

Australian Standard[®]

**Workplace atmospheres—Method for
sampling and gravimetric determination
of respirable dust**



This Australian Standard® was prepared by Committee CH-031, Methods for Examination of Workplace Atmospheres. It was approved on behalf of the Council of Standards Australia on 14 September 2009.

This Standard was published on 2 November 2009.

The following are represented on Committee CH-031:

- Australian Aluminium Council
 - Australian Chamber of Commerce and Industry
 - Australian Institute of Occupational Hygienists
 - Australian Mines and Metals Association
 - Bureau of Steel Manufacturers of Australia
 - Clean Air Society of Australia & New Zealand
 - Coal Services
 - Commonwealth Department of Health and Ageing
 - Department for Administrative and Information Services, SA
 - Department of Consumer & Employment Protection, WorkSafe Division, WA
 - Department of Mineral Resources, NSW
 - National Association of Testing Authorities Australia
 - WorkCover New South Wales
-

This Standard was issued in draft form for comment as DR AS 2985.

Standards Australia wishes to acknowledge the participation of the expert individuals that contributed to the development of this Standard through their representation on the Committee and through the public comment period.

Keeping Standards up-to-date

Australian Standards® are living documents that reflect progress in science, technology and systems. To maintain their currency, all Standards are periodically reviewed, and new editions are published. Between editions, amendments may be issued.

Standards may also be withdrawn. It is important that readers assure themselves they are using a current Standard, which should include any amendments that may have been published since the Standard was published.

Detailed information about Australian Standards, drafts, amendments and new projects can be found by visiting www.standards.org.au

Standards Australia welcomes suggestions for improvements, and encourages readers to notify us immediately of any apparent inaccuracies or ambiguities. Contact us via email at mail@standards.org.au, or write to Standards Australia, GPO Box 476, Sydney, NSW 2001.

Australian Standard[®]

**Workplace atmospheres—Method for
sampling and gravimetric determination
of respirable dust**

Originated as AS 2985—1987.
Previous edition 2004.
Third edition 2009.

COPYRIGHT

© Standards Australia

All rights are reserved. No part of this work may be reproduced or copied in any form or by any means, electronic or mechanical, including photocopying, without the written permission of the publisher.

Published by Standards Australia GPO Box 476, Sydney, NSW 2001, Australia

ISBN 0 7337 9292 8

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee CH-031, Methods for the Examination of Workplace Atmospheres, to supersede AS 2985—2004, *Workplace atmospheres—Method for sampling and gravimetric determination of respirable dust*. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian Standard rather than an Australian/New Zealand Standard.

The objective of this revision is to enable calibration laboratories to meet the requirements for the balance and uncertainty requirements.

During the course of the preparation of this Standard, the Committee became aware of new technology for personal respirable dust monitoring, using a tapered element oscillating microbalance technique, but it was decided not to address this issue at this time and to leave it for a future date.

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.

CONTENTS

	<i>Page</i>
FOREWORD.....	4
1 SCOPE.....	5
2 OBJECTIVE	5
3 REFERENCED DOCUMENTS.....	5
4 DEFINITIONS.....	6
5 PRINCIPLE	7
6 APPARATUS	7
7 FLOW RATE DETERMINATION.....	10
8 PROCEDURE.....	10
9 CALCULATIONS	13
10 EXPRESSION OF UNCERTAINTY IN MEASUREMENT	13
11 LIMIT OF REPORTING	13
12 REPORTING OF RESULTS	14
APPENDICES	
A BIBLIOGRAPHY.....	15
B CALIBRATION OF SECONDARY FLOWMETER.....	17

FOREWORD

Most airborne industrial dusts contain particles of a wide range of sizes. The behaviour, deposition and fate of any particle after entry into the human respiratory system and the response that it elicits depends on the nature and size of the particle.

Occupational hygiene practice commonly differentiates between two size fractions of airborne dust, namely respirable and inhalable dust. Where particles may have toxic effects if absorbed in the nasopharyngeal (nose and throat) region or may have toxic effects if ingested after deposition in this region, it is appropriate to measure the mass concentration of inhalable particles in the atmosphere. It may also be apt to measure this size fraction for particles that exhibit no specific toxic effects, namely ‘particulates/dusts not otherwise classified.’ AS 3640, *Workplace atmospheres—Method for sampling and gravimetric determination of inhalable dust*, should be referred to for determining inhalable particles in workplace atmospheres.

Respirable particles can be measured when the nature of these particles is such that they exhibit toxic effects primarily when deposited in the alveolar region (deepest reserve) of the lungs. This usually applies to toxic insoluble particles that accumulate in the lungs such as crystalline silica, coal dust and cadmium oxide fume. This Standard sets down the method for determining the mass concentration of these respirable sized particles in workplace atmospheres.

STANDARDS AUSTRALIA

Australian Standard

Workplace atmospheres—Method for sampling and gravimetric determination of respirable dust**1 SCOPE**

This Standard sets out a method of the collection and gravimetric determination of respirable dust in workplace atmospheres. This method does not consider the measurement of ‘inhalable’ dust, which is covered in AS 3640.

2 OBJECTIVE

The objective of this Standard is to provide a method to assess personal exposure to respirable dust by sampling in a worker’s breathing zone.

Whilst the method only allows for personal sampling, it can also be used to assist in controlling the occupational environment by means of static samples, i.e. samples taken at a fixed location. However, static samples are not to be used to evaluate health risks unless a specific situation or circumstance indicates otherwise.

3 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

- | | |
|--------|---|
| 2162 | Verification and use of volumetric apparatus |
| 2162.1 | Part 1: General—Volumetric glassware |
| 3640 | Workplace atmospheres—Method for sampling and gravimetric determination of inhalable dust |

AS/NZS

- | | |
|------------|---|
| 60079 | Explosive atmospheres |
| 60079.10.1 | Part 10.1: Classification of areas—Explosive gas atmospheres |
| 60079.11 | Part 11: Equipment protection by intrinsic safety ‘i’ |
| 61241 | Electrical apparatus for use in the presence of combustible dust |
| 61241.3 | Part 3: Classification of areas where combustible dusts are or may be present |

ISO

- | | |
|-------|--|
| 7708 | Air quality—Particle size fraction definitions for health-related sampling |
| 15767 | Workplace atmospheres—Controlling and characterizing errors in weighing collected aerosols |
| 20988 | Air quality—Guidelines for estimating measurement uncertainty |

MORRIS, Edwin C. and FEN, Kitty M.K. *The Calibration of Weights and Balances* Monograph 4: Technology Transfer Series, 3rd Edition, National Measurement Institute, November 2003.

NOTE: See Appendix A for bibliography.

4 DEFINITIONS

For the purpose of this Standard the following definitions apply.

4.1 Breathing zone

A hemisphere of 300 mm radius extending in front of the face and measured from the mid-point of a line joining the ears.

4.2 Equivalent aerodynamic diameter (EAD)

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

4.3 Field blank

A blank filter that undergoes the same handling as the sample filter, generally including conditioning and, often, loading into the samplers or transport containers, as well as transportation between laboratory and sampling site, but without being exposed to sampling.

4.4 Limit of performance

The limit of performance of an analytical balance is a parameter, F , associated with its performance such that:

$$F = 2.26s_r(\text{max}) + |Corr_{\text{max}}| + U(Corr_{\text{max}}) \quad \dots 4.1$$

where

$s_r(\text{max})$ = the maximum value of the repeatability of measurement of the balance

$Corr_{\text{max}}$ = the magnitude of the maximum correction to balance reading

$U(Corr_{\text{max}})$ = the expanded uncertainty associated with $Corr_{\text{max}}$

For example, a typical value of F for a six-place microbalance is 0.030 mg, and a typical value for a five-place semi-microbalance balance is 0.11 mg.

4.5 Pulsation ratio

The ratio of peak-to-peak flow rates to the average flow rate.

NOTE: For further information, see Appendix A, References 1 and 2.

4.6 Resolution of a displaying device

The smallest difference between indications of a displaying device that can be meaningfully distinguished.

NOTE: Resolution can be seen for a balance as equal to the scale division when that can be reliably read.

4.7 Respirable dust

The proportion of airborne particulate matter that penetrates to the unciliated airways when inhaled. This fraction is further described in ISO 7708 as the percentage of inhalable matter collected by a device conforming to a sampling efficiency curve that passes through the points shown in Table 1.

Alternatively, it can be described by a cumulative log-normal distribution with a median EAD of $4.25 \mu\text{m}$ and a geometric standard deviation of $1.5 \mu\text{m}$.

TABLE 1
RESPIRABLE DUST

Equivalent aerodynamic diameter μm	Respirability %
0	100
1	100
2	97
3	80
4	56
5	34
6	20
7	11
8	6
10	2
12	0.5
14	0.2
16	0.1
18	0

5 PRINCIPLE

Airborne concentrations of respirable dust in the workplace are determined by passing a measured volume of air through a filter of predetermined weight. By reweighing the filter at the end of the sampling period, the weight of material collected is determined by difference.

To separate the respirable fraction, a size-selective sampler is used prior to the filter.

6 APPARATUS

6.1 Sampling systems

The essential features of a sampling system are a filter (on which the sample is collected) and a pump for drawing the air through the filter. The filter shall be secured in a holder that prevents air from leaking around the edge of the filter. The filter shall be preceded by a size-selective sampler.

In personal sampling instruments, the filter holder/size selector is an integral unit that is located within the worker's breathing zone and this is connected to the pump unit (worn on a belt or in a pocket) by flexible tubing.

6.2 Sampling device

The respirable fraction shall be collected by using a size-selective sampler conforming to the sampling efficiency curve, see Clause 4.7. Such devices include miniature cyclones such as the BCIRA (British Cast Iron Research Association) Higgins and Dewell (see Appendix A, Reference 3) and Simpeds (Safety in Mines Research Establishment Personal Dust Sampler, Appendix A, Reference 4 and Figure 1) and aluminium cyclones (Appendix A, Reference 5) as in Table 2.

TABLE 2
DESIGNATED FLOW RATES FOR SIZE-SELECTIVE SAMPLERS

Size-selective sampler	Designated flow rate, L/min
BCIRA cyclone	2.2
SIMPEDS cyclone	2.2
Aluminium cyclone	2.5

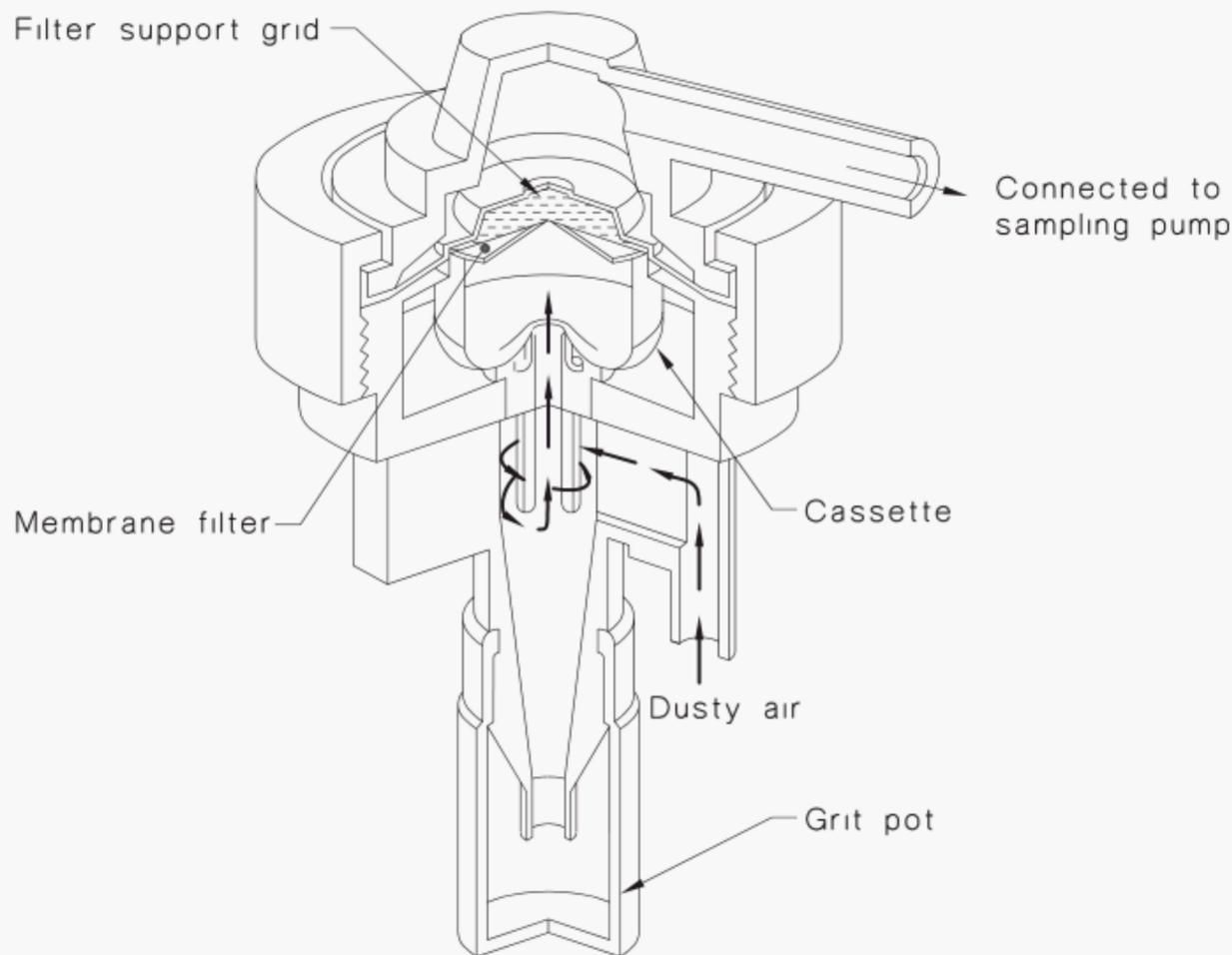


FIGURE 1 ONE TYPE OF SAMPLER WITH CYCLONE ELUTRIATOR

6.3 Filter

The filter size shall be chosen to suit the sampling head. Filters of 25 mm diameter are preferred, but a 37 mm diameter filter may be used.

Filters of nominal pore size of 5 μm or less shall be used. The type of filter material shall be chosen so that electrostatic charge, moisture variations, and loss of filter or sample do not significantly affect the analysis. In general, electrostatic charge problems have to be overcome with PVC and polycarbonate filters; significant moisture variations affect cellulose filters; loss of filter can occur with silver membrane and glass fibre filters. If polycarbonate filters are used, the nominal pore size shall be 0.8 μm or less. Care should be taken to ensure that there is no sample loss during use or transportation.

NOTE: For additional analysis (such as quartz or cristabolite) other factors such as filter type and treatment should be taken into account.

6.4 Sampling pumps

Sampling pumps shall be capable of operation at the designated flow rate ± 0.1 L/min (see Table 2) for the duration of the sample period. The pulsation ratio shall not exceed 0.2 and preferably be less than 0.1. (For further information, see Appendix A, References 1, 2,

6 and 7.) Some pumps may require pulsation dampers to achieve this performance. Pumps shall be fitted with automatic flow control facilities.

CAUTION: WHEN SAMPLING IN EXPLOSIVE GAS OR DUST ATMOSPHERES, AS DEFINED IN AS/NZS 60079.10.1 OR AS/NZS 61241.3, ENSURE THAT THE SAMPLING PUMP MEETS THE REQUIREMENTS OF AS/NZS 60079.11.

6.5 Secondary flowmeter

A flowmeter or any secondary device such as a rotameter or electronic flowmeter shall be calibrated against the primary flowmeter as set out in Appendix B. The secondary flowmeter shall be used to measure the flow rate of the sampling train immediately before and after sampling. The secondary flowmeter shall be re-calibrated whenever it is to be operated under conditions substantially different from those of the previous calibration. For example—

- (a) when sampling and/or flow rate determination is conducted at an altitude differing by more than 500 m or at a temperature differing by more than 15°C from that at the previous calibration; or
- (b) when experience indicates such re-calibration is necessary due to stability and maintenance history of the flowmeter.

NOTES:

- 1 It is generally not possible to simply calculate the different flow rates that will inevitably result from a change of conditions such as those given above.
- 2 Rotameters can give incorrect readings due to sticking of the float, high humidity and use in a non-vertical position, or under conditions of vibration.
- 3 Errors can occur using electronic flowmeter due to adverse environmental conditions.

6.6 Timing device

A stopwatch or other timing device capable of measuring elapsed time within 1% of true elapsed time.

6.7 Microbalance

6.7.1 General

A five-place microbalance with a scale division of 10 µg or six-place microbalance with a scale division of 1 µg. A standard laboratory four-place analytical balance is not suitable for this application.

6.7.2 Microbalance calibration

The following requirements and recommendations apply:

- (a) The microbalance shall be calibrated every three years, using the following principles, by either—
 - (i) a suitable accredited testing authority; or
 - (ii) competent staff employing test methods as described by Morris and Fen.
- (b) Tests for departure from nominal linearity shall be conducted for at least 5 and preferably 10 points from zero up to not more than 50 or 100 mg. If the measured departure from nominal linearity exceeds the expanded uncertainty of the reference weights, the balance should be serviced, or appropriate corrections should be made.
- (c) Hysteresis and, where applicable, off-centre pan loading shall be conducted using a weight in the range of 50 to 100 mg. Any hysteresis and off-centre effects greater than the scale of the balance should be rectified by servicing, or by an appropriate change in operating procedures.

- (d) Repeatability tests on the microbalance shall be conducted with a weight not smaller than around the working range used for weighing filters, and not greater than 50 mg, every six months, e.g. in accordance with Morris and Fen.
- (e) A limit of performance shall be calculated whenever a full calibration of the balance is performed.

6.8 Static eliminator

Suitable instruments for eliminating static include the following, any of which may be used:

- (a) an ionising electrode static elimination bar or U-shaped electrode;
- (b) a high voltage corona discharge device; or
- (c) a positive ion or an alpha particle source ionizing unit (Americium 241 of 0.4 to 4 MBq activity or Polonium 210 of 20 MBq activity). The Po unit should be renewed when found to be ineffective (i.e. generally every one to two years). Both units will require a government licence to operate/dispose of them.

7 FLOW RATE DETERMINATION

The sampling pump battery should be re-charged or the dry cells replaced and, if necessary, the pump should be run for up to 15 min in a clean atmosphere immediately before flow rate determination. It is advisable to stabilize the flow rate through a 'warm-up' sampler, which is not otherwise used, e.g. in calibration to reduce the risk of contamination. Some automatic flow control pumps require little or no settling-in period.

The pump flow rate should be adjusted accurately to the designated flow rate (see Table 2) using a calibrated flowmeter (see Clause 6.5). Immediately prior to determining the flow rate, disconnect the warm-up sampler and connect the sampling train to be used in the field.

The calibration equipment and technique should be of such accuracy that the flow rate can be measured to within $\pm 5\%$.

8 PROCEDURE

8.1 Routine weighing checks

The accuracy of the microbalance used in the gravimetric measurements shall be checked in the following manner:

- (a) *Before every weighing session* Before weighing the filters:
 - (i) Ensure the balance is switched on for the manufacturer's recommended warm up period or at least 30 minutes.
 - (ii) Exercise the balance by placing a mass of near full load on the pan at least once.
 - (iii) Check the balance with a reference weight at or near to the working range of the weighing filters and not greater than 50 mg.
 - (iv) If the weight reading is grossly different from the nominal value, then the balance shall be serviced.
 - (v) If the weight reading is not grossly different from the nominal value, then proceed and perform a balance adjustment.

NOTE: This procedure is often referred to as an 'internal calibration' by many balance manuals.

- (vi) Recheck the balance with a reliable reference weight at or near to the working range of the weighing filters and not greater than 50 mg.

NOTE: The difference of the reading of the reference weight to the nominal value should be less than the limit of performance of the balance.

- (b) *During every weighing session* When weighing filters conduct a zero check after each filter weight determination.
- (c) *After every weighing session* Check the calibration of the balance with the same reference weight as used previously.

NOTE: The difference of the reading of the reference weight to the nominal value should be less than the limit of performance of the balance.

- (d) *Long weighing sessions* If a series of filters is being weighed the microbalance accuracy shall be checked at appropriate intervals during the procedure.

NOTE: The difference of the reading of the reference weight to the nominal value should be less than the limit of performance of the balance.

8.2 Filter pre-weighing

The weighing procedure for filters shall be as follows:

- (a) Place the filters in individually labelled, clean containers and leave with the lids slightly ajar in the balance room for a suitable time (e.g. overnight but this may depend on the filter type) to come to equilibrium with the balance room atmosphere. If filters that are prone to static build-up are being used, they shall be passed over the static eliminator (Clause 6.8) to dissipate any electrostatic charge. Repeated exposure to the static eliminator with subsequent weighing shall be conducted to verify that the electrostatic charge has dissipated and is causing no weighing errors.
- (b) 10% of filters (with a minimum of two) shall be selected as field blanks and submitted to the same procedures as for the sample filters with omission of the sampling step.

Weighing of blank filters shall be carried out over the same period as the sample filters.

NOTE: This may mean multiple weighing of blank filters so they are representative of changes to the sample filters due to atmospheric conditions during the weighing period. If there is a significant change of atmospheric conditions or in blank weights over the weighing session, it will be necessary to divide the sample filters into groups so that appropriate blank corrections can be applied.

- (c) Weigh each sample and blank filters and record the weights, in milligrams (w_1 and b_1 respectively).

8.3 Sampling

Unless special circumstances dictate otherwise, sampling times should be as long as is reasonably practicable (generally not less than 4 h) and should be representative of the working periods of individuals exposed. A long sampling time also ensures a heavier deposit and therefore reduces inaccuracies. The procedure shall be as follows (as appropriate):

- (a) When ready to commence sampling, turn on the pump and record the following information:
 - (i) Size-selective sampler number.
 - (ii) Filter identification.
 - (iii) Pump identification number.
 - (iv) Date and pump start time.

- (v) Initial flow rate of pump (see Note 1).
 - (vi) Secondary flowmeter used.
 - (vii) Worker's name/identification, or description of static location.
- (b) Attach the sampling pump to the worker.
 - (c) Fasten the size-selective sampler containing a pre-weighed filter (see Clause 8.1(c)) to the worker's clothing within the breathing zone. Ensure that the tubing is free from leakage and kinks, and is located to minimize inconvenience to the worker.
 - (d) During sampling, note the following:
 - (i) Description of the task undertaken during sampling period.
 - (ii) Risk control measures in place and atmospheric conditions where relevant.
 - (iii) Any other relevant data.

At the conclusion of the sampling period prior to switching the pump off, record the time, and immediately re-measure the flow rate through the sampling device.

- (e) If the final flow rate varies by more than $\pm 5\%$, of the initial flow rate, the sample shall be deemed invalid.
- (f) Place the size-selective sampler or cassette in a pre-labelled dust-free container ensuring that it cannot be inadvertently used again.

NOTES:

- 1 It is prudent to check the pump periodically to ensure correct operation.
- 2 Some size-selective samplers develop leakage past the filter or grit-pot, which should be rectified prior to sampling.
- 3 Inverting the cyclone may cause oversized particles falling out of the grit-pot onto the filter.

8.4 Transporting filters after sampling

The layer of dust collected on the filter is fragile; shock or vibration may cause loss of material unless precautions are taken during transport. The best method of transportation is by using a reliable person who is aware of the need for care. For long distances, the filters shall be packed in such a way that normal transportation shocks do not cause loss of material. Filters should only be removed from size-selective samplers by trained/competent people because of possible filter or dust deposit damage.

8.5 Weighing filters after sampling

The weighing procedures for filters shall be as follows:

- (a) Allow filters to come to equilibrium with the balance room atmosphere for a suitable time (e.g. overnight). Repeat Steps (a) and (b) of Clause 8.2 in reference to blank filters and the use of the static eliminator.
- (b) After applying the routine weighing checks as described in Clause 8.1, weigh sample and blank filters and record the weights in milligrams (w_2 and b_2 respectively).

9 CALCULATIONS

The following calculations shall be carried out:

- (a) Calculate the weight of dust collected, from the following equation:

$$w = (w_2 - w_1) - (b_2 - b_1) \quad \dots 9.1$$

where

w = blank corrected weight of dust collected on the filter, in milligrams

w_1 = weight of filter before sampling, in milligrams

w_2 = weight of filter after sampling, in milligrams

b_1 = average weight of blank filter before sampling, in milligrams

b_2 = average weight of blank filter after sampling, in milligrams

- (b) Calculate the average flow rate (Q), and volume of air (V) passed through each filter for the duration of sampling from the following equations:

$$Q = \frac{Q_1 + Q_2}{2} \quad \dots 9.2$$

$$V = \frac{Q \times t}{1000} \quad \dots 9.3$$

where

Q = average flow rate, in litres per minute

Q_1 = initial flow rate, in litres per minute

Q_2 = final flow rate, in litres per minute

t = sampling duration, in minutes

V = air volume, in cubic metres

- (c) Calculate the average concentration (C) of respirable dust from the following equation:

$$C = \frac{w}{V} \quad \dots 9.4$$

where

C = dust concentration, in milligrams per cubic metre

w = net weight of dust, blank corrected, in milligrams

V = air volume, in cubic metres

10 EXPRESSION OF UNCERTAINTY IN MEASUREMENT

Uncertainty in measurement may arise from a variety of sources in the method. For characterization of and estimations of uncertainty in weighing measurements, see ISO 15767 and ISO 20988 respectively.

11 LIMIT OF REPORTING

If uncertainties and detection limits are not available, the practical limit of reporting for sampling periods greater than 60 min shall be taken as 0.01 mg/m^3 for six-place microbalances, and 0.1 mg/m^3 for five-place semi-microbalances.

12 REPORTING OF RESULTS

12.1 Gravimetric report

The test report shall include:

- (a) Identification of sample either as name of person wearing sampler or sampler location.
- (b) Name of laboratory or authority that performed the test.
- (c) Date on which the test was carried out and sampling duration.
- (d) Net weight of dust on filter.
- (e) Reference to this Standard, i.e. AS 2985.

12.2 Concentration report

The concentration report shall include:

- (a) The name of the person doing the sampling.
- (b) Activities being conducted during sampling.
- (c) Any personal protective equipment worn.
- (d) Average pump flowrate and sampling duration.
- (e) If uncertainties are not available, for sampling periods greater than 60 min the concentration should be reported to two decimal places and three significant figures for six-place microbalances, and the one decimal place and two significant figures for five-place microbalances.
- (f) Any observation, in relation to either the test sample or the performance of the test that may assist in the correct interpretation of the test results.
- (g) Reference to this Standard, i.e. AS 2985.

NOTE: Occupational hygiene reports generally contain additional information, and generally include advice on remedial action if required.

APPENDIX A
BIBLIOGRAPHY

(Informative)

- 1 AMERICAN SOCIETY FOR TESTING MATERIALS, D6061-96 Evaluating the Performance of Respirable Aerosol Samples. (2007).
- 2 BARTLEY, D.L., CHEN, C, SONG R, and FISCHBACH, T.J. Respirable Aerosol Sampler Performance Testing. *AIHA Journal*: Vol. 55, 11, (1994) pp 1036-1046.
- 3 BS EN 1232:1997 Workplace atmospheres. Pumps for personal sampling of chemical agents. Requirements and test methods, British Standards Institute, 1997.
- 4 COOK, R.R. Assessment of Uncertainties of Measurement for Calibration and Testing Laboratories, National Association of Testing Authorities, 1999.
- 5 ELLISON, S.L.R., ROSSLEIN, M. and WILLIAMS, A (ed) *Qualifying Uncertainty in Analytical Measurement*, EURACHEM/CITAC, 2nd edition 2000.
- 6 HARPER, M., FANG C. P., BARTLEY D.L. and COHEN B.S., Calibration of the SKC, Inc aluminium cyclone for operation in accordance with ISO/CEN/ACGIH respirable aerosol sampling criteria, *Journal of Aerosol Science* 29 (S1) (1998) pp. 347-348.
- 7 HIGGINS, R.I. AND DEWELL, P.A. Gravimetric Size-selecting Personal Sampler. In: *Inhaled Particles and Vapours II*. Ed. C.N. Davies, Pergamon Press. (1967) p 575.
- 8 INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) 'Guide to the expression of uncertainty in measurement', Switzerland, 1993.
- 9 KENNY, L., CHUNG, K., DILWORTH, M., HAMMOND, C., WYNN, J., JONES, SHREEVE, Z., WINTON, J., Applications of low-cost, dual-fraction dust samplers. *The Annals of Occupational Hygiene* 45 (1) (2001) pp 35-42.
- 10 KENNY, L.C., BOWRY, A., CROOK, B., STANCLIFFE, J.A. Field Testing of a Personal Size-selective Bioaerosol Sampler, *The Annals of Occupational Hygiene* 43 (6) (1999) pp 393-404.
- 11 LAMONICA, J.A. & TREAFTIS, H.N. 'Investigation of Pulsation Dampers for Personal Respirable Dust Samplers' U.S. Bureau of Mines Report 7545, 1971.
- 12 LAMONICA, J.A. & TREAFTIS, H.N. 'The Effect of Pulsation Damping on Respirable Dust Collected by Coalmine Dust Personal Samplers' U.S. Bureau of Mines Report 7636, 1972.
- 13 LIDEN, G., MELIN, B. LIDBLOM, A. LINDBERG, K. AND NOREN, J-O Personal sampling in Parallel with Open-face filter Cassettes and IOM Samplers for Inhalable dust- Implications for Occupational Exposure Limits, *Applied Occupational and Environmental Hygiene* Vol 15 (3): 2000 pp 263-276.
- 14 MAGURIE, B.A. BARKER, D. AND BADEL D.A. SIMPEDS 70: An Improved Version of the SIMPEDS Personal Gravimetric Dust Sampling Instrument. In: *Inhaled Particles III*. Ed W.H. Walton, Unwin. Old Woking. (1971) pp 1053-1056.
- 15 OGDEN, T.L. 'Inhalable, Inspirable and Total Dust' in *Aerosols in the Mining and Industrial Work Environments*, Vol 1: editors Marple and Liu. Ann Arbor Science, Ann Arbor, 1983, vol. 1, pp 185-204.
- 16 PHALEN, R.F., HINDS, W.C., JOHN, W., LIOY, P.J., LIPPMANN, M., MCCAWLEY, M.A. RAABE, O.G., SODERHOLM, S.C. and STUART, B.O. Rationale and recommendations for particle size-selection sampling in the workplace'. *Appl. Ind. Hyg.* 1, (1986) 3-4.

- 17 UNITED KINGDOM HEALTH AND SAFETY EXECUTIVE (HSE). *General methods for sampling and gravimetric analysis of respirable and total inhalable dust*. Methods for the Determination of Hazardous Substances (MDHS) 14/3 February 2000.
- 18 JOINT COMMITTEE FOR GUIDES IN METROLOGY (JCGIM) 200: *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*, Switzerland, 2008.

APPENDIX B
CALIBRATION OF SECONDARY FLOWMETER
(Normative)

B1 SCOPE

This Appendix sets out a procedure for calibrating the secondary flowmeter using the soap film flowmeter.

B2 APPARATUS

B2.1 General

Typical apparatus as described in Paragraphs B2.2 to B2.4 should be set up as illustrated in Figure B1.

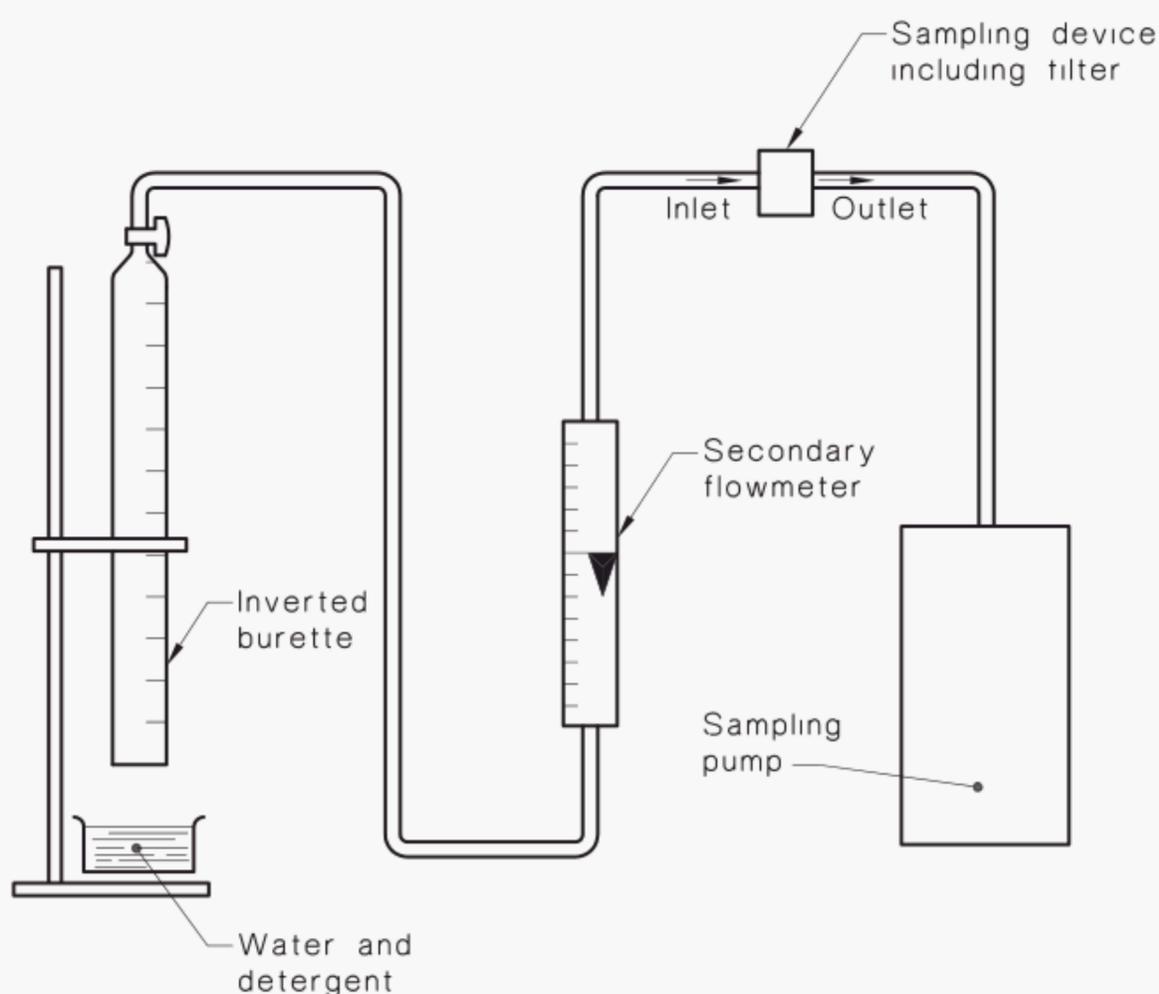


FIGURE B1 SCHEMATIC DIAGRAM OF APPARATUS FOR CALIBRATION OF FLOWMETER

B2.2 Primary flowmeter

Primary flowmeters such as a soap film flowmeter, wet-test gas meter or bell spirometer shall be used to calibrate the secondary flowmeter. It is not acceptable to calibrate one secondary flowmeter against another calibrated secondary flowmeter, e.g. an electronic mass flow device. Any pressure drop due to the flowmeter shall be taken into account. A primary flowmeter can consist of modified glass burette or other accurately calibrated tube of 500 mL to 2000 mL. The diameter of the burette/tube shall be such as to facilitate the formation of the bubble that will travel the full length of the burette/tube in accordance with Paragraph B3 without bursting. The end shall be of such a diameter as to form an airtight seal between it and the flexible tubing (see Figure B1).

NOTES:

- 1 Modification of the burette (removal of the burette tip and tap) may be necessary to ensure that any pressure-drop caused by flow constriction does not affect calibration. See also AS 2162.1.
- 2 Care should be taken to ensure that the addition of any flowmeter does not introduce an unknown change of flow rate into the calculation system due to an inadvertent increase or decrease of pressure drop.
- 3 When timing the movement of the bubble, care should be taken to avoid parallax errors.

B2.3 Battery pack

A fully charged battery pack or fresh dry cells to power the pump.

B2.4 Sampling train

The sampling train (pump, flexible tubing and sampling device) shall be identical to that used in the field.

B2.5 Timing device

A stopwatch or other timing device capable of measuring elapsed time to an accuracy of 1%.

B3 PROCEDURE

A typical procedure using a modified burette/tube as a primary flowmeter is as follows:

- (a) Prior to connecting the burette into the system (Figure B1) rinse it thoroughly with clean water, ensuring that it is coated with a uniform film of water and that it is free of patches of droplets and dryness.

NOTE: The continuous film of water is an indication of burette cleanliness and assists in the smooth transportation of soap bubbles over its length.

- (b) Assemble the apparatus as shown in Figure B1.
- (c) Partly fill a beaker or other appropriate container with water containing just sufficient detergent so as to cause bubbles, and place it under the open end of the burette.
- (d) Switch on the pump and adjust the flow rate according to the designated flow rate.
NOTE: Flow pulsations in the sampling train can be a major source of error when using a variable orifice flowmeter (rotameter). It is important that the flowmeter is calibrated under conditions similar to those used in the field.
- (e) Allow at least a five minute warm-up period for the pump or until the indicated flow rate is stable. Readjust the pump, if necessary, to the predetermined level.
- (f) Raise the beaker of detergent solution until the open end of the burette is momentarily closed off by the surface of the detergent solution and a bubble forms in the burette.
- (g) Using the timing device, measure the time required for a bubble film to travel a set length of the graduated scale on the burette.

NOTE: The flowmeter reading should be checked at the end of each run to be assured of its stability.

- (h) Repeat Steps (f) and (g) until three consecutive results agree to within $\pm 1\%$ of the mean value.
- (i) Calculate the mean value of the three consecutive results, t_{av} .

Calculate the calibration flow rate, Q_c , of the pump as follows:

$$Q_c = \frac{V}{t_{av}} \quad \dots \text{A3.1}$$

where

Q_c = calibration flow rate under calibration conditions, in millilitres

V = set volume of burette/calibrated tube over which measurement was taken, in millilitres

t_{av} = average time taken for bubbles to traverse the set length of tube, in minutes.

NOTE: Theoretically, the water vapour content in the soap film flowmeter air should be taken into consideration in determining the calibration flow rate. However, for practical purposes acceptable accuracy is maintained without this correction.

- (j) Repeat Steps (d) to (i) with a range of flow rates in the expected range of use.

B4 CALIBRATION RECORD

The calibration record shall include the following information:

- (a) Identification or unambiguous description of the primary and secondary flowmeter, where applicable, the pump used and flowmeter tested.
- (b) Capacity of burette/calibrated tube.
- (c) Nominal flow rate as indicated on flowmeter during calibration.
- (d) Average time (t_{av}) and the values of three consecutive results from which the average time was calculated.
- (e) Calibration flow rate, Q_c .
- (f) Name of testing organization and date of conducting the calibration.
- (g) Any additional information that will assist in the correct interpretation of the results, e.g. unduly long pump warm-up time, instability in pump flowmeter, difficulty in obtaining 3 consecutive results to agree within $\pm 1\%$ of the mean value.
- (h) Reference to this method, i.e. AS 2985, Appendix B.

NOTES

Standards Australia

Standards Australia develops Australian Standards® and other documents of public benefit and national interest. These Standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth Government, Standards Australia is recognized as Australia's peak non-government national standards body. Standards Australia also supports excellence in design and innovation through the Australian Design Awards.

For further information visit www.standards.org.au

Australian Standards®

Committees of experts from industry, governments, consumers and other relevant sectors prepare Australian Standards. The requirements or recommendations contained in published Standards are a consensus of the views of representative interests and also take account of comments received from other sources. They reflect the latest scientific and industry experience. Australian Standards are kept under continuous review after publication and are updated regularly to take account of changing technology.

International Involvement

Standards Australia is responsible for ensuring the Australian viewpoint is considered in the formulation of International Standards and that the latest international experience is incorporated in national Standards. This role is vital in assisting local industry to compete in international markets. Standards Australia represents Australia at both the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

Sales and Distribution

Australian Standards®, Handbooks and other documents developed by Standards Australia are printed and distributed under license by SAI Global Limited.

For information regarding the development of Standards contact:

Standards Australia Limited
GPO Box 476
Sydney NSW 2001
Phone: 02 9237 6000
Fax: 02 9237 6010
Email: mail@standards.org.au
Internet: www.standards.org.au

For information regarding the sale and distribution of Standards contact:

SAI Global Limited
Phone: 13 12 42
Fax: 1300 65 49 49
Email: sales@sai-global.com



ISBN 0 7337 9292 8

This page has been left intentionally blank.