichotomous Ambient Particulate Monitor with FDMS - PM2.5 Class III
Test site:	Bakersfield, CA 2007 - (Site location A)

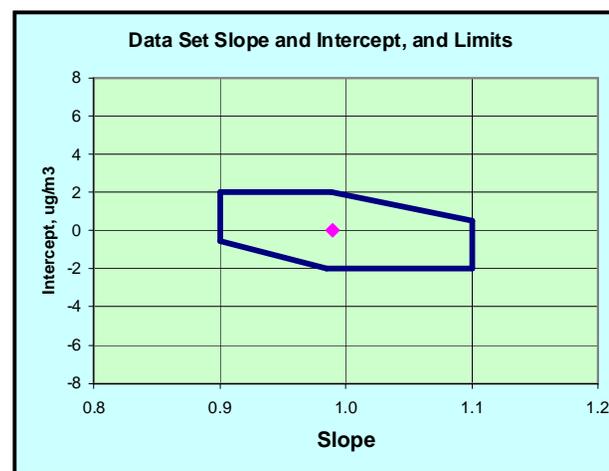
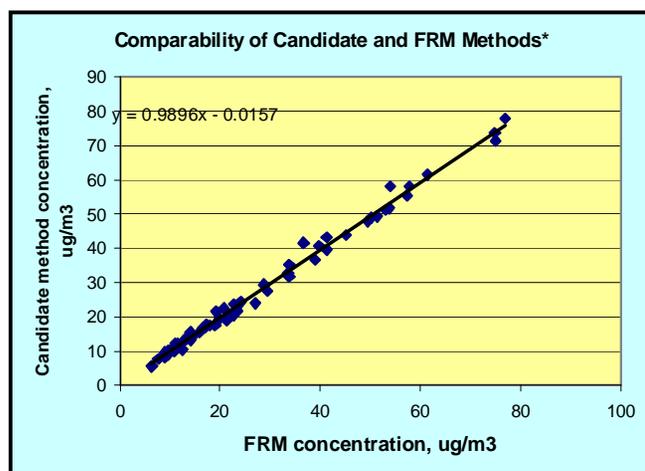
Data sets	Number
Valid data sets available:	64
Number of valid data sets required for Class III, location A:	46
Number of valid data sets for this test is:	OK
Additional data sets needed:	--

Precision	Data set mean, $\mu\text{g}/\text{m}^3$		Data set precision, $\mu\text{g}/\text{m}^3$		Relative precision (CV)	
	FRM	Candidate	FRM	Candidate	FRM	Candidate
Mean:	26.8	26.5	0.4	0.9	2.2%	3.8%
Maximum:	76.8	77.9	1.4	2.7	7.8%	10.2%
Minimum:	6.3	5.6	0.0	0.1	0.1%	0.4%
Candidate / FRM Ratio:	98.9%		203.9%		170.0%	
RMS Relative Precision for this site:					2.8%	4.2%
Test requirements - PM2.5 Class III:					10.0%	15.0%
Precision Test Results for site:					OK	PASS



Regression statistics	Slope <sup>1</sup>	Intercept <sup>2</sup>	Correlation (r)
Statistics for this test site:	0.990	-0.016	0.99671
Limits for PM2.5 Class III	Upper: 1.100	1.987	
	Lower: 0.900	-2.000	0.95000
Test Results (Pass/Fail):	PASS	PASS	PASS

<sup>1</sup>Multiplicative bias    <sup>2</sup>Additive bias

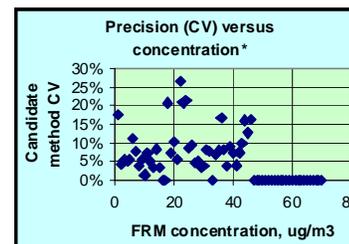


# TEOM 1400ab with 8500C FDMS FEM Results - St. Louis

Applicant:	Thermo Fisher Scientific
Candidate method:	TEOM Series 1400a Ambient Particulate Monitor with Series 8500C Filter Dynamics Measurement System - PM
Test site:	St Louis, MO 2007 - (Site location C)

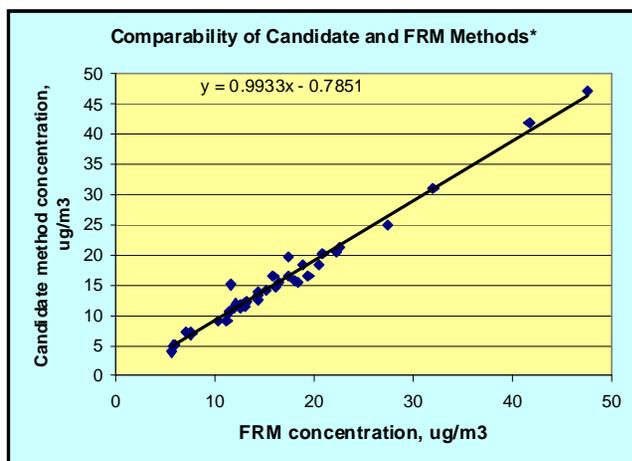
Data sets	Number
Valid data sets available:	43
Number of valid data sets required for Class III, location C:	23
Number of valid data sets for this test is:	OK
Additional data sets needed:	--

Precision	Data set mean, $\mu\text{g}/\text{m}^3$		Data set precision, $\mu\text{g}/\text{m}^3$		Relative precision (CV)	
	FRM	Candidate	FRM	Candidate	FRM	Candidate
Mean:	16.1	15.2	0.3	1.1	2.3%	8.9%
Maximum:	47.6	47.2	1.2	2.7	10.3%	26.6%
Minimum:	5.6	4.0	0.1	0.2	0.2%	1.5%
Candidate / FRM Ratio:	94.5%		360.7%		383.6%	
<b>RMS Relative Precision for this site:</b>					<b>3.2%</b>	<b>10.6%</b>
<b>Test requirements - PM2.5 Class III:</b>					<b>10.0%</b>	<b>15.0%</b>
<b>Precision Test Results for site:</b>					<b>OK</b>	<b>PASS</b>



Regression statistics	Slope <sup>1</sup>	Intercept <sup>2</sup>	Correlation (r)
Statistics for this test site:	0.992	-0.758	0.99064
Limits for PM2.5 Class III	Upper: 1.100	1.957	
	Lower: 0.900	-2.000	0.95000
Test Results (Pass/Fail):	PASS	PASS	PASS

<sup>1</sup>Multiplicative bias    <sup>2</sup>Additive bias

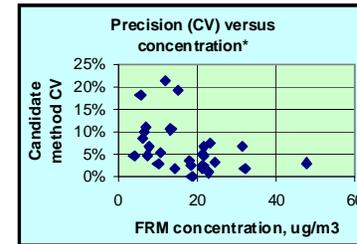


# SHARP 5030 FEM Results - New Haven

Applicant:	Thermo Fisher Scientific, Inc.
Candidate method:	SHARP - PM2.5 Class III
Test site:	New Haven, CT - CTDEP State Street Monitoring Site - (Site location D )

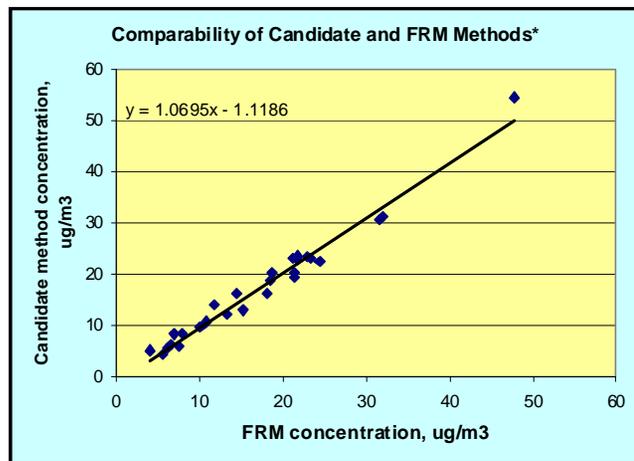
Data sets	Number
Valid data sets available:	27
Number of valid data sets required for Class III, location D:	23
Number of valid data sets for this test is:	OK
Additional data sets needed:	--

Precision	Data set mean, $\mu\text{g}/\text{m}^3$		Data set precision, $\mu\text{g}/\text{m}^3$		Relative precision (CV)	
	FRM	Candidate	FRM	Candidate	FRM	Candidate
Mean:	17.2	17.3	0.3	0.9	2.4%	6.6%
Maximum:	47.7	54.4	1.1	3.0	8.3%	21.3%
Minimum:	4.0	4.3	0.1	0.0	0.6%	0.2%
Candidate / FRM Ratio:	100.4%		262.8%		273.0%	
<b>RMS Relative Precision for this site:</b>					<b>3.0%</b>	<b>8.5%</b>
<b>Test requirements - PM2.5 Class III:</b>					<b>10.0%</b>	<b>15.0%</b>
<b>Precision Test Results for site:</b>					<b>OK</b>	<b>PASS</b>



Regression statistics	Slope <sup>1</sup>	Intercept <sup>2</sup>	Correlation (r)
Statistics for this test site:	1.069	-1.119	0.98667
Limits for PM2.5 Class III	Upper: 1.100	0.933	
	Lower: 0.900	-2.000	0.95000
Test Results (Pass/Fail):	PASS	PASS	PASS

<sup>1</sup>Multiplicative bias    <sup>2</sup>Additive bias

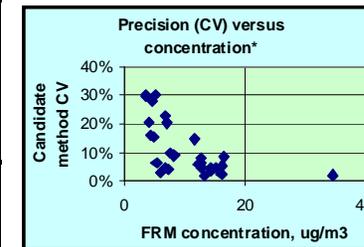


# FH62C14-DHS Beta Monitor FEM Results - Denver

Applicant:	Thermo Fisher Scientific, Inc.
Candidate method:	FH62C14 - PM2.5 Class III
Test site:	Denver, CO - DMAS Denver Municipal Animal Shelter - (Site location B)

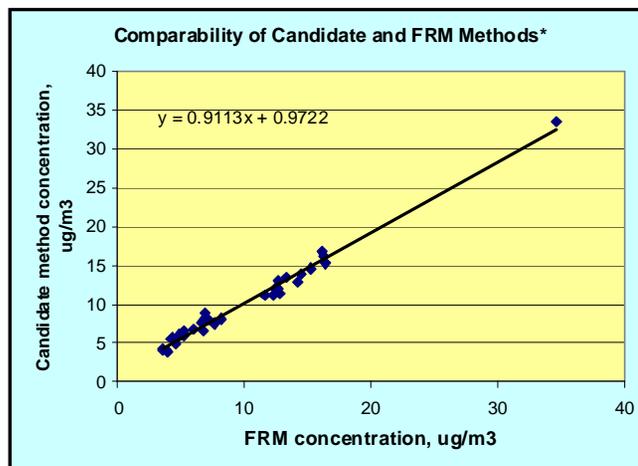
Data sets	Number
Valid data sets available:	29
Number of valid data sets required for Class III, location B:	23
Number of valid data sets for this test is:	OK
Additional data sets needed:	--

Precision	Data set mean, $\mu\text{g}/\text{m}^3$		Data set precision, $\mu\text{g}/\text{m}^3$		Relative precision (CV)	
	FRM	Candidate	FRM	Candidate	FRM	Candidate
Mean:	10.3	10.4	0.3	0.8	3.7%	11.2%
Maximum:	34.7	33.4	0.8	1.8	8.7%	30.4%
Minimum:	3.5	3.9	0.1	0.2	0.5%	1.6%
Candidate / FRM Ratio:	100.5%		267.3%		305.9%	
<b>RMS Relative Precision for this site:</b>					<b>4.2%</b>	<b>14.5%</b>
<b>Test requirements - PM2.5 Class III:</b>					<b>10.0%</b>	<b>15.0%</b>
<b>Precision Test Results for site:</b>					<b>OK</b>	<b>PASS</b>



Regression statistics	Slope <sup>1</sup>	Intercept <sup>2</sup>	Correlation (r)
Statistics for this test site:	0.911	0.972	0.99307
Limits for PM2.5 Class III	Upper: 1.100	2.000	
	Lower: 0.900	-0.733	0.95000
Test Results (Pass/Fail):	PASS	PASS	PASS

<sup>1</sup>Multiplicative bias    <sup>2</sup>Additive bias



# Particulate Monitoring – Instruments & Designation Status

## ■ Manual Method Samplers

- Partisol 2000 FRM
- Partisol 2000-D Dichotomous Sampler
- Partisol-Plus 2025
- Partisol-Plus 2025-D Dichotomous Sampler

Instrument	EPA PM-10	EPA PM-2.5	EPA PM-Coarse
<b>2000FRM</b>	FRM RFPS-1298-126	FRM RFPS-0498-117	FRM <sup>1</sup> RFPS-0509-175
<b>2025</b>	FRM RFPS-1298-127	FRM RFPS-0498-118	FRM <sup>1</sup> RFPS-0509-176
<b>2000D</b>	To be submitted	FEM* EQPS-0509-177	FEM EQPS-0509-178
<b>2025D</b>	To be submitted	FEM EQPS-0509-179	FEM EQPS-0509-180

<sup>1</sup> Co-located pairs

# Particulate Monitoring – Instruments & Designation Status

## ■ Continuous Monitors

- TEOM 1400ab/1405
- TEOM 1400ab with 8500C FDMS/1405F
- TEOM 1405DF Dichotomous Monitor with FDMS
- FH62C14/Model 5014*i*
- Model 5030 SHARP/Model 5030*i* SHARP

Instrument	EPA PM-10	EPA PM-2.5
<b>1400ab</b>	FEM EQPM-1090-079	N/A
<b>1400ab w/FDMS</b>	To be submitted	FEM EQPM-0609-181
<b>1405</b>	FEM EQPM-1090-079	N/A
<b>1405D</b>	To be submitted	N/A
<b>1405F</b>	To be submitted	Pending
<b>1405DF</b>	Pending	FEM EQPM-0609-182
<b>FH62C14-DHS</b>	FEM EQPM-1102-150	FEM EQPM-0609-183
<b>5030 (SHARP)</b>	N/A	FEM EQPM-0609-184

# Thermo Scientific FH62C14-DHS Beta Monitor & Model 5030 SHARP

- Thermo Scientific FH62C14-DHS Beta Monitor
- Synchronized Hybrid Ambient Real-time Particulate Monitor Model 5030 SHARP
- Installation Options and Operation
- iSeries Model Development Status

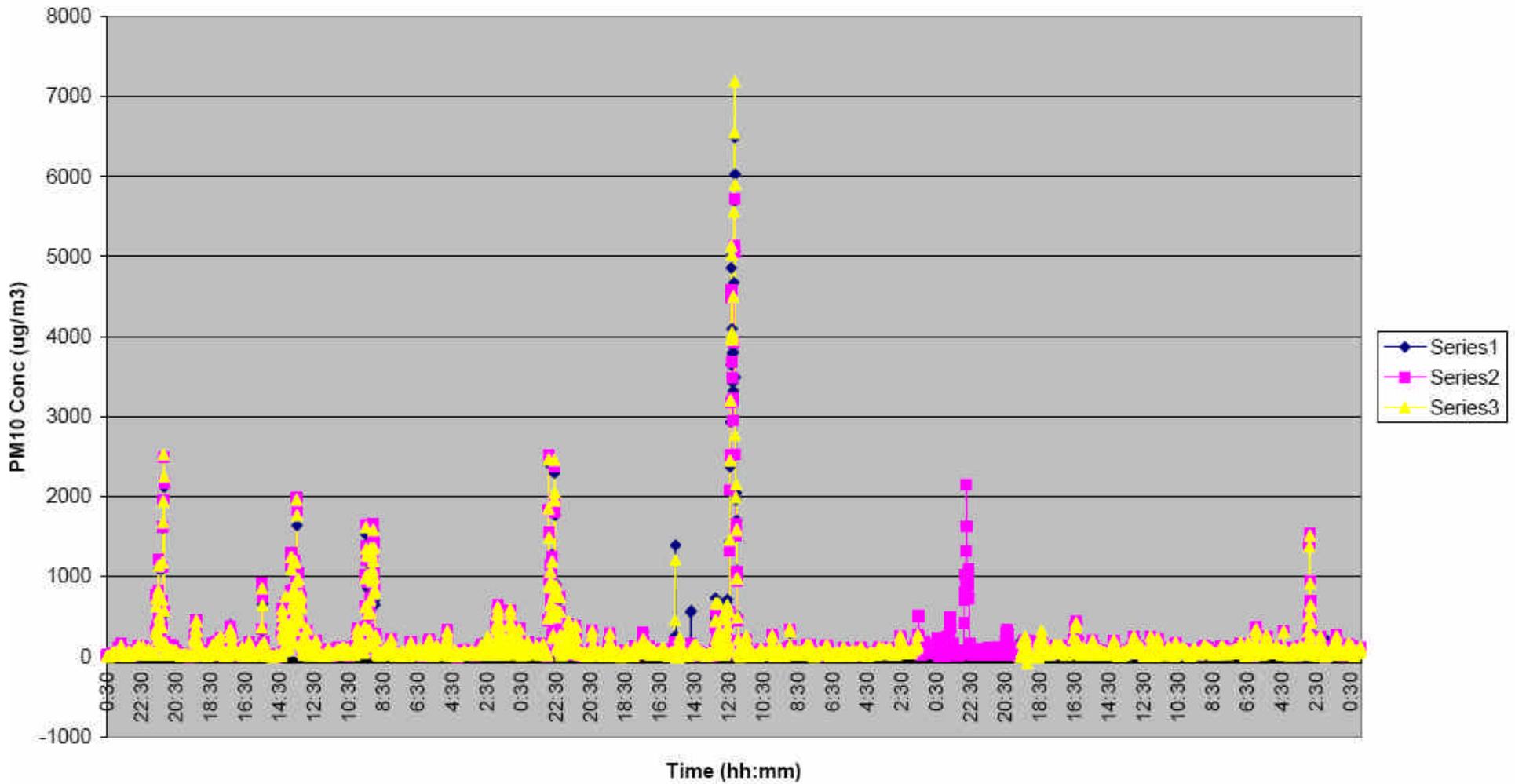
# Thermo Scientific FH62C14-DHS Beta Monitor

- Continuous Concentration Measurement During Sampling
  - No tape movement until after measurement complete
  - Automated temporal and mass saturation filter change
  - Provides ability to track short term events
- Background rejection of naturally occurring beta emitters through alpha measurement
- Active volumetric flow control
- FEM  $PM_{2.5}$  Designation: EQPM-0609-183
- FEM  $PM_{10}$  Designation: EQPM-1102-150



# FH62C14 Data – Calexico Dust Storm

30 Minute Average Concentrations During USEPA Designation Testing in Calexico, CA  
April 16th - June 24th, 2002



# Synchronized Hybrid Ambient Real-time Particulate Monitor Model 5030 SHARP

- Hybrid nephelometry and beta attenuation combined is a single instrument
- Two types of data available simultaneously
- 1-minute time resolved data
- 880 nm light source, <math><100 \mu\text{Ci} \text{ }^{14}\text{C}</math>
- 1 & 2 meter sample heaters w/humidity control
- FEM  $\text{PM}_{2.5}$  Designation: EQPM-0609-184



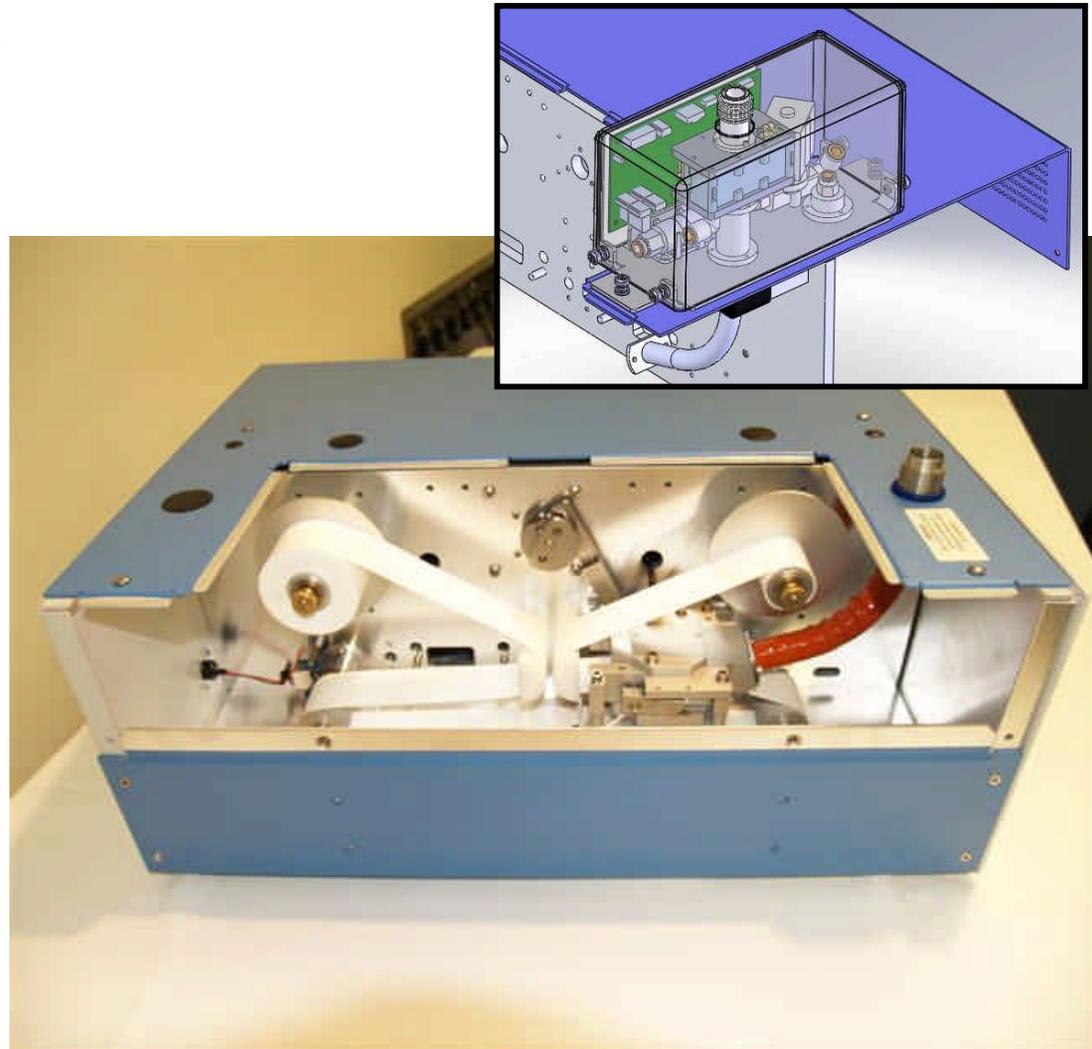
# Installation Options and Operation

- Standard 19" rack mount
- Climate controlled or ventilated shelter (-10 to 50 deg C)
- Annual calibration
  - temperature
  - barometric pressure
  - volumetric flow
  - mass
- Annual service
  - filter tape replacement
  - pump service
  - inlet assembly o-ring replacement
  - mass sensors cleaned by trained technician
  - sample down tube cleaning
- Monthly/Quarterly servicing per user QA Project Plan
  - inlet cleaning, flow checks, control charting



# Model 5014*i* Beta & Model 5030*i* SHARP Development Status

- Legacy beta-attenuation measurement head, filter tape and similar exchange mechanics
- Modular Nephelometer with Scheduled Auto-zero
- Customer Configurable Between Beta and SHARP
- All i-Series features
  - Ethernet ready
  - Customized data logging
  - I/O Expansion
  - 100/110/220 VAC



# Model 5014*i* Beta & Model 5030*i* SHARP Development Status

- Universal heater
  - Temperature control for PM<sub>10</sub>
  - Sample humidity control for PM<sub>10</sub> or PM<sub>2.5</sub>
- Ambient RH sensor
- Universal pump
- Model 5014*i*
  - USEPA FEM PM10 Approval (EQPM-1102-150)
  - USEPA FEM PM2.5 Application submitted
  - Target Product Launch December 2009
- Model 5030*i* SHARP
  - Target Product launch Q1 2010



# The TEOM 1405-DF and TEOM 1400a with 8500C with FDMS

- TEOM 1400ab with 8500C FDMS
- TEOM 1405-DF Dichotomous Monitor with FDMS
- Installation Guidelines
- Operating Parameters
- Calibration, Audits and Verification
- Audit and Maintenance Schedule
- Firmware Updates
- Hardware Improvements

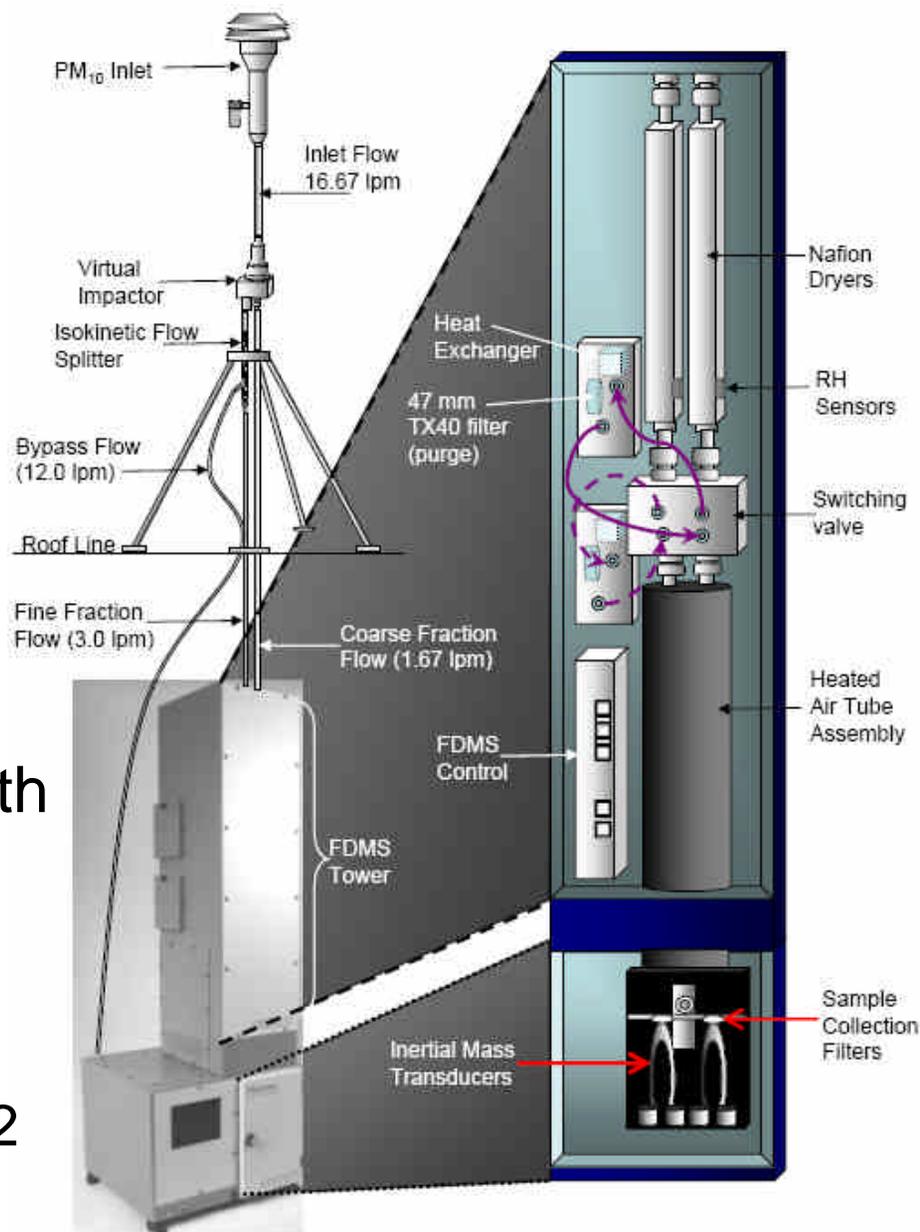
# Introduction to the TEOM 1400ab with 8500C FDMS

- Based on Established TEOM Mass Measurement Technology
- FDMS Allows Monitor to Account for Non-volatile and Semi-Volatile PM
- Update to 8500B version FDMS
- Can be Added to Existing TEOM 1400ab Monitors
- Firmware Version 3.50 Required for FEM Reporting
  - Automatically reports FEM PM<sub>2.5</sub> Mass Concentrations
  - 1-hour, 8-hour, and 24-hour averages
- FEM PM<sub>2.5</sub> Designation: EQPM-0609-181



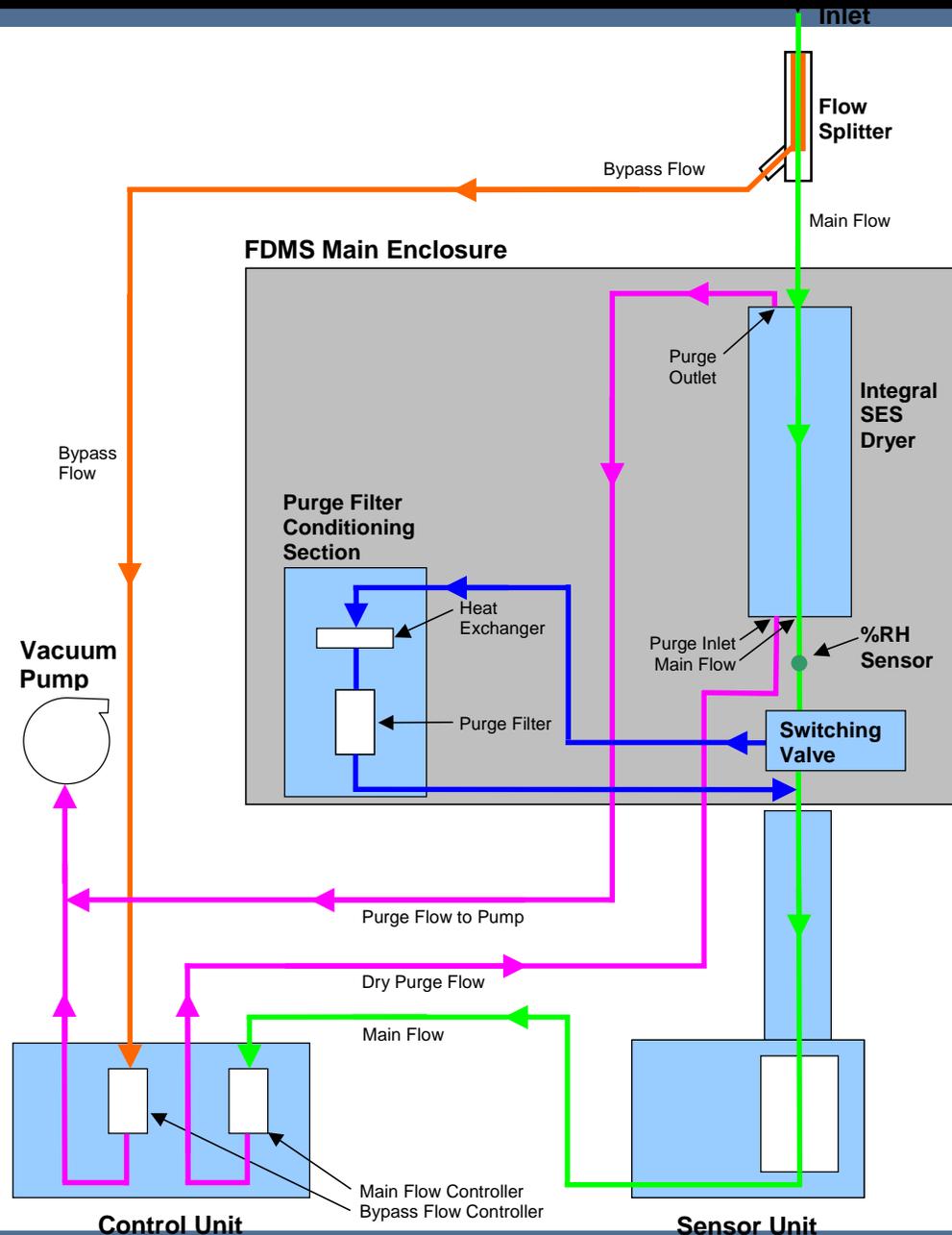
# The TEOM 1405-DF Dichotomous Monitor with FDMS

- Virtual Impactor Separates Fine and Coarse Fractions
- Dual Mass Transducers Provide Simultaneous  $PM_{2.5}$ ,  $PM_{coarse}$ , and  $PM_{10}$  Measurements
- FDMS Allows Monitor to Account for Semi-Volatile PM on Both Fine and Coarse Samples
- User Friendly Instrument Interface with Touch Screen Display
- Firmware Version 1.51 (or Later) Required for FEM Reporting
- FEM  $PM_{2.5}$  Designation: EQPM-0609-182



# Filter Dynamics Measurements System (FDMS)

- Switching valve alternates the sample between Base and Reference Channels every 6 minutes.
- The Reference Filter is maintained at 4 °C to provide a time-integrated sample that can be used for subsequent laboratory analysis.
- Provides Measurement of non-volatile and semi-volatile PM concentrations



# Installation Guidelines

- Enclosure Temperature from 8-25C
- Minimize Rapid Temperature Fluctuations in Sampling Enclosure
- Minimize Exposure to Air Conditioner Drafts
- Ensure Proper Sample Tube Alignment
- Ensure Proper Clearance at top and sides for access
- Mount Pump with Sufficient Tubing to Minimize Pump Pulsations



# Operating Parameters (For FEM PM<sub>2.5</sub>)

- Instrument Temperatures: Case, Cap, Air Tube at 30C
- FDMS Chiller at 4C (10C under Hot Humid Conditions)
- Instrument Flow Control Set to Active Control
- Instrument Data Reporting Set to Actual Conditions
- TEOM 1405-DF Flow Rates
  - PM<sub>2.5</sub> Sample Flow: 3 L/min
  - PM<sub>coarse</sub> Flow: 1.67 L/min
  - Bypass Flow: 12 L/min
- TEOM 1400ab with 8500C Flow Rates
  - Main Flow: 3 L/min
  - Bypass Flow; 13.67 L/min

# Calibration, Audits and Verification

- All Audit and Calibrations are Performed using Software “Wizards”
- Wizards Step Operator Through Procedures - The manual is built into the instrument
  
- Initial Installation Checks
  - Flow Calibration
  - Ambient Temperature and Pressure Sensor Calibration
  - Leak Checks
- Flow Audits
- Initial K0 Audit

# Audit and Maintenance

- Flow Audits: Monthly
- Leak Checks: Monthly
- Replace TEOM and FDMS Filters: Monthly (or as necessary)
- Clean FDMS Valve: Annually
- Dryer Maintenance: Annually (Can be provided by Thermo)
- Sample Pump Vacuum Requirement: 20 in Hg vacuum or 0.33 atm pump pressure. Rebuild or replace as required.

# TEOM 1405-DF Firmware Version 1.51

- PM<sub>2.5</sub> FEM Calculation Display in Addition to TEOM PM2.5 MC
- Firmware enhancements to improve performance & reliability
- Added Functionality to Leak Check
  - Base & Reference valve positions are now included in the leak check routine
- Added User Storage Ordering (ePort 1.40 Required for Download)
- Added Status Flag for Low Pump Vacuum
- Added USB firmware update procedure. Requires New Flash Card

# 1405 DF PM2.5 FEM Display

**TEOM 1405-DF**

Thermo SCIENTIFIC

TEOM Data

	PM <sub>2.5</sub>	FEM PM <sub>2.5</sub>	PM <sub>c</sub>	PM <sub>10</sub>
MC (µg/m³):	0.00	0.00	0.00	0.00
30-Min MC (µg/m³):	0.00	0.00	0.00	0.00
1-Hr MC (µg/m³):	0.00	0.00	0.00	0.00
8-Hr MC (µg/m³):	0.00	0.00	0.00	0.00
12-Hr MC (µg/m³):	0.00	0.00	0.00	0.00
24-Hr MC (µg/m³):	0.00	0.00	0.00	0.00

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Filter loading:	22.26 %	9.80 %
Frequency:	263.7265 Hz	250.5211 Hz
Noise:	0.000 µg	0.000 µg

Stabilizing Normal status 08/23/2009 12:12

# 1405 F/DF Leak Check Valve Selection Screen

**Select TEOM**

The wizard will verify each TEOM independently

The following control allows you to specify the FDMS valve position to use in the leak check. When you leave this page, the instrument will be restored to it's previous state.

Current valve position:

Reference

Please select which TEOM for which you'd like to run the Leak Check on and select Next.

Verify Base Leak Check

Verify Reference Leak Check

< Back      Next >      Cancel

# 1405 F/DF Leak Check Results Screen

**Complete Leak Check Wizard**

The Leak check was unsuccessful (Reference failed). Replace the TEOM filter(s) in the mass transducer now.

position:		Base	zero	Reference	zero
PM-2.5 flow:	actual:	00,02	00,03	00,89	00,03
	limit :	00,15		00,15	
PM-Coarse flow:	actual:	00,00	00,00	00,00	00,00
	limit :	00,15		00,15	
bypass flow	actual:	00,00	00,01	00,00	00,01
	limit :	00,60		00,60	

The instrument will be put in Run mode when this wizard is finished.

To close this wizard, press Finish.

< Back      Finish      Cancel

# 1405 Data Storage Selection Ordering

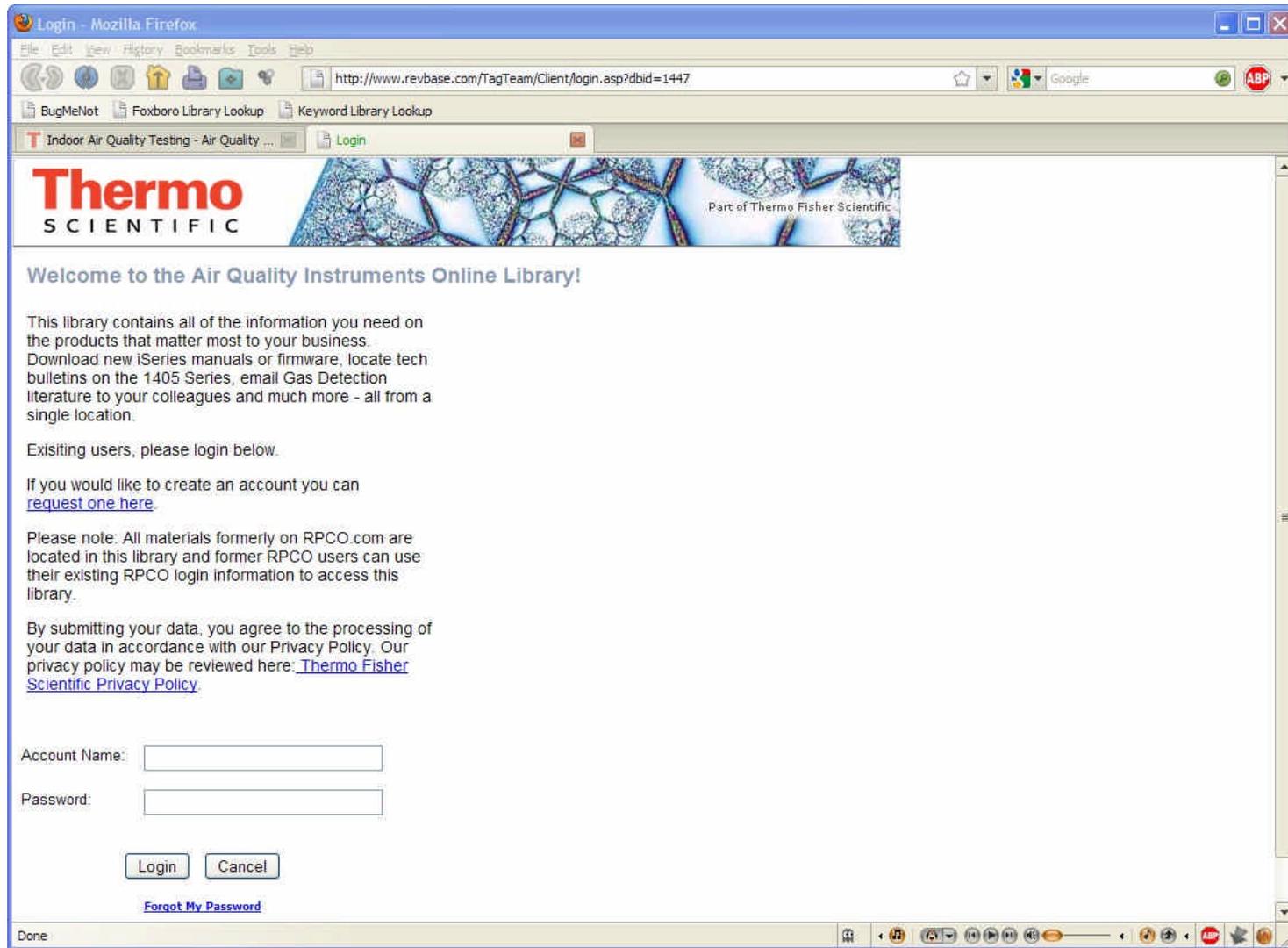
The screenshot shows a software window titled "TEOM 1405-DF" with the Thermo Scientific logo. The window is titled "Settings->Data Storage" and contains the following elements:

- Header:** "TEOM 1405-DF" and "Thermo SCIENTIFIC" logo.
- Section:** "Settings->Data Storage".
- Instruction:** "Instrument variables to store. You can change order of variables by clicking on the field and dragging it up or down using the arrow buttons on the right."
- Variable List:** A list of three variables: "PM-Coarse reference MC", "Ambient temperature", and "Ambient relative humidity".
- Ordering:** The "Ambient relative humidity" variable is highlighted in blue, and the "v" arrow button below it is also highlighted, indicating it is selected for reordering.
- Buttons:** An "Edit List" button is located to the right of the variable list. A "< Back" button is located below the storage interval.
- Storage Interval:** A box displays "Storage interval: 3600 seconds".
- Status Bar:** At the bottom, there is a status bar with a checkmark icon, "Stabilizing", "Normal status", a lock icon, and the date/time "08/27/2009 16:29".

# Planned Firmware Enhancements

- Touch Screen Calibration
- Time Synchronization
- RH Sensor Calibration
- Ability to Calculate Actual ( $PM_{2.5}$ ,  $PM_{coarse}$ ) & Standard ( $PM_{10}$ ) Concentrations Simultaneously

# Firmware Updates Available on Thermo Online Library



<http://www.thermo.com/aqi>