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SOP – DRAFT -

RUPPRECHT & PATASHNICK SERIES 1400a TEOM PM2.5 MONITOR

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RUPPRECHT & PATASHNICK SERIES 1400a TEOM PM25 MONITOR

1. PURPOSE AND APPLICABILITY

This OP contains the protocol for performing measurements of the fine particle mass concentration (<2.5 μm in diameter) in ambient air for the Baltimore PM supersite study using the Rupprecht and Patashnick (R&P) Series 1400a Tapered Element Oscillating Microbalance (TEOM). This procedure is intended to supplement the R&P 1400a TEOM manual. It is recommended that the manual be used in conjunction with this document during installation, operation or calibration

2. DEFINITIONS

TEOM tapered element oscillation microbalance
Gillibrator: soap-bubble flow meter
SOP: standard operating procedure

3. REFERENCES

Rupprecht and Patashnick Co., Inc. (May, 1996, Revision B). TEOM Series 1400a Ambient particulate (PM-10) Monitor (AB Serial Number) Operating Manual R&P Part Number 42-003347. Rupprecht and Patashnick Co. Inc. 25 Corporate Circle, Albany, NY 12203.

State of California Air Resources Board, (Monitoring and Laboratory Division, January 1995). Quality Assurance Volume II Standard Operating Procedure for Air Quality Monitoring, appendix Z, Rupprecht & Patashnick Series 1400a TEOM PM10 Monitor, State of California Air Resources Board 2020 L Street, Sacramento, CA 49331.

STANDARD OPERATING PROCEDURES FOR RUPPRECHT & PATASHNICK SERIES 1400a TEOM PM10 MONITOR FOR FRESNO SUPERSITE, Draft Prepared by: DESERT RESEARCH INSTITUTE ATMOSPHERIC SCIENCES CENTER ENVIRONMENTAL ANALYSIS FACILITY

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4. DISCUSSION

4.1 Principles and Applicability

This procedure describes the operation of the Rupprecht and Patashnick (R&P) Series 1400a Tapered Element Oscillating Microbalance (TEOM). This procedure is intended to supplement the R&P 1400a TEOM manual. It is recommended that the manual be used in conjunction with this document during installation, operation or calibration.

4.2 Summary of Method

The TEOM product is designated as an equivalent method for the determination of 24 hour average $PM_{2.5}$ concentrations. The TEOM continuously monitors $PM_{2.5}$ levels by capturing particulates on a sample filter attached to a vibrating inertial mass transducer. The rate of mass accumulation on the filter and the flowrate through the sample (main) flow controller, the TEOM's microprocessor calculates the mass concentrations. The flowrate through the sample filter is set at a nominal 3.0 liters per minute (LPM). A bypass (auxiliary) flow is used to provide an additional 13.67 LPM for a total flowrate of 16.67 LPM (design flowrate of the size selective inlet). Additional information of the operation of the TEOM is provided in Section 1 of the manual.

Units with the serial number containing "AB" designation include, but not limited to, redesign of the mass transducer, new layout of the control unit, inclusion of temperature and pressure sensors and use of R&P designed mass flow controllers.

Table 4-1 provides the range, accuracy, and resolution for the TEOM 1400a.

Parameter	Value
Flowrate Range	5 LPM to 25 LPM (environmental conditions at 16.67 LPM, only)
Flowrate Accuracy	2%
Flowrate Resolution	0.01 LPM
Flowrate Stability	Coefficient of Variation: less than 2%
Barometer Accuracy	10 millimeters (mm) Mercury (Hg)
Barometer Resolution	1 mm Hg
Pressure Sensor (meter differential) Accuracy	10 mm Hg
Pressure Sensor (meter differential) Resolution	1 mm Hg
Filter Temperature Sensor Accuracy	2 Degree Centigrade C
Filter Temperature Sensor Resolution	0.1 Deg C
Measurements (ambient, active filter, inactive	Maximum error: 2 Deg C Resolution: 0.1 Deg C

filter and meter)	Ambient inaccuracy due to solar radiation: less than 1.6 Deg C at windspeed of 2 m/s

4.3 Health and Safety Warnings

The TEOM 1400a instrument manual should be carefully reviewed prior to installation, operation, and maintenance of the TEOM 1400a. All health and safety procedures described in the instrument manual should be strictly adhered to by anyone operating the instrument. High voltages may be present in all instrument enclosures. The operator should also review and adhere to any applicable Federal, State, or District agency safety regulations.

4.4 Cautions

The TEOM 1400a instrument manual should be carefully reviewed prior to installation, operation, and maintenance of the TEOM 1400a. All cautionary procedures described in the instrument manual should be strictly adhered to by anyone operating the instrument. Only appropriately trained personnel should operate the instrument.

4.5 Measurement Interferences

1) Operating Temperatures: The default operating temperatures for the TEOM 1400a is 50 degrees Centigrade (Deg C). However, R&P recommends a 30 deg C operating temperature for sampling locations with a high ambient volatile content. The higher operating temperature may result in less than ambient levels of volatiles aerosol actually being collected on the sample filter. To maintain the equivalency designation, EPA has required that the use of the low temperature is limited to the winter months, when temperatures exceed 25 deg C only 5% of the time and to monitoring locations where prevalent PM_{10} aerosols has or is expected to have a significant contribution of volatile or semi-volatile components. A special request must be submitted and accepted by EPA to operate the unit at the lower temperature.

2) Excessive Dirt in the $PM_{2.5}$ Inlet: The $PM_{2.5}$ inlet must remain free of significant particulate loading to ensure a correct particulate cut-point. The manual recommends that the inlet is cleaned immediately after a new TEOM filter is installed (see Appendix F of the manual). This allows for the cleaning procedure to be performed during the half-hour flow and temperature stabilization period following instrument reset (see Section 4 of the manual).

3) Air Inlet System: The air inlet must remain free of excessive build-up of particulates on its inner walls, as this can effect the particulate mass collected on the filter. Section 7.5 of the manual describes the air inlet cleaning procedure.

4) System Leaks: The TEOM only provides accurate mass concentration measurements if there are no leaks in the flow handling system. Section 7.6 of the manual describes leak check procedures.

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5. Responsibilities

NA

6. Equipment and materials

6.1 Equipment

6.1.1 TEOM

7 TEOM Sensor unit S/N
8 TEOM control unit S/N
9 PM2.5 inlet S/N
10 Spare parts

6.1.2 Data acquisition

Section 4 of the manual describes the TEOM system operations and data storage. Appendices A and B of the manual provide information about the program variables and instrument screens, respectively. The TEOM monitor gives the user full control over its operations directly from the keypad. It menu driven software can be used to monitor a variety of system parameter, including but not limited to viewing systems data on the four-line display, changing instrument operating parameters, determining when to change filter cartridges and how to store data in the unit's internal data logger.

The software configuration consists of setting various parameters in the software such as analog outputs, temperature, pressures and flowrates. The menu screen provides access to all instrument displays.

The storage capacity of the TEOM internal data logger depends upon the number of data fields (system variables) stored in each record. The instrument always stores time, date, and station number in each record in addition to the data fields selected by the user. The data logger uses a circular storage buffer, meaning that physical record 0 is overwritten once the end of the storage area is reached. Section 4.11 of the manual provides an approximate internal storage capacity of the data logger as 8 data fields per record, 1,753 records and 5.2 weeks time (using a storage interval of 30 minutes). Real-time information and the data stored in the circular storage buffer can be transmitted to a computer directly via the RS232 serial port, or through a modem over telephone lines to an off-site computer. Once information is received and stored by the computer, it can be analyzed using a variety of data analysis and spreadsheet software packages. Section 6 of the manual describes the TEOM 1400a serial output and two-way communication. Appendix C of the manual provides hardware configuration information for the TEOM 1400a. Appendix H describes the most commonly used procedures for interacting with the TEOM software using the RS232 port.

The TEOM 1400a monitor provides 3 user definable analog outputs, 2-user definable contact closure circuits and 7 analog inputs. Section 5 of the manual provides information on the analog inputs and outputs. Refer to this section for information on connecting the analog outputs of the TEOM to a data logger.

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6.1.3 Flow control

a) Gilian Gilibrator 2 S/N: 0044669
7Flow cell 2-30 lpm S/N: 003454-H
8Flow cell 20 cc – 6 lpm S/N: 906092-S
9Flow cell soap

6.2 Materials

7 Spare sample filter R&P part no. 57-000397-0020 (min. 10 available)
8 Large bypass filter R&P part no. 57002758 (min. 2 available)
9 Flow controller filter R&P part no. 30-003097 (min. 4 available)

6.3 Paper materials

a) Field forms to record performance parameters of TEOM in the field
7Laboratory book for TEOM

7. PROCEDURES

ALL MAINTANCE PROCEDURES MUST BE RECORDED IN THE FIELD FORM

7.1 Every second day maintenance of TEOM

a) Record the TEOM front panel status conditions.
b) Record the current mass concentration.
c) Review the previous day's data to verify correct instrument operation. Verify correct date and time.
d) Record filter loading in percentage from the TEOM display. Replace filter if loading >85%.
e) Record the Case, Air, and Cap temperatures from the TEOM display.
f) Record the front display main/auxiliary flows from the TEOM.

7.2 Biweekly maintenance of TEOM

7 Perform precision flow check on Main, Auxiliary and Total flows. Record all information on the flow check form.

A precision flow check is performed by measuring the main and total flowrates with an external flow check device and comparing these measurements to the TEOM's flowrate indicated on the instrument display. The values should differ no more than +/- 5%. If the difference exceeds +/- 5%, the cause of the exceedance should be investigated and corrected.

1. Record the TEOM main and total flows (sum of main and auxiliary flows) from the TEOM display on the precision check form.
2. Connect one end of the connector line to the flow outlet port on calibrated external flow measuring device (Gilibrator). Connect the other end of the connector line to the R & P flow adapter. Remove the inlet and install the R & P flow adapter.
3. Turn on the BIOS. Verify that the Gilibrator digital display is on.
4. Push the flow measurement button on the Gilibrator.
5. Record the indicated total flow measured by the Gilibrator in LPM.
6. Repeat step d) and e) ten times to obtain an average measured total flow. Record each of the ten readings and calculate the average total flow. Calculate and record the percent deviation between the TEOM indicated total flow and the measured total flow. The percent deviation should be +/- 5%, if it is not, investigate and correct the cause of the exceedance.
7. Remove the auxiliary flow line and cap at the flow splitter.
8. Repeat steps d), e) and f) for the main flow.
9. Reinstall inlet and auxiliary flow line.
10. Disconnect connector tubing from the Gilibrator and turn off the power.

8 Record average temperature/barometric pressure settings from TEOM display during flow check.

9 Inspect and clean the sample inlet. The frequency may need to be increased based on location.

10 Survey and record the replacement parts and expendable supplies for the TEOM. Contact the main laboratory, if only one left.

7.5 Every six month maintenance of the TEOM

a) Replace large bypass Main and Auxiliary in-line filters (replace earlier if necessary).
b) Calibrate flow controllers:

The flow controller software procedure (Section 8.2 of the R&P manual) consists of measuring the total, main, and auxiliary flowrates with a certified transfer standard and calculating the deviations from the inlet design and the TEOM's displayed and setpoint flowrates. Flowrate deviations are corrected by editing the Flow Adjust software settings for main and auxiliary flows. The R&P manual describes measuring flows at the back of the control unit with the main and auxiliary in-line filters removed. It is preferable to measure flows with the sampling train in place. Therefore, it is recommended that the flows be measured at the flow splitter inlet as described in the Flow Audit Procedure in the R&P manual. It is suggested that an external flow measuring device be used to perform the flow controller software calibration.

7 Display the Set Temps/Flows screen on the instrument by pressing "Set Temps/Flows" from the menu screen. Use appropriate keys to position the screen so that "F-Main" and "F-Aux" appears. Record the set points for the main and

auxiliary flows.

8 Bring "T-A/S" and "P-A/S" onto the screen. Record the existing settings for Average Temperature/Pressure. Set the Average Temperature/Pressure to the current local conditions at the flow meter.
9 Bring "FAdj main" and "FAdj Aux" onto the screen. Record the values.
10 Attach a reference flow meter to measure the main flow. Record the flow meter value and compare this value to the flow value recorded in step a). If a mass flow meter is being used, its readings must be adjusted for temperature/pressure to obtain volumetric flow. No adjustment is needed if the reference flow meter is a volumetric flow device. Calculate the "As Is" deviation between the flow meter value and the TEOM value.
11 If necessary, edit the "Fadjmain" value so that the flowrates indicated by the flow meter match the set point recorded as "F-Main" above. Record the new value and calculate the deviation. If a step adjustment greater than +/- 10% is needed to calibrate the mass flow controller, a hardware calibration must be performed per Section 8.4 of the R&P Manual.
12 If the system has an auxiliary flow controller, repeat step d) and e) above except attach the reference flow meter so that auxiliary flow is measured.
13 Change the Average Temperature/Pressure values back to the original values recorded in step a).
14 Perform a system leak check per Section 7.6 of the manual.
15 Perform and record a flow check of the main and auxiliary flowrates using the station flow measuring device.

7.4 Yearly maintenance of the TEOM

7Perform leak check.
8Replace flow controller filters.
9Clean air inlet system.
10Analog Calibration

This procedure consists of adjusting the analog input and output potentiometers on the TEOM's Analog Input/Output Board. Section 8.3 of the R&P manual provides analog calibration instructions. Record date of procedure.

11Mass Flow Controller Hardware Calibration

The analog calibration should be performed prior to the mass flowmeter hardware calibration. Both the analog calibration and the mass flow controller hardware calibration should be performed on at least an annual basis or if the "as is" flow deviation is found to be greater than +/- 10% during the flow controller software calibration. The hardware calibration procedure changes based on if Tylan or Brooks flow controllers are installed. Section 8.4 of the TEOM instrument manual describes procedures used to calibrate the flow controllers.

Section 8.4 of the manual described the use of a volumetric flow meter. If a non-volumetric flow meter (such as a mass flow meter) is used, it is necessary to convert the flow meter's flow to

volumetric flow using the ambient temperature/pressure.

7.5 TROUBLESHOOTING

1) **TEOM Status Condition: The status condition is a one to four character code that summarizes the operational status of the instrument, indicating whether any exception condition exists. Whenever a status code other than "OK" is shown on the display, the instrument automatically turns on the light labeled "Check Status" on the front panel of the control unit. Section 4.2.1 of the instrument manual provides the codes for the various status conditions. The status condition is used as a troubleshooting tool.**

2) **Main Flow In-Line Filter: New filter cartridges generally exhibit figures of 15 to 30% at a main flow of 3 LPM, and less at lower flow rates. Since the value is determined by the pressure drop of the main (sample) flow line, the instrument shows a non-zero value even if no filter is installed in the transducer. If filter loading is high when a new filter is placed in the mass transducer or the life of the filter becomes noticeably shorter, this usually indicates that the in-line filter in the main flow needs to be exchanged (6-month replacement frequency is recommended). The TEOM must be operated with the in-line filter in place to avoid contaminating the flow controllers.**

3) **Bypass Flow In-Line Filter: The bypass flow in-line filter should be replaced when the main flow in-line filter is replaced (6-month replacement frequency is recommended). The TEOM must be operated with the in-line filter in place to avoid contaminating the flow controllers.**

4) **Flow Controller Filters: There is a filter attached to each mass flow controller to provide particle-free air supply to the flow regulation hardware and are essential for long term instrument operation (1 year replacement recommended).**

5) **Particulate Build-Up in the Air Inlet System: Particulates will build up inside the inner walls of the air inlet system and must be cleaned on a periodic basis.**

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8. ANALYTICAL PROCEDURES

8.1 Averaging of hourly and daily mean mass concentrations

Hourly average concentrations are calculated if at least 66% of the valid data for one hour are available. Daily average number concentrations are valid, if at least 16 hourly averages are available for one day.
Daily means will be provided for time intervals from midnight to midnight.

The following equations are used to perform the TEOM biweekly flow check. The TEOM displays flow in LPM (volumetric flow). If flows are measured with a mass flow meter, the mass flow meter units of SLPM must be converted to LPM using the ambient temperature/pressure present at the mass flow meter.

$$LPM = \frac{760\ mmHg}{Pa\ mmHg} \times \frac{T_a + 273\ C}{298\ C} \times SLPM$$

$$\%\ Dev = \frac{TEOM\ indic.\ flowrate\ (LPM) - Meas.\ flowrate\ (LPM)}{Meas.\ Flowrate\ (LPM)} \times 100$$

The following equations are used to perform TEOM software calibration:

$$T/P\ Correction\ Factor = \frac{760\ mmHg}{Pa\ mmHg} \times \frac{T_a + 273\ C}{298\ C}$$

$$Q_a = T/P\ Corr\ factor \times Q_{std}$$

$$\%\ Dev\ (tf) = \frac{Q_a - 16.67\ LPM}{16.67\ LPM} \times 100$$

$$\%\ Dev\ (ts) = \frac{Main/Aux - Q_a}{Q_a} \times 100$$

$$Q_{std}\ (calc) = Setpt \times \frac{P_{avg}}{1.0\ atm} \times \frac{298\ C}{T_{avg} + 273\ C}$$

$$\%\ Dev\ (calc) = \frac{Q_{std}\ (calc) - Q_{std}}{Q_{std}} \times 100$$

where

Pa = Outdoor Ambient Pressure
Ta = Outdoor Ambient Temperature
Qa = Volumetric Flow (LPM)
Qstd = Standard Flow (SLPM)

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SetPt = Flowrate Setpoint
%Dev (tf) = % Dev from 16.67 (total flow)
%Dev (ts) = % Dev from Transfer Std
Main/Aux = Main or Auxiliary Displayed Flow
%Dev (ts) = % Dev from Transfer Std
Qstd (calc) = Calculated Main Flow (SLPM)
Pavg = Aver. Press. Setting
Tavg = Aver. Temp. Setting
%Dev (calc) = % Dev from Transfer Std

Sample field form:

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PROJECT:	SITE OPERATOR NAME:
CALIBRATED BY:	SITE TEMPERATURE (ta) (DEG CENT.):
SITE NAME:	SITE BAROMETER READING (pa) (mm Hg):
SITE ELEVATION:	

SITE FLOW DEVICE MFG	RANGE	READINGS IN Qstd or Qa	SERIAL #	CAL DATE	SLOPE	INTERCEPT	CORR.

FORMULAS:

T/P CORR FACTOR = $\frac{760\text{mmHg}}{Pa\ \text{mmHg}} * \frac{Ta + 273\ C}{298\ C}$

Where:

Pa = Ambient Pressure

Ta = Ambient Temperature

Qa = Volumteric Flow (lpm)

Qstd = Flow Device Standard Flow (slpm)

%Dev(tf) = % Dev from 16.67 (total flow)

%Dev(ts) = % Dev from Flow Check device

Main/Aux = TEOM Displayed Main or Aux flow

Qa = T/P Corr factor * Qstd

$\%Dev.(tf) = \frac{Qa - 16.67\ lpm}{16.67\ lpm} * 100$

$\%Dev.(ts) = \frac{Main/Aux - Qa}{Qa} * 100$

TEOM 1400a Serial #:

	BOTH	MAIN FLOW	AUX FLOW	COMMENTS:
Aver. Temp. Setting				
Avg. Pressure Setting				

	TOTAL FLOW		**MAIN FLOW**			**AUXILIARY FLOW**			
DATE	SITE FLOW CHECK DEVICE READING (Qa)	% DIFFERENCE FROM 16.67 LPM (tf) (< 5.0%)	TEOM INDICATED FLOW LPM	SITE FLOW CHECK DEVICE READING (Qa)	% DIFFERENCE FROM FLOW CHECK (ts) DEVICE (< 10.0%)	TEOM INDICATED FLOW LPM	SITE FLOW CHECK DEVICE READING (Qa)	% DIFFERENCE FROM FLOW CHECK (ts) DEVICE (< 10.0%)	ADD TEOM MAIN & AUX INDICATED FLOWS (COMPARE TO TOTAL MEAS. FLOW Qa)