

AS/NZS 3580.9.13:2022



Australian/New Zealand Standard™

Methods for sampling and analysis of ambient air

**Method 9.13: Determination of suspended particulate matter — PM_{2.5}
continuous direct mass method using a tapered element oscillating
microbalance monitor**



AS/NZS 3580.9.13:2022

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- Clean Air Society of Australia & New Zealand
- Department of Environment and Science, Qld
- Department of Planning, Industry and Environment, NSW
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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EV-007, Methods for Examination of Air, to supersede AS/NZS 3580.9.13:2013.

The objective of this document is to provide regulatory and testing bodies with a standard method for continuously monitoring suspended particulate matter with an equivalent aerodynamic diameter (EAD) of less than 2.5 μm (PM_{2.5}) in ambient air, providing near real-time measurement of mean particle concentration. It also allows for the use of a dichotomous instrument thereby providing simultaneous measurement of coarse particulates with diameters between 2.5 and 10 μm (PM_{10-2.5}).

The major changes in this edition are as follows:

- (a) Alignment with current technology and to ensure consistency and uniformity across the different methods used in other continuous particulate monitoring Standards.
- (b) Provision of an essential reference to AS 3580.19.

The requirements for instruments specified in this document are given in the United States Environmental Protection Agency (US EPA) Code of Federal Regulations, Title 40 Protection of Environment, Part 53 Ambient Air Monitoring Reference and Equivalent Methods (40 CFR 53).

The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

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Australian/New Zealand Standard

Methods for sampling and analysis of ambient air

Method 9.13: Determination of suspended particulate matter — PM_{2.5} continuous direct mass method using a tapered element oscillating microbalance monitor

1 Scope

This document sets out a method for the continuous determination of PM_{2.5} in ambient air using a tapered element oscillating microbalance (TEOM) monitor incorporating a filter dynamic measurement system (FDMS) unit.

NOTE PM_{2.5} has been statistically associated with certain human health end points, including daily mortality, hospital admissions and exacerbation of asthma. PM_{2.5} emission sources include industrial processes, fuel combustion, burning of vegetation, incineration and natural causes such as windblown dust and salt laden air. Combustion processes tend to contribute more PM_{2.5} than non-combustion sources. Important anthropogenic sources include domestic wood heaters and motor vehicles (especially diesel fuelled vehicles).

The method can provide a measure of mean particle concentration over periods from 1 h to 24 h. The rolling 1 h mean is updated every 6 min, whereas the rolling 24 h mean mass concentration is updated every 60 min on the hour. Results are normally reported as 24 h, time-integrated mean values. PM₁₀ and PM_{10-2.5} may also be measured simultaneously with PM_{2.5} if a dichotomous instrument is used.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents for informative purposes are listed in the Bibliography.

AS 3580.9.10, *Methods for sampling and analysis of ambient air, Method 9.14: Determination of suspended particulate matter—PM_{2.5} low volume sampler—Gravimetric method*

AS 3580.19, *Methods for sampling and analysis of ambient air, Method 19: Ambient air quality data validation and reporting*

AS/NZS 3580.1.1, *Methods for sampling and analysis of ambient air, Part 1.1: Guide to siting air monitoring equipment*

AS/NZS 3580.9.14, *Methods for sampling and analysis of ambient air, Method 9.14: Determination of suspended particulate matter—PM_{2.5} high volume sampler with size selective inlet—Gravimetric method*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

US EPA 40 CFR 50 Appendix L, Code of Federal Regulation, Title 40 Protection of Environment, Part 50 National Primary and Secondary Ambient Air Quality Standards, Appendix L Reference Method for the Determination of Fine Particulate Matter as PM_{2.5} in the Atmosphere

US EPA 40 CFR 53 Subpart D, 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 PM₁₀

US EPA 40 CFR 53 Subpart E, 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_{10-2.5} or PM_{2.5}

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 equivalent aerodynamic diameter

EAD

diameter of a spherical particle of density 1 g/cm³ that exhibits the same aerodynamic behaviour as the particle in question

3.2 may

indicates the presence of an option

3.3 PM_{2.5}

suspended particulate matter consisting of particles having an EAD of less than 2.5 µm, which is passed by a size classifier having defined performance characteristics

Note 1 to entry: Performance characteristics are defined in US EPA 40 CFR 50 Appendix L.

3.4 PM₁₀

suspended particulate matter consisting of particles having an EAD of less than 10 µm, which is passed by a size classifier having defined performance characteristics

Note 1 to entry: Performance characteristics are defined in US EPA 40 CFR 53 Subpart D.

3.5 PM_{10-2.5}

suspended particulate matter consisting of particles having an EAD ranging from 2.5 to 10 µm

Note 1 to entry: Performance characteristics are defined in US EPA 40 CFR 53 Subpart E.

3.6 range

nominal minimum and maximum concentrations that a method is capable of measuring

Note 1 to entry: The nominal range is given by lower and upper range limits in concentration units, e.g. 0 to 1 000 µg per cubic metre (µg/m³).

3.7 shall

indicates that a statement is mandatory

3.8 should

indicates a recommendation

3.9 U₉₅

estimate of expanded uncertainty at a confidence interval of 95 %

Note 1 to entry: Refer to ISO/IEC Guide 98-3 for further information.

4 Principle

Ambient air is drawn through a PM₁₀ inlet then through a PM_{2.5} particle size separator at a constant flow rate of 16.67 l per minute (L/min) as shown in [Figure 1](#). Downstream of the PM_{2.5} particle size

separator, an isokinetic flow splitter divides the total flow (16.67 L/min) into a main flow and a bypass flow stream. The main flow should be set at 3.00 L/min.

NOTE 1 Single channel TEOMs utilize a very sharp cut cyclone (VSCC) to achieve PM_{2.5} particle separation. With dichotomous TEOMs, the VSCC separator is replaced with a virtual impactor which partitions the coarse (PM_{10-2.5}) and fine (PM_{2.5}) fractions into separate air streams at 1.67 L/min and 15.00 L/min respectively. The PM_{2.5} air stream is then further split isokinetically into main (3.00 L/min) and bypass (12.00 L/min) flow streams. The PM_{10-2.5} stream contains 10 % of the total mass of PM_{2.5}. This is corrected by the instrument processor.

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 6 min, 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](#).

In the base cycle, the main flow then passes through the heated air inlet and enters the mass transducer unit, and is passed through an exchangeable sample filter cartridge placed at the tip of a hollow tapered element, then passes to the mass flow controller that maintains constant flow. The bypass flow is controlled by a separate mass flow controller set at 13.67 L/min (or 12.00 L/min in a dichotomous TEOM where a third mass flow controller maintains the coarse air stream at 1.67 L/min). A single pump provides the vacuum necessary to draw the sample stream(s) 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 10 s 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 µg/m³ using the flow rate of the sampled air stream (corrected for standard temperature and pressure).

As in any spring mass system, the frequency follows [Equation 4\(1\)](#):

$$f = \left(\frac{K}{m} \right)^{0.5} \quad 4(1)$$

where

- f = frequency, in Hz
- K = spring constant, in Hz².g
- m = mass, in g

The relationship between mass and change in frequency can be expressed as [Equation 4\(2\)](#):

$$dm = K_0 \{f_1^{-2} - f_0^{-2}\} \quad 4(2)$$

where

dm = change in mass of the filter, in g

K_0 = spring constant (including mass conversions), in $\text{Hz}^2 \cdot \text{g}$

f_0 = initial frequency, in Hz

f_1 = final frequency, in Hz

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). The overall mass concentration is equal to the “reference” mass concentration subtracted from the “base” mass concentration [see [Equation 4\(3\)](#)].

$$MC = MC_{\text{base}} - MC_{\text{ref}} \quad 4(3)$$

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 1 h rolling mean of particulate matter mass concentration that is updated every 6 min.

NOTE 2 The method of operation means that the monitor is measuring particle-laden air for five 6 min periods per hour (or half the time) and filtered air for five alternating 6 min periods each hour.

5 Apparatus

5.1 Monitor

A TEOM consists of a temperature-controlled sensor unit, a control unit and an FDMS unit (existing either as separate components or as an integrated unit). The FDMS and sensor units are located directly

beneath the sample inlet assembly and are connected to and operated by the flow control unit and vacuum pump.

NOTE High capacity vacuum pumps should be used because they provide flow reliability over a greater operating period.

The TEOM shall be operated in accordance with the requirements of the relevant US EPA equivalent method designation for PM_{2.5}.

Figures 1 to 3 show the main components of a typical TEOM with FDMS.

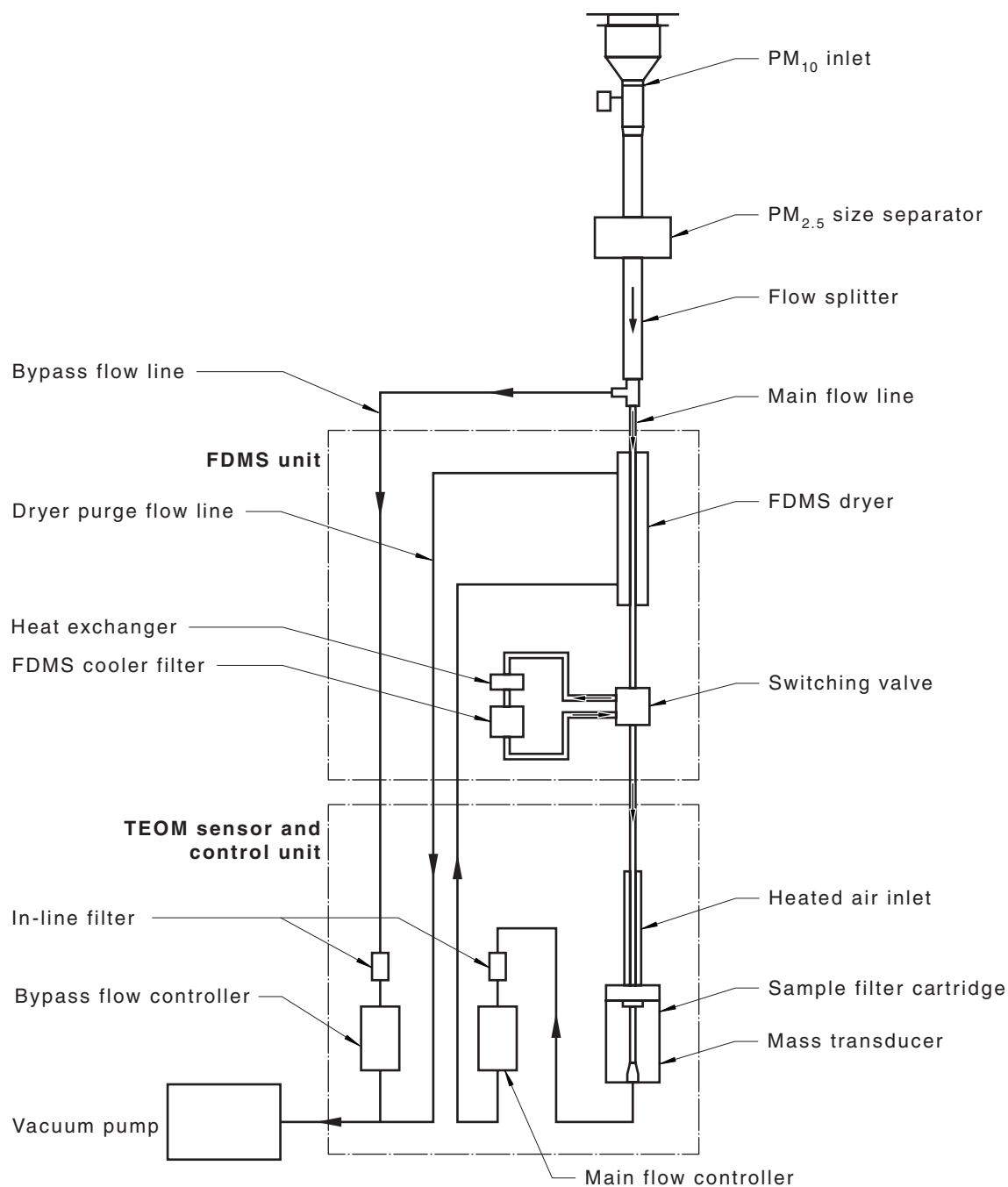


Figure 1 — Schematic diagram of FDMS TEOM flow system

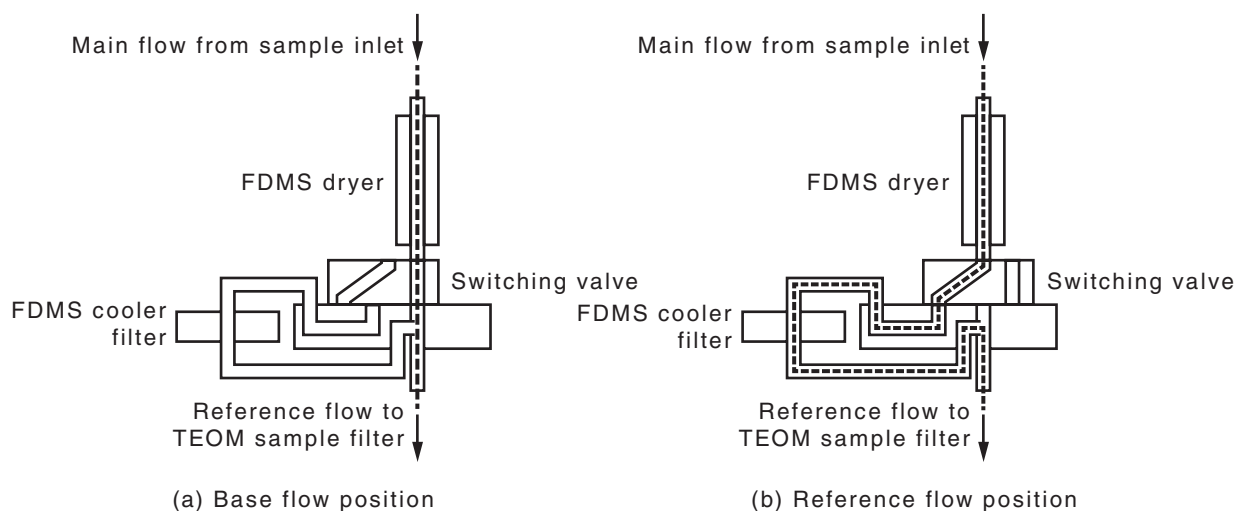


Figure 2 — Schematic diagram of FDMS unit in base flow and reference flow positions

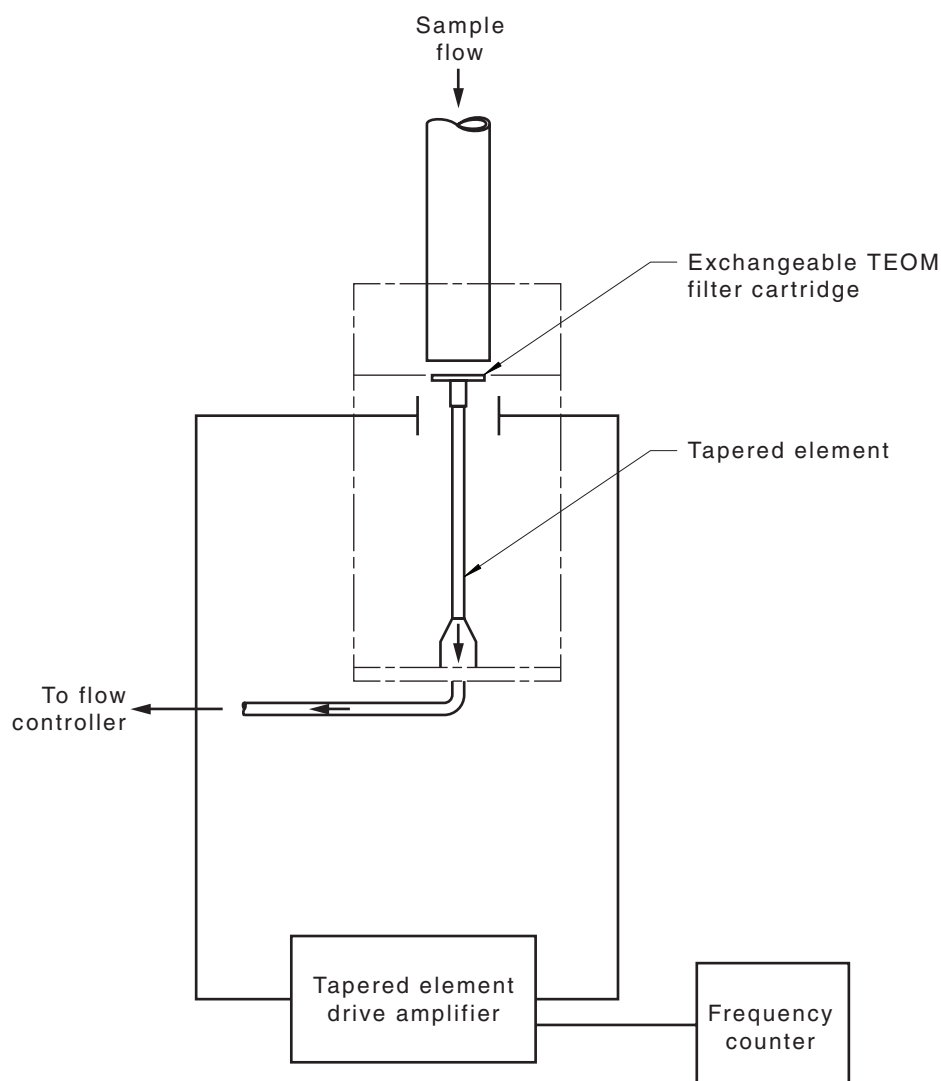


Figure 3 — Schematic diagram of mass transducer