WBEA – Standard Operating Procedure

SOP Title	**Procedures for operating continuous R&P TEOM PM_{10} and $PM_{2.5}$ Analyzers**
SOP Number	**WBEA SOP-PAR-001**
Author	
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Revision History

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Introduction and Background

This document is intended to be used as a reference for use in the calibration, maintenance and operation of continuous analysis of particulate matter in ambient air. The proper utilization of this procedure in conjunction with the operators manual will conform to the current Alberta Air Monitoring Directive (AMD) and enable the data to be included in provincial and national air quality data bases

The Tapered Element Oscillating Microbalance (TEOM) provides real time mass measurement of selected size particles in ambient air samples. This instrument is used in national and local air monitoring networks to provide continuous data on the mass concentrations of particulate matter (PM) of 10µm aerodynamic diameter and less (PM_{10}) or 2.5µm aerodynamic diameter and less ($PM_{2.5}$) in ground level ambient air.

Principle of the Method

This method is a continuous mass measurement of PM present in ambient air. Air is drawn through a size-selective inlet at the rate of 16.7 lpm. The air sample is split with 13.7 lpm discarded and the remaining 3 lpm is directed down onto a sample filter. The sample filter is attached to a hollow, tapered glass tube through which the air is drawn. The tapered tube is maintained in a fixed amplitude oscillating motion. When particles are deposited and accumulated on this sample filter, the oscillating frequency of the tapered tube/filter system changes due to the mass increase of the filter. The oscillating frequency is measured by an electronic counter. A direct analytical relation between the mass of the tube/filter system and its oscillation frequency is calculated by solving the equation of motion for the oscillator system. This calculation is done by the instrument every 2 seconds. Therefore the mass of particles collected on the filter is continuously measured. Typical averaging periods for the instrument are 5 minutes, 10 minutes, half-hour, one hour, and 24-hours.

Measurement Range and Sensitivity

The manufacturer states that the minimum detectable limit for the mass transducer is 0.01 µg. R&P, the TEOM manufacturer, further states that the microbalance mechanism has an operational range of up to five grams per cubic meter. Typical full range settings are -50 to 450 ug/m^3.

Equipment and Apparatus

The following models are used in this method.

- Rupprecht & Patashnick (R&P) TEOM Series 1400/1400a including serial number prefixes 1400, 140A, 140AA, 140AB, 140AT, and 140UP.
- R&P TEOM 1400a including serial number prefixes 140AB, 140AT, and 140UP used with Sample Equilibrium Systems (SES).
- R&P TEOM 1400a including serial number prefixes 140AB used with the Filter Dynamics Measurement System (FDMS).

Interferences

The R&P TEOM is susceptible to several types of interference. Its overall design has two mechanical potential sources of error. The cyclone impactor head and sample tube may become encrusted with dust and particulate which may later become free and cause erroneous instantaneous readings. The tubing may also become susceptible to leaks which can affect the overall performance and invalidate the calculations. Other sources of error include volatile compounds which can sublimate on the filter causing negative bias.

Precision and Accuracy

The measurement precision is generally considered to be the "repeatability of the measurement". Precision of the data output by the analyzer is established by the manufacturer, but confirmed during daily and monthly maintenance, KO factor verification and flow audits.

The accuracy of the sensor is generally considered the "deviation from true". This means how close it is to what it should be. The benchmark of "what it should be" is provided by the Alberta Environment Audit Program staff and the use of high quality transfer standards such as available from the National Institute of Standards and Technology (NIST). The manufacturer states that in mass determination, at a flow rate of 3 lpm, the instrument has a precision of ±1.5 µg/m^3 (1-hour average) and ±0.5 µg/m^3 (24-hour average).

Site Requirements

Site location of the particulate monitoring station in urban, industrial and rural areas should be determined according to the intended application of the monitoring data. Detailed requirements for selection of sites for monitoring PM_{10} and $PM_{2.5}$ for the Canada Wide Standard (CWS) determination can be found in "Guidance Document on Achievement Determination-Canada Wide Standards for Particulate Matter and Ozone section 3.0. Requirements for the immediate surroundings of the site can be found in the Station Site Criteria section of the AMD.

Installation Requirements

The installation procedures of the TEOM are detailed in the R&P Operating Manual. All the steps outlined therein must be followed closely. In particular, attention should be given to locating the system so as to minimize potential rapid fluctuations in room temperature. In addition, the system should be installed so as to minimize physical vibration.

Probe Location Criteria

The location of the TEOM inlet must conform to the probe location criteria below:

- Height above ground 2 to 15 meters.
- Distance from support structure > 1 meter.

- Distance from trees — > 20 meters or twice the height of tree above the inlet whichever is greater.
- Distance from obstacle — 2×height of obstacle above the inlet.
- Airflow Restrictions — unrestricted in at least 3 of the 4 wind quadrants.
- Local Source Influences — Local source influences must be considered in locating the site for ambient PM10 or PM2.5 monitoring.

Mechanical Vibration

The operating principle of the instrument is based on the changing vibrating frequency of the sensor of the instrument. Extraneous mechanical vibration interferes strongly with the measurement capability of the instrument. Usually this problem manifests itself in the form of high noise level or unusually large fluctuations in mass concentration.

Temperature Stability

Temperature fluctuations in the air sample should not influence the performance of the instrument. However if the sensor and control units are placed in close proximity to air conditioning units and/or heating sources, the temperature control of the instrument may not be able to compensate rapidly enough to maintain the temperature stability of the sensor unit. The flow sensor in the control unit may also be affected by rapid fluctuations in temperature. These problems may be manifested as noise or baseline drifts in the data output.

Electric Power Supply

The electrical line voltage to the instrument can influence its performance. Variations in the vacuum pump speed can create feedback problems with the flow controller and hence the stability in the output of the instrument. This problem is often encountered in remote sites where power supply frequency, voltage and spikes may fluctuate significantly.

Exterior Enclosures

Where the site does not allow a straight intake from the sampling inlet to the sensor unit, an exterior installation must be considered. This would involve the installation of a temperature-controlled enclosure with heating and cooling capabilities to house the control and sensor modules and the pump. The outdoor enclosure must maintain the instrument temperature within the range of 2 to 25°C and it should be insulated to reduce the effect of rapid ambient temperature changes. A flat roof or surface would be required to mount such an enclosure.

Operating Parameters and Instrument Configuration

The operating parameters of the TEOM in the AENV network are specified in Table 1 below.

Table 1. Operating Parameters for the TEOM

Parameter	Configuration / Setting	Application
Inlet Design	PM10	PM10
	Modified PM10 + PM2.5 Sharp Cut Cyclone	PM2.5
Case Temperature	40°C	Standard TEOM
(Tcase)	30°C	TEOM w/ SES or FDMS
Air Temperature	40°C	Standard TEOM
(Tair)	30°C	TEOM w/ SES or FDMS
Cap Temperature	40°C	Standard TEOM
(Tcap)	30°C	TEOM w/ SES or FDMS
Scaling Factor A	3.0	PM10
	0	PM2.5
Scaling Factor B	1.03	PM10
	1	PM2.5
Averaging Temperature	Automatic (99)	All TEOMs
Averaging Pressure	Automatic (9)	All TEOMs
Standard Temperature	25°C	All TEOMs
Standard Pressure	1 atm	All TEOMs
Waiting Time	1800 sec	All TEOMs
Averaging Time (MC/MR ave)	300 sec	All TEOMs
Averaging Time	300 sec	All TEOMs

(TM ave)

Main Flow Rate	3.0 lpm	All TEOMs
Aux. Flow Rate	13.67 lpm	All TEOMs

All operating parameters must be documented in the station log book, or electronic log book and updated as needed. A copy of this documentation should be kept on file. The following is a list of these parameters and typical settings.

- Sensor unit Calibration Factor (Instrument Specific)
- Offset for PM2.5 monitoring
- Data Multiplication Factor for PM2.5 monitoring
- Version of Operating Software
- Temperature of Mass Transducer
- Temperature of Air at Base of Heated Inlet
- Temperature of top of Mass Sensor
- Volumetric Flow through Filter/Mass Sensor
- Volumetric Flow through Bypass
- Setting For Ambient Volumetric Flow Control/ Standard Temperature at which Mass Concentrations are reported
- Setting For Ambient Volumetric Flow Control/Standard Pressure at which Mass Concentrations are reported
- Main Flow Controller Software Adjustment (Maximum Adjustment of ±10%)
- Bypass Flow Controller Software Adjustment (Maximum Adjustment of ±10%)

Operational and Maintenance Requirements

The following activities must be performed when operating a continuous TEOM monitor in Alberta. The maintenance schedules such as filter change and cyclone inlet cleaning are for a typical site. There are sites with heavy PM concentrations that require more frequent service and an alternate schedule must be used. All operational activities conducted at any ambient monitoring station, must be documented in the station logbook, and/or station checklists. This allows other operators to access a history of the station if the regular technician is not available. The following documentation must be available to the operators on site: operational and maintenance manual(s), quality system manual and station site documentation.

Operational Checks

The analyzer monitors and displays test functions in order for the operator to monitor the performance of specific systems within the analyzer. These test parameters should be monitored during a site visit and recorded on a site/instrument audit or calibration form.

System Leak Check

The system leak check should be completed every month following the manufacturer's instructions laid out in the operations manual. Both the primary and auxiliary lines should be checked. This is done to ensure that air is being pulled through the sample inlet only.

Sample Filter Change

The sample filter loading is monitored within the TEOM system. This displays a percent load, 100% being a fully loaded filter. The rate of filter loading depends on the site and the particulate concentrations observed there. For heavy particulate sites the filter will have to be changed more frequently. Typically once the filter load reaches 50% ($PM_{2.5}$ AB models and FDMS) the filter should be changed. At a minimum the sample filter must be changed monthly. Use care when replacing filters as the tapered element is fragile. Follow the manufacturer's instructions in the operations manual to complete the filter change.

In Line Filter Change

On both the main flow and bypass flow lines, particulate filters are installed. These are to prevent particulates from reaching the mass flow controllers that measure and control both flows. Preventing particulate from reaching these controllers extends their operating life. These inline filters should be changed at least twice per year, again, the schedule depends on the amount of particulate observed at the site.

Inlet Head Cleaning

The sample fractioning head must be kept clean on a regular basis to avoid poor cut points as described in interferences. If the system is set up to monitor $PM_{2.5}$, both heads must be cleaned. Clean the heads as per the instructions found in the operations manual. They must be dismantled and cleaned with water only. To dry, blow clean dry compressed air on the wetted surfaces to avoid any contamination. The frequency of inlet head cleaning must be at least monthly or every filter change, whichever is the shorter period of time.

Sample Tube Cleaning

Other components of the inlet system, mainly the main sample tubes, need to be cleaned on a periodic basis as well. Fine particulates will build up on the walls of these tubes and potentially cause erroneous

readings. This procedure should be completed once per year or as per manufacturer if recommended frequency is less than one year. Follow the instructions in the manufacturer's operations manual.

KO Verification

The KO verification is completed to verify the response of the TEOM monitor. This process determines the TEOMs response with a filter of known weight installed. Similar to a span check on a continuous analyzer, the known value is compared to the observed response. The output can then be adjusted if required. This process should be completed at least once per quarter and according to the manufacturer's instructions in the operations manual.

Flow Controller Filter

Older Model TEOMs use filters built into the flow controller. Follow the manufacturer's instructions on checking and changing the flow controller filters.

Pump Overhaul

The vacuum pump needs to be rebuilt on a periodic basis in order to maintain the required vacuum for proper operation of the monitor. This procedure should be completed at least once per year, or more frequently as required.

Calibration Requirement

To maintain the accuracy of the TEOM within acceptable limits, the following calibration schedule is recommended.

- Flow controllers calibration (software) at **6 month intervals**.
- Ambient and Pressure sensors calibration at **6 month intervals**.
- Mass calibration verification (Ko) at **3 month intervals**.
- Analog calibration at **upon installation and following repair**

This calibration schedule may be accelerated for specific sites depending on the particulate matter concentration characteristics of the site. A flow standard with up to date certification by Environment Canada should be used for calibrating flow controllers.

Data Collection and Management

The analog output of the R&P TEOM PM_{10} and $PM_{2.5}$ monitor is typically wired to the analog input channels of the station Campbell's Scientific CR3000 Micro Logger. This data recorded at 5 minute intervals and is then polled remotely via cellular modem. It is a best practice to down load all the data filed into a separate storage device monthly to ensure data is backed up.

Reference Documents

- Operating Manual, TEOM Series 1400a, Ambient Particulate (PM-10) Monitor, (AB serial numbers), revision B, R&P Part Number 42-003347, March 2002
- Environmental Technology Report, ETV Advanced Monitoring Systems Centre, Rupprecht & Patashnick Co., Series 1400a TEOM Particle Monitor, Kenneth Cowen et al. Batelle, Columbus, August 2001
- Environmental Technology Report, ETV Advanced Monitoring Systems Centre, Rupprecht & Patashnick Co., Series 1400a TEOM Particle Monitor with Sample Equilibration System, Kenneth Cowen et al. Batelle, Columbus, August 2001.
- Canada Wide Standard (CWS) “Guidance Document on Achievement Determination-Canada Wide Standards for Particulate Matter and Ozone” 2000 and 2007 Amendments