Australian/New Zealand Standard™

AS/NZS 3580.9.16:2016

Methods for sampling and analysis of ambient air

Method 9.16: Determination of suspended particulate matter—PM_{10} continuous direct mass method using a tapered element oscillating microbalance monitor incorporating a filter dynamic measurement system (FDMS) unit

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EV-007, Methods for Examination of Air.

The objective of this Standard is to provide regulatory and testing bodies with a standard method for continuously monitoring suspended particulate matter changes of particles less than 10 micrometres in diameter (PM_{10}) in ambient air, providing near real time measurement of average particle concentration.

The requirements for instruments found to be suitable for using this method are given in the United States Environmental Protection Agency (US EPA) Title 40, Part 53 of the Code of Federal Regulations (40 CFR Part 53)—*Ambient Air Monitoring Reference and Equivalent Methods, Subpart D—Procedures for Testing Performance Characteristics of Methods for* PM_{10}. Elements of this Standard have been drawn from the September 2009 document *Standard Operating Procedure for the Continuous Measurement of Particulate Matter, Thermo Scientific TEOM® 1405-DF Dichotomous Ambient Particulate Monitor with FDMS®, Federal Equivalent Method EQPM-0609-182 for* $PM_{2.5}$.

FOREWORD

This Standard sets out the operational requirements for the continuous determination of PM_{10} in ambient air using a tapered element oscillating microbalance (TEOM) monitor incorporating a filter dynamic measurement system (FDMS) unit. The FDMS unit provides a representative determination of the particulate matter mass concentration as it exists in the ambient air by accounting for both non-volatile and volatile particulate matter components.

The TEOM monitor offers continuous operation, providing near real-time measurements for assessment and study of the temporal changes in ambient suspended particulate matter.

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To minimize the contribution of liquid water to measured particle mass, TEOM monitors operating without FDMS units typically condition the incoming sample aerosol to 50°C prior to and during its measurement to provide constant sampling conditions. These conditions can result in loss of volatile and semi-volatile particulate species. At sampling locations with a high proportion of volatile and semi-volatile particulate species, the correlation between measurements using a time-integrated non-FDMS TEOM monitor (AS 3580.9.8, *Methods for sampling and analysis of ambient air*, Method 9.8: *Determination of suspended particulate matter—PM_{10} continuous direct mass method using a tapered element oscillating microbalance analyser*) and a co-located manual gravimetric filter method (e.g. AS/NZS 3580.9.9, *Methods for sampling and analysis of ambient air*, Method 9.9: *Determination of suspended particulate matter—PM_{10} low volume sampler—Gravimetric method*) may vary.

The FDMS unit utilizes a diffusion dryer to lower the sample stream relative humidity, allowing sample aerosol conditioning at a lower temperature (typically 30°C). In addition, the FDMS unit alternately directs the sample flow either to the sample collection filter (the base cycle) or through a separate purge filter typically maintained at 4°C prior to passing through the sample collection filter (the reference cycle). Measurements obtained during the reference cycle provide an estimate of the volatile losses that occur during sampling of particle-laden air, and are used to derive an ambient particle mass concentration that accounts for volatile component losses that occur during sampling.

Suspended particulate matter measured by this method includes particles with an equivalent aerodynamic diameter (EAD) of less than 10 µm, as passed by a size selective inlet (PM_{10}). PM_{10} may affect human health end points, including daily mortality, hospital admissions and exacerbation of asthma, and visibility due to their light scattering properties. PM_{10} emission sources include industrial processes, combustion of fuels, burning of vegetation, incineration and natural causes, such as windblown dust and salt-laden air. Important anthropogenic sources include domestic wood heaters and motor vehicles (especially diesel fuelled vehicles).

METHOD

1 SCOPE

This Standard sets out a method for the continuous determination of PM_{10} particulate matter in ambient air using a tapered element oscillating microbalance (TEOM) monitor incorporating a filter dynamic measurement system (FDMS) unit. The method can provide a measure of average particle concentration over periods from 1 hour to 24 hours. The rolling 1-hour average is updated every 6 minutes, whereas the rolling 24-hour average mass concentration is updated every 60 minutes on the hour. Results are normally reported as 24-hour, time-integrated average values.

This Standard covers the measurement of PM_{10} concentrations using the TEOM 1405-F monitor. Where measurement of PM_{10} concentrations is conducted using a TEOM 1405-DF monitor, users should refer to AS/NZS 3580.9.13.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS/NZS

3580	Methods for sampling and analysis of ambient air	
3580.1.1	Method 1.1:	Guide to siting air monitoring equipment
3580.9.13	Method 9.13:	Determination of suspended particulate matter—$PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance monitor
3580.14	Part 14:	Meteorological monitoring for ambient air quality monitoring applications

ISO/IEC

Guide 98-3 Uncertainty of measurement, Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

Environment Protection and Heritage Council
National Environment Protection (Ambient Air Quality) Measure, Technical Paper No. 5, Data Collection and Handling

US EPA
Standard Operating Procedure for the Continuous Measurement of Particulate Matter, Thermo Scientific TEOM® 1405-DF Dichotomous Ambient Particulate Monitor with FDMS®, Federal Equivalent Method EQPM-0609-181 and EQPM-0609-182 for $PM_{2.5}$. STI-905505.03-3657-SOP

Code of Federal Regulations—Title 40: Protection of Environment, Part 50, Appendix B

Code of Federal Regulations—Title 40: Protection of Environment, Part 53: Ambient Air Monitoring Reference and Equivalent Methods, Subpart D: Procedures for Testing Performance Characteristics of Methods for PM_{10}

Code of Federal Regulations—Title 40: Protection of Environment, Part 53: Ambient Air Monitoring Reference and Equivalent Methods, Subpart E: Procedures for Testing Physical (Design) and Performance Characteristics of Reference Methods and Class I and Class II Equivalent Methods for $PM_{2.5}$ or $PM_{10-2.5}$

MCERTS Product Conformity Certificate No. Sira MC130210/00 11 June 2013 (TEOM 1405F)

TUV Product Conformity Certificate No. 0000055015 (TEOM 1405F) published in the German Federal Gazette (BAnz) 02 March 2012, No. 36, p. 920, chapter IV, No. 1.1

3 DEFINITIONS

For the purpose of this Standard the definitions below apply:

3.1 Equivalent aerodynamic diameter (EAD)

The diameter of a spherical particle of density (1 g/cm^3) that exhibits the same aerodynamic behaviour as the particle in question.

3.2 PM_{10}

Suspended particulate matter consisting of particles having an EAD of less than 10 µm, which is passed by a size classifier having performance characteristics as defined in US EPA Code of Federal Regulations—Protection of Environment, 40 CFR, Part 53, Subpart D.

3.3 U_{95}

A measurement uncertainty at a confidence interval of 95% according to ISO/IEC Guide 98-3.

4 PRINCIPLE

Ambient air is drawn through a PM_{10} particle size separator at a constant flow rate of 16.7 litres per minute (L/min) as indicated in Figure 1, which shows a schematic diagram of the flow system. Below the PM_{10} particle size separator, an isokinetic flow splitter separates the total flow (16.7 L/min) into a main flow and a bypass flow stream. The main flow is adjustable and should be set at 3.0 L/min.

The main flow passes through a diffusion dryer specially designed to minimize particle loss. The dryer lowers the main flow relative humidity, making possible mass transducer operation at 5°C above monitoring station temperature (mass transducer temperature set point is usually 30°C). The dryer efficiency is monitored by a downstream humidity sensor. The dryer uses re-circulated air that has passed through the sample collection filter to avoid the need for an external source of air to remove the extracted moisture.

When the main flow exits the dryer it enters a switching valve that, every six minutes, alternately directs the main flow either to the sample filter cartridge (the base cycle) or through a separate purge filter typically maintained at 4°C (the cooler filter) prior to passing through the sample filter cartridge (the reference cycle), as shown in Figure 2.

The main flow then passes through the heated air inlet and enters the mass transducer unit, passing through an exchangeable sample filter cartridge placed at the tip of a hollow tapered element, then to the mass flow controller that maintains constant flow. The bypass flow is controlled by a separate mass flow controller set at 13.7 L/min. A single pump provides the vacuum necessary to draw the sample stream and bypass stream through the system.

The mass transducer detection system (see Figure 3) is a hollow tapered element, clamped at one end and free to oscillate at the other end. An exchangeable sample filter cartridge is placed over the hollow element at the end that is free to oscillate, then ambient air is drawn through the filter and down the tapered element. For mass determination, the device makes use of the resonant frequency of the hollow tapered element. As the mass of the filter increases with deposited particles, the oscillating frequency of the tapered element decreases. An electronic control circuit senses this oscillation and through positive feedback, adds sufficient energy to the system to overcome losses. A precision electronic counter measures the frequency with a ten-second sampling period.

The method makes a direct mass determination from the first-principle physical law describing a spring mass system. (The spring constant, K, of the mass transducer, which is unique to each mass transducer assembly, is used in the calculation of mass from the oscillation frequency.) The total particle mass is then converted to the particle mass concentration in micrograms per cubic metre ($\mu g/m^3$) using the flow rate of the sampled air stream (corrected for standard temperature and pressure).

As in any spring-mass system the frequency follows the equation:

$$F = (\mathrm{K}/M)^{0.5} \qquad \ldots 4(1)$$

where

F = frequency, in hertz

K = spring constant

M = mass, in grams

where K and M are in consistent units.

The relationship between mass and change in frequency is expressed as:

$$dm = K_0 \left\{ f_1^{-2} - f_0^{-2} \right\} \qquad \ldots 4(2)$$

where

dm = change in mass of the filter

K_0 = spring constant (including mass conversions)

f_0 = initial frequency, in hertz

f_1 = final frequency, in hertz

K_0 (the spring constant for the instrument) is determined from Equation 4(2) by measuring the frequency with and without a known mass (e.g. pre-weighed sample filter cartridge).

In the reference cycle, the main flow passes through a polytetrafluoroethylene (PTFE) coated borosilicate glass purge filter typically maintained at 4°C. The low temperature causes any volatile particulate matter components to condense on the filter, resulting in an air stream free of both non-volatile and volatile particulate matter components. This clean ‘reference’ air then passes through the mass transducer sample filter cartridge. The mass concentration measured during the reference cycle provides an estimate of the volatile particulate matter losses that occur during sampling of ambient particle-laden air. Any loss of mass from the sample filter cartridge during the reference cycle is added back to the particle mass concentration measured during the base cycle.

In summary, the ‘base’ mass concentration is equal to the particulate matter concentration of the particle laden sample stream (which is usually a positive number); the ‘reference’ mass concentration is equal to the particulate matter concentration of the particle-free sample stream after passing through the purge filter (which can be a negative value if mass volatilizes from the sample filter cartridge); and the overall mass concentration is equal to the ‘reference’ mass concentration subtracted from the ‘base’ mass concentration (see Equation 4(3)).

$$MC = MC_{\mathrm{base}} - MC_{\mathrm{ref}} \qquad \ldots 4(3)$$

where

MC = reported particle mass concentration

MC_{base} = particle mass concentration measured during base flow cycle

MC_{ref} = particle mass concentration measured during reference flow cycle

The monitor generates a one-hour rolling average of particulate matter mass concentration that is updated every six minutes.

NOTE: The method of operation means that the monitor is measuring particle-laden air for five 6-minute periods per hour (or half the time) and filtered air for five alternating 6-minute periods each hour.