

Australian/New Zealand Standard™

AS/NZS 3580.9.14:2013

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

PREFACE

This Standard was prepared by the joint Standards Australia/Standards New Zealand Committee EV-007, Methods for Examination of Air. This standard method deals with the determination of suspended matter with an equivalent aerodynamic diameter (EAD) of less than approximately 2.5 µm. This is one in a series of Standards for the determination of particulate matter in ambient air.

The procedure described in this Standard involves batch sampling and the gravimetric determination of PM_{2.5}. Committee EV-007 acknowledges the assistance of Thermo Fisher Scientific and Lear Siegler Australasia in providing data and illustrations used in this document.

The objective of this Standard is to provide regulatory and testing bodies with a standard method for the determination of suspended particulate matter with an equivalent aerodynamic diameter of less than 2.5 µm in ambient air.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

FOREWORD

Suspended particulate matter measured by this method includes particles with an equivalent aerodynamic diameter (EAD) of less than 2.5 µm, as passed by a size selective inlet (PM_{2.5}). 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).

METHOD

1 SCOPE

This Standard specifies a gravimetric method for the determination of suspended particulate matter in ambient air. The method provides a measure of mean concentration of PM_{2.5} over the sampling period employed.

NOTES:

- 1 Sampling is normally of 24 h duration to average out the effect of the diurnal variations in particle levels and to enable collection of sufficient mass of particulate matter. Provided that the mass of the filter is determined under carefully controlled laboratory conditions, mean concentrations of 1 µg/m³ and greater may be determined using a 24 h sampling period.
- 2 It is possible that some particulate matter, depending upon its hygroscopicity or volatility, may alter in mass from its initial as-sampled state because of the environmental conditions and filter equilibration procedure referred to in Clauses 7.1 and 7.8. The degree of mass change is largely due to the nature of the sampled aerosol and may vary from day to day, site to site and seasonally.

2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- 3580 Methods for sampling and analysis of ambient air
3580.1.1 Part 1.1: Guide to siting air monitoring equipment

ISO/IEC

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

NATA

- Technical Note 13: User checks and maintenance of laboratory balances

US EPA

- Code of Federal regulations—Protection of Environment 40CFR, Part 53

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 1000 kg/m³ which exhibits the same aerodynamic behaviour as the particle in question.

3.2 Measurement uncertainty

A variable associated with the result of a measurement that characterizes the dispersion of the values that could be reasonably attributed to the measurand.

NOTE: The variable may be, for example, a standard deviation (or given multiple of it), or the half-width of an interval having a stated level of confidence. ISO/IEC Guide 98-3 provides a basis of evaluation uncertainty in the output of measurement system.

3.3 PM_{2.5}

Atmospheric suspended particulate matter having an approximate EAD of less than 2.5 µm that is passed by a size selective inlet having the dimensions specified in Figures 2 to 5.

3.4 PM₁₀

Atmospheric suspended particulate matter having an approximate EAD of less than 10 µm, which is passed by a size selective inlet having performance characteristics as defined in US Code of Federal Regulations: Title 40, Chapter I, Parts 53.40 to 53.43 inclusive.

3.5 U₉₅

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

4 PRINCIPLE

Ambient air is drawn at a constant flow rate through a prepared filter via a PM_{2.5} size-selective inlet where the suspended particulate matter is inertially separated, with particles larger than PM_{2.5} being retained on a layer of grease. The PM_{2.5} fraction of suspended particulate matter is collected on a prepared filter mounted in the high volume sampler filter holder and subsequently weighed (gravimetric method). The PM_{2.5} concentration is determined by dividing the mass of collected particulate matter by the sample volume, which is calculated from the sample duration and either the average or totalized flow rate.

5 APPARATUS

5.1 PM_{2.5} sampler

The PM_{2.5} sampler shall consist of a PM_{2.5} size-selective inlet fitted to a high volume sampler. The performance of the PM_{2.5} sampler shall comply with requirements described in US Code of Federal Regulations for a PM₁₀ high volume sampler with the exception of the size selective inlet specifications. The PM_{2.5} sampler consists of:

- (a) *PM_{2.5} size-selective inlet* The PM_{2.5} size-selective inlet shall be a device designed to separate particles and permit only the PM_{2.5} fraction to pass through to the filter. The PM_{2.5} size-selective inlet shall be designed to collect particles of EAD 2.5 ± 0.5 µm at a 50% efficiency, on a mass basis, at a flow rate of $1.13 \text{ m}^3/\text{min} \pm 10\%$.

The flow rate of $1.13 \text{ m}^3/\text{min}$ at actual temperature and barometric pressure through the inlet is designed to achieve the PM_{2.5} cut-point of 2.5 µm.

NOTE: The cut-point will be maintained within acceptable limits if the flow rate is controlled between 1.02 and $1.24 \text{ m}^3/\text{min}$ at ambient conditions.

Because the collection efficiency of the size-selective inlet is dependent on its geometry, periodic checking, inspection and maintenance is necessary to ensure that the dimensions are within the specifications.

The performance of size-selective inlets may be affected by the accumulation of particles within the sampler inlet. Regular cleaning and regreasing of size-selective inlets is required in accordance with Clause 8.

NOTE: Silicone grease spray has been found to be suitable for Australian and New Zealand conditions.

Size-selective inlets designed for high volume samplers require a volumetric flow rate of approximately $1.13 \text{ m}^3/\text{min}$ to achieve the correct aerodynamic particle size cut-point, which is dependent on the internal velocity of sample air through the nozzles within the inlet. A change in flow-rate will result in a change in the nominal particle size collected. The nozzle velocity is determined by the actual volumetric flow rate, not the mass flow rate. Therefore the actual volumetric flow rate through the size selective inlet shall be maintained within $\pm 10\%$ of the nominal design flow rate specified for the inlet. The size selective inlet design flow rate is always given as a volumetric flow rate.

- (b) *High volume sampler* The high volume sampler shall consist of a filter holder, a motorized fan, a shelter, an air flow measuring device and an elapsed time meter that measures the actual sampling duration to within $\pm 1\%$ U_{95} . Samplers shall have a programmable time clock capable of controlling the operation of the sampler to within 2% of the selected time period.

NOTE: A seven-day time clock is useful for operating the sampler on pre-set days in unattended locations. A six-day time clock may be used when the sampler is required to operate on a six-day cycle (sampling 24 hours every sixth day). Battery backup for the programmable time clock is preferable to avoid incorrect sampling times, and/or the installation of an hour run meter to verify the sample duration.

Automatic flow controlled samplers shall be designed to maintain fixed volumetric flow despite a build-up of particles on the filter by either—

- (i) adjustable flow control and a method for automatic flow adjustment to maintain a constant flow rate; or
- (ii) be constructed in such a way that only a constant and known air flow rate can pass through the filter, irrespective of variations in power supply voltage, power supply frequency or filter resistance normally experienced on a routine basis.

NOTE: If the ambient air temperature or barometric pressure changes, a mass flow controlled high volume sampler changes the volumetric flow to achieve a constant mass flow rate, whereas the volumetric flow controlled sampler maintains a constant volumetric flow rate, independent of temperature changes.

A typical $PM_{2.5}$ sampler is illustrated in Figure 1(a) and a typical filter holder is illustrated in Figure 1(b). The dimensions and assembly of the $PM_{2.5}$ size selective inlet insert are shown in Figures A1 to A4 contained in Appendix A.

The sampler shall be capable of passing ambient air at all times during the sampling period through an approximately 40 000 mm² portion of a clean filter (nominal overall filter dimensions 200 mm × 250 mm) at a constant flow rate within the range 1.02 to 1.24 m³/min (1.13 m³/min $\pm 10\%$).

The motor shall be capable of continuous operation over the range of expected environmental conditions for periods of at least 24 h. The shelter and size-selective inlet shall be constructed of materials capable of withstanding extremes of temperature, relative humidity and the air pollutants to which they will be exposed.

The filter shall be installed in a filter holder (Figure 1(b)). The filter holder shall be horizontally mounted in the high volume sampler so that the sample air is drawn downwards through the filter. The filter holder shall be clamped firmly to provide an air-tight seal against the high volume sampler.

The high volume sampler and its installation shall comply with relevant statutory electrical requirements. As the instrument is operating outdoors under all weather conditions it is recommended that regular electrical safety inspections are conducted. It is recommended that a residual current device (RCD) be installed in the electrical supply circuit and tested according to the manufacturer's instructions at regular intervals.

An exhaust muffler or other noise reducing technique should be used where noise pollution is of concern (for example in residential areas).

The exhaust from the sampler shall be dispersed to minimize re-entrainment of filtered air and stirring up dust from the ground.

The high volume sampler shall be firmly secured to prevent it from being blown over. When the size-selective inlet is fitted to the high volume sampler, the sampler's centre of gravity is raised such that the sampler can topple if it is not adequately secured.

The high volume sampler's air flow measuring device shall be capable of being calibrated, and of providing the basis for measuring the flow rate through the filter, and subsequent calculation of the air volume sampled.

NOTES:

- 1 Typical devices include a mass flowmeter or an orifice located in the sample air stream or a bypass flowmeter.
- 2 The air flow measuring device may provide feed-back to the automatic flow control system.
- 3 Some devices have an insect screen fitted to the size selective inlet.

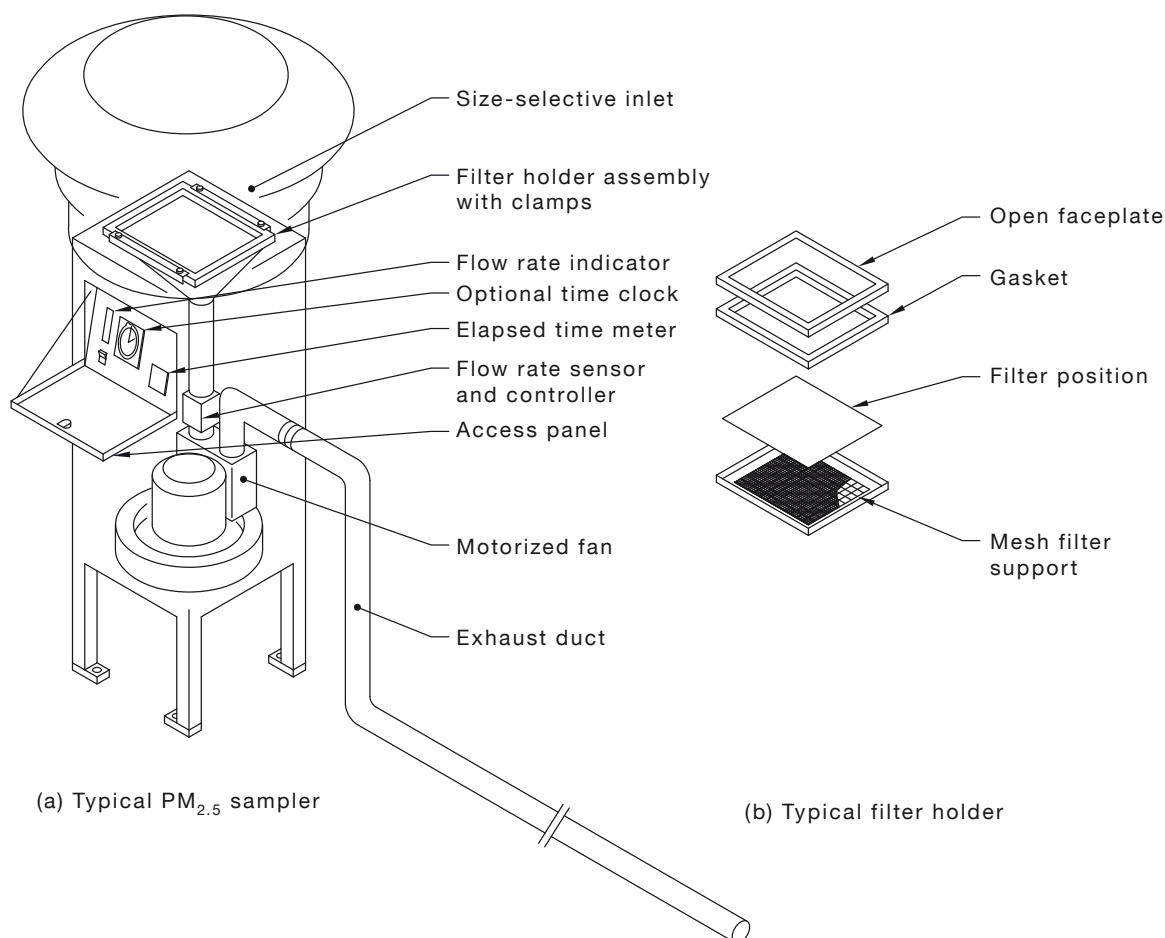


FIGURE 1 APPARATUS

5.2 Flow rate calibration unit

For the purpose of calibration, it is necessary to have a means of varying the flow rate through the high volume sampler. The high volume sampler may have this flow rate set-point adjustment capability built in. This may be achieved by varying the speed of the motorized fan, by throttling the flow with a valve, or by some other means. If the high volume sampler is not provided with flow rate set-point control, internal resistance (multi-holed plates) may be used to give differing air flows for a complete calibration range.

The flow rate calibration unit provides a means of calibrating the high volume sampler flow measuring device in the field. It is a transfer standard that shall itself be calibrated against a certified flow meter (refer to Appendix B), or provided with a certified calibration chart. It shall be capable of temporary connection to the high volume sampler during calibrations. Either one of the following flow rate calibration units shall be used:

- (a) *An orifice flow rate calibration unit* This shall consist of an orifice unit incorporating an adaptor plate that connects to the inlet of the high volume sampler and a differential manometer to measure the differential pressure across the orifice. The differential manometer connects to the side tapping on the orifice unit via a suitable length of flexible tubing with air-tight connections at each end.

NOTE: The differential manometer may be a water filled U-tube manometer or electronic manometer. A water filled U-tube manometer should have a graduated scale.

The manometer shall have a total range of at least 300 mm of water, graduated in 2 mm divisions or less. An electronic manometer shall have a range equivalent to at least 3.0 kPa (approximately 300 mm of water), with 0.02 kPa (approximately 2 mm of water) resolution or less. If an electronic manometer is used to measure the differential pressure across the orifice, it shall be calibrated against a primary standard differential manometer (such as a water filled U-tube manometer) at an interval not exceeding every twelve months. The manometer shall be zeroed prior to connection to the orifice flow rate calibration unit.

NOTE: The differential pressure is the total difference in the level of water in the two halves of the U-tube and is measured in millimetres of water. The water manometer must be secured in a vertical position during use.

The orifice unit shall itself be calibrated in accordance with Appendix B. It shall at all times be handled with care to prevent damage, which could jeopardize the accuracy of the unit. The orifice flow rate calibration unit shall be inspected for damage prior to each use. Any visible damage to the area around the orifice shall necessitate recalibration or replacement of the unit.

The dimensions of the orifice flow rate calibration unit shall be as defined in Appendix B.

- (b) *A calibrated volumetric flowmeter* This shall be capable of measuring flow rates of between 1.02 m³/min and 1.24 m³/min with negligible pressure drop.

5.3 Filters

Quartz, glass, PTFE or PTFE-coated glass fibre filters of approximately 200 mm × 250 mm should be used. Quartz or PTFE-coated filters shall be used if the risk of artefact formation (from oxidation of acid gases) is present. The filters shall have a specified collection efficiency of at least 99% for particles of 0.3 µm EAD and shall permit an air flow rate of 1.24 m³/min. The filters shall be free from pinholes and other defects (see Clause 5.4). Unless folding will result in cracking or material separation, the filter shall be able to withstand one crosswise crease to prevent loss of collected particles or contamination.

NOTE: Where the collected sample is to be used for other determinand(s), the filter should be selected to ensure minimum interference to such determinand(s).

5.4 Light-table

A light-table to check filters for pinholes or other defects.

5.5 Analytical balance

An analytical balance with a resolution of 0.1 mg or less and capable of accommodating the filter without creasing.

5.6 Relative humidity and temperature measuring devices

Devices for measuring and continuously recording the relative humidity to within ±5% U₉₅ and temperature to within ±1°C U₉₅ of the filter conditioning environment.

5.7 Reference barometer

A reference (working standard) barometer, traceable to national standards, with an uncertainty of ± 0.5 kPa U_{95} , is required for the calibration of any pressure transducers that form part of the flow control and measurement system.

5.8 Reference thermometer

A reference (working standard) thermometer, traceable to national standards with an uncertainty of $\pm 0.5^\circ\text{C}$ U_{95} , is required for the calibration of any temperature sensors that form part of the flow control and measurement system.

6 CALIBRATION

6.1 General

Checks and calibrations shall be carried out in accordance with the frequencies specified in Table 1.

6.2 Flow calibration

High volume samplers used for $\text{PM}_{2.5}$ measurements shall have automatic flow control to maintain a constant volumetric flow through the size selective inlet. Commonly used high volume samplers have either a mass flow sensor or a volumetric flow sensor. The operator shall determine whether the high volume sampler being used controls mass flow rate or volumetric flow rate and the sampler shall be calibrated accordingly.

Calibration shall be carried out in accordance with the manufacturer's instructions, using either a volumetric flowmeter (5.2(b)) or an orifice flow rate calibration unit (5.2(a)). Appropriate correction formulae for mass flow or volumetric flow shall be provided with the orifice flow rate calibration unit. The correction formulae should also provide a means of adjusting for actual calibration conditions of temperature and pressure. They should take the form:

- (a) Equation relating volumetric flow rate ($Q_{\text{VOLUMETRIC}}$) to differential pressure (ΔP) across orifice:

$$\Delta P = \left(\frac{Q_{\text{VOLUMETRIC}}}{c} \right)^2 \times \frac{P_{\text{AC}}}{T_{\text{AC}}} \quad \dots 6.2(1)$$

- (b) Equation relating mass flow rate (Q_{MASS}) to differential pressure (ΔP) across orifice:

$$\Delta P = \left(\frac{Q_{\text{MASS}}}{c} \right)^2 \times \left(\frac{101.3}{273} \right)^2 \times \frac{T_{\text{AC}}}{P_{\text{AC}}} \quad \dots 6.2(2)$$

NOTES:

- 1 Subscript 'AC' refers to actual calibration conditions of temperature (K) and barometric pressure (kPa).
- 2 The effect of the change in diameter of the actual orifice, due to thermal expansion, is considered negligible.
- 3 The calibration equation for the orifice plate contains a constant term, c , which is unique to the particular orifice plate calibration unit. A different equation is used for mass flow rate and volumetric flow rate.

Where possible, the air flow measuring device should be adjusted at the zero flow rate condition to indicate zero flow rate.

If the high volume sampler is equipped with a means of adjusting the flow rate, the sampler shall be calibrated at the nominal operating flow rate. Where the high volume sampler is mass flow controlled, the nominal operating flow rate shall be calculated according to Clause 7.4.

If the high volume sampler can maintain the flow rate to within $\pm 1\%$, the sampler may be calibrated at one flow rate. This flow rate shall be within $\pm 1\%$ of the operating flow rate.

If the high volume sampler cannot maintain the flow rate to within $\pm 1\%$, the sampler shall be calibrated at a minimum of 3 flow rates. The 3 flow rates should be 1.02, 1.13 and 1.24 m³/min to cover the permissible flow range of 1.13 m³/min $\pm 10\%$. A calibration curve or graph shall be produced showing the relationship between indicated flow rate and actual flow rate and shall specify whether the graph refers to mass or volumetric flow rate.

If the high volume sampler is not provided with flow rate set-point control, internal resistance (multi-holed plates) may be used to give differing air flows for a complete calibration range. At least 3 such plates shall be used to give a calibration chart or graph showing the relationship between indicated flow rate and actual flow rate, and shall specify whether the graph refers to mass or volumetric flow rate.

Recalibration of the sampler shall be carried out after installation or relocation, following significant maintenance or repair and, in any event, at intervals not exceeding two months.

If the temperature during high volume sampler calibration differs by more than $\pm 5^\circ\text{C}$ from the temperature during orifice calibration, a correction is required.

NOTES:

- 1 The chart that is provided with the orifice flow rate calibration unit should provide details of the corrections required at different calibration temperature and barometric pressure conditions.
- 2 Wind effects across the top of the orifice will cause fluctuations in manometer readings. Field calibrations should occur during calm conditions or measures taken to minimize wind effects.

6.3 Pressure transducer checks and calibration

Pressure transducers are used by some samplers for volumetric flow control. Transducers shall be checked and, if necessary, calibrated at an interval not exceeding twelve months. A reference barometer that complies with the requirements of Clause 5.7 shall be used. The sampler manufacturer's instructions detailing the specific pressure sensor check and calibration procedure(s) shall be followed.

A check shall also be done whenever a sampler is subject to maintenance or repair that is likely to affect such measurements. If there is a difference of more than ± 1 kPa between the transducer and the reference barometer, the transducer shall be calibrated.

6.4 Temperature sensor check and calibration

Temperature sensors are used by some samplers for volumetric flow control. Temperature sensors shall be checked and, if necessary, calibrated at an interval not exceeding twelve months. A reference thermometer that complies with the requirements of Clause 5.8 shall be used. The sampler manufacturer's instructions detailing the specific temperature sensor check and calibration procedure(s) shall be followed.

A check shall also be done whenever a sampler is subject to maintenance or repair that is likely to affect such measurements. If there is a difference of more than $\pm 1^\circ\text{C}$ between the sensor and the reference thermometer, the sensor shall be calibrated.