
Compressed air —

Part 4:

Test methods for solid particle content

Air comprimé —

Partie 4: Méthodes d'essai pour la détermination de la teneur en particules solides



Reference number
ISO 8573-4:2001(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 8573 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 8573-4 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, Subcommittee SC 4, *Quality of compressed air*.

ISO 8573 consists of the following parts, under the general title *Compressed air*:

- *Part 1: Contaminants and purity classes*
- *Part 2: Test methods for aerosol oil content*
- *Part 3: Test methods for measurement of humidity*
- *Part 4: Test methods for solid particle content*
- *Part 5: Determination of oil vapour and organic solvent content*
- *Part 6: Determination of content of gaseous contaminants*
- *Part 7: Test methods for viable microbiological particle content*
- *Part 8: Test methods for mass concentration of solid particle content*
- *Part 9: Test methods for liquid water content*

Annexes A and B of this part of ISO 8573 are for information only.

Compressed air —

Part 4: Test methods for solid particle content

1 Scope

This part of ISO 8573 provides a guide for choosing a suitable method to determine the solid particle concentration in compressed air, expressed as the number of solid particles in respective size classes. It describes the limitations of the various methods.

This part of ISO 8573 identifies sampling techniques and measurement methods based on the counting of particles, and describes the evaluation, uncertainty considerations and reporting of the air purity parameter, solid particles.

NOTE 1 The test methods described in this part of ISO 8573 are those suitable for determining the purity classes given in ISO 8573-1.

NOTE 2 Particle content determined as mass concentration is dealt with in ISO 8573-8.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 8573. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 8573 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1217, *Displacement compressors — Acceptance tests*.

ISO 3857-1, *Compressors, pneumatic tools and machines — Vocabulary — Part 1: General*.

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*.

ISO 5598, *Fluid power systems and components — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO 8573, the terms and definitions given in ISO 5598, ISO 3857-1 and ISO 1217 and the following apply.

3.1

solid particle

discrete mass of solid matter

3.2

microbiological particle

solid particle that has the property of forming viable colony units

3.3

aerodynamic particle diameter

diameter of a sphere of density of 1 g/cm³ with the same settling velocity, due to gravitational force in calm air, as the particle under the prevailing conditions of temperature, pressure and relative humidity

4 Units

For the purposes of this part of ISO 8573, the following non-preferred units are used:

1 bar = 100 000 Pa

1 l (litre) = 0,001 m³

bar(e) = effective pressure

5 Particle classes

5.1 Solid particles

Solid particles are characterized by their properties of shape, size, density and hardness. Solid particles include microbiological units. Reference is made to microbiological particles in this part of ISO 8573 to identify what problems may arise that can affect the discrimination of non-microbiological particles from microbiological particles and when to use this part of ISO 8573 or ISO 8573-7.

The influence of liquids on particle size and number must be eliminated in order to obtain a correct reading.

The influence of liquids other than water shall be given due consideration when selecting a test method.

In order to discriminate non-microbiological particles from microbiological particles, measurements must be taken within a period of 4 h.

5.2 Microbiological particles

This part of ISO 8573 should be used to count the number of microbiological particles present in a sample. The method used to count the particles does not identify microbiological particles directly, therefore if more information is required, ISO 8573-7 should be used to determine their viability.

5.3 Aerodynamic particle diameter

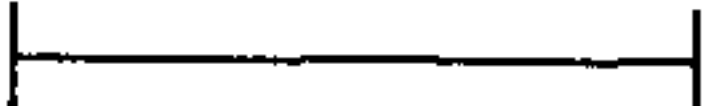
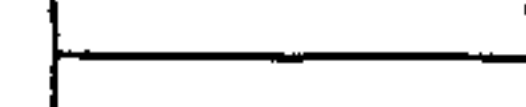
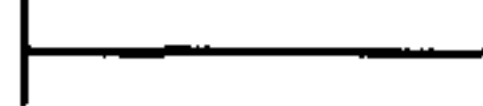
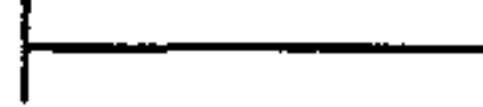
Aerodynamic particle diameter is a function of density. For the purposes of the test methods described in this part of ISO 8573, it is assumed that solid particles have uniform density.

6 Selection of method

The method to be selected depends on the concentration range and the sizes of solid particles in the compressed air. For choosing the method most suitable for the concentration range and sizes of particles estimated to be present in the sample, see Table 1.

The applicability of particular measurement equipment to a method should be verified with the equipment manufacturer.

Table 1 — Guide to selection of method

Method	Applicable concentration range particles/m ³	Applicable solid particle diameter <i>d</i> µm
		≤ 0,10 0,5 1 ≤ 5
Laser particle counter	0 to 10 ⁵	
Condensation nucleus counter	10 ² to 10 ⁸	
Differential mobility analyser	Not applicable	
Scanning mobility particle sizer	10 ² to 10 ⁸	
Sampling on membrane surface in conjunction with a microscope	0 to 10 ³	

7 Sampling techniques

7.1 General

Solid particles can be measured at atmospheric pressure or under ambient pressure conditions depending on the equipment used. Measurement can be carried out at partial or full flow.

- a) Full flow — sampling of total airflow.
- b) Partial flow — sample taken from a percentage of the airflow.

If the particle diameter is greater than 1 µm, then sampling shall be isokinetic.

7.2 Full-flow sampling

7.2.1 General

For full-flow sampling using physical methods, if the particle diameter is greater than 0,5 µm, a gridded membrane shall be used.

The method detailed here deals with the sampling and analysis of airborne particles at constant flowrate, and permits the quantification and sizing of particles in a compressed air system.

Airflow is passed through the test equipment via suitable in-line valves, which have been previously checked to ensure they do not contribute to the level of contamination already present.

Particular attention shall be paid to the cleanliness of the test equipment, and other precautions shall be taken, e.g. valve purging and stabilization to constant test conditions.

Where air is directed to the atmosphere, means should be taken to ensure that the system pressure is maintained.

The temperature and velocity ranges shall be within the ranges specified by the manufacturer.

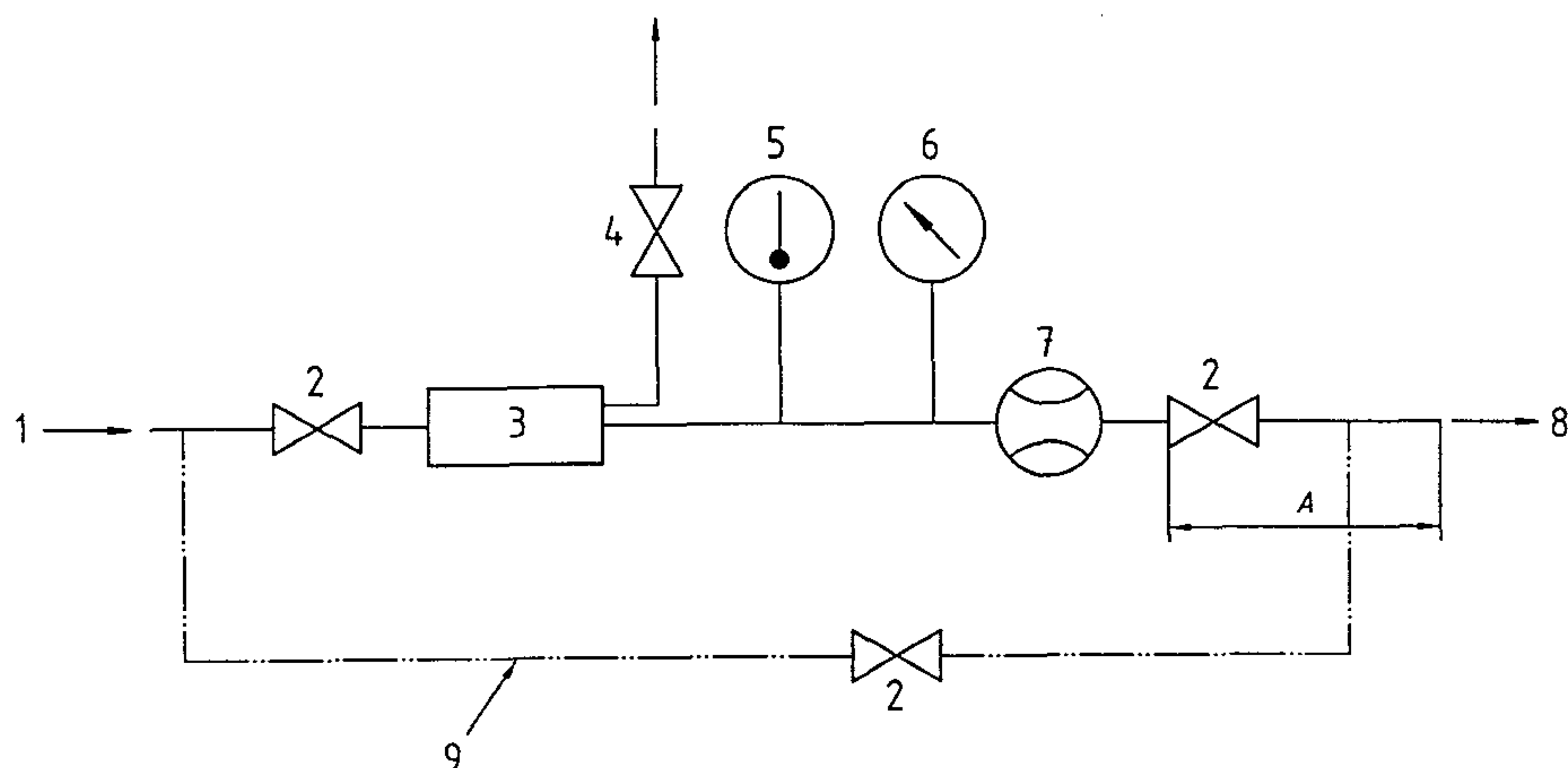
Using this method, the total airflow passes through the sampling equipment.

7.2.2 Test equipment

Full-flow sampling shall be carried out by gridded membrane only.

The general arrangement of the test equipment for full-flow sampling is shown in Figure 1. It is important that the test equipment does not affect the collected sample.

As the test apparatus is portable, different test locations may be chosen, provided the stated parameters are not exceeded and suitable valving for insertion of the test equipment into the circuit exists.



Key

- 1 From process
- 2 Full-flow shut-off valve
- 3 Membrane holder
- 4 Device to depressurize membrane holder
- 5 Temperature indicator
- 6 Pressure indicator
- 7 Flow-measuring device
- 8 To atmosphere or process
- 9 Optional by-pass
- A Minimum distance to discharge to atmosphere as specified in ISO 5167-1

Figure 1 — Test equipment for full-flow sampling

7.3 Isokinetic sampling

7.3.1 General

Accurate isokinetic sampling is not critical for small particles (less than 1 μm), although approximate isokinetic conditions are advisable.

Isokinetic sampling devices should exhibit the following characteristics.

- a) The probe should be a minimum distance of 10 pipe diameters from upstream bends or restrictions and 3 diameters from downstream bends or restrictions.
- b) The size of the probe should not influence the air stream. The nozzles may vary in shape and construction (see 7.3.3).
- c) Impaction onto the internal surface of the probe should be taken into account.
- d) Turbulent flow conditions within the main air stream are required (Reynolds number Re greater than 4 000). In normal industrial use, compressed air is in a state of turbulent flow, which occurs when the following conditions are met:

$$Q \geq \frac{D}{20}$$

where

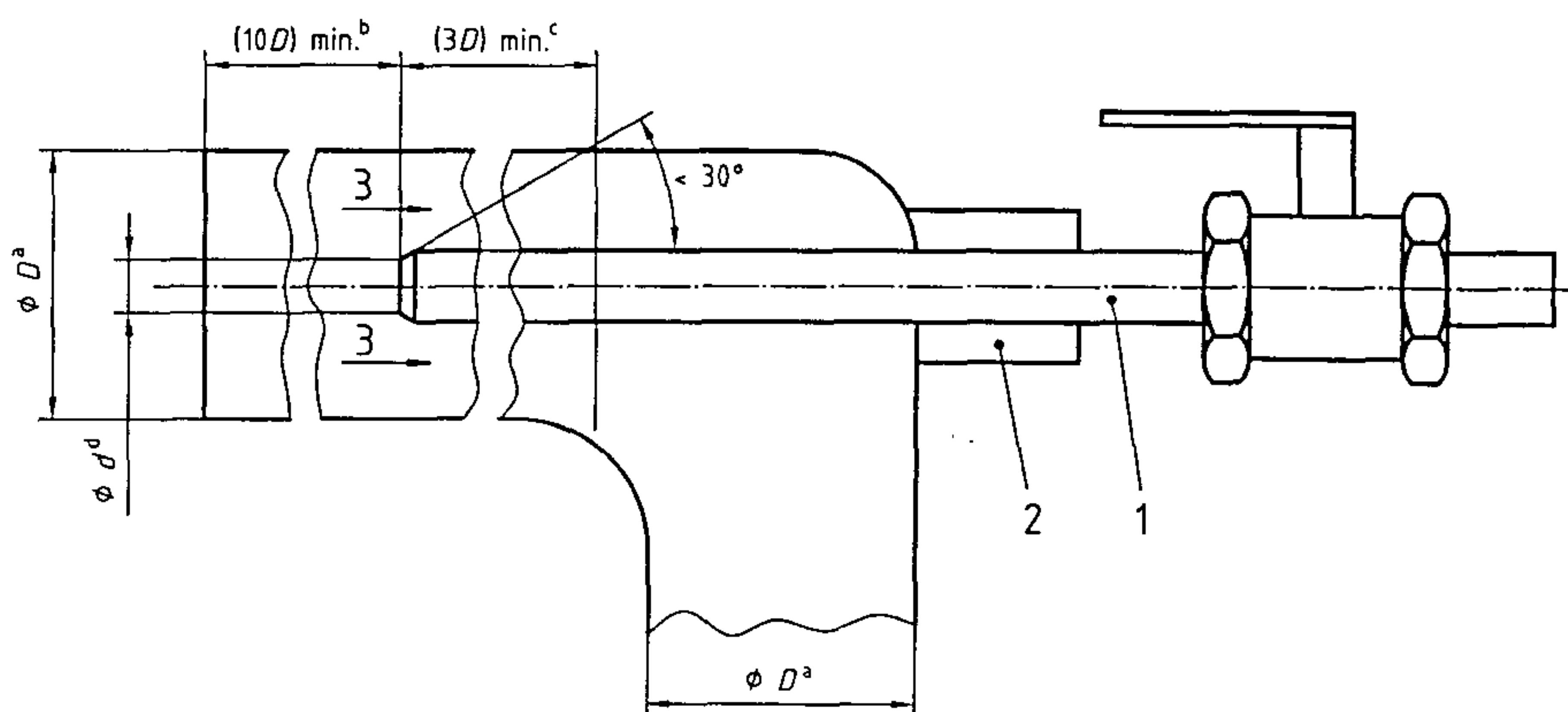
Q is the pipe flowrate, in litres per second (at reference conditions);

D is the actual compressed air pipe diameter, in millimetres.

NOTE Under the test conditions specified, scanning across the pipe diameter with a sampling probe is unnecessary.

7.3.2 Equipment set-up for isokinetic sampling

The set-up for the isokinetic sampling probe at the insertion point of the compressed air system under investigation is shown in Figure 2.



Key

- | | |
|---|---|
| 1 Sampling probe in the main pipe | b Minimum straight length before probe, $10 \times D$ |
| 2 Adjustable gland to allow adjustment of probe | c Probe insertion point at minimum of $3 \times D$ |
| 3 Direction of air flow | d Internal probe diameter, d |
| a Main pipe diameter, D | |

Figure 2 — Equipment set-up of probe insertion for isokinetic sampling

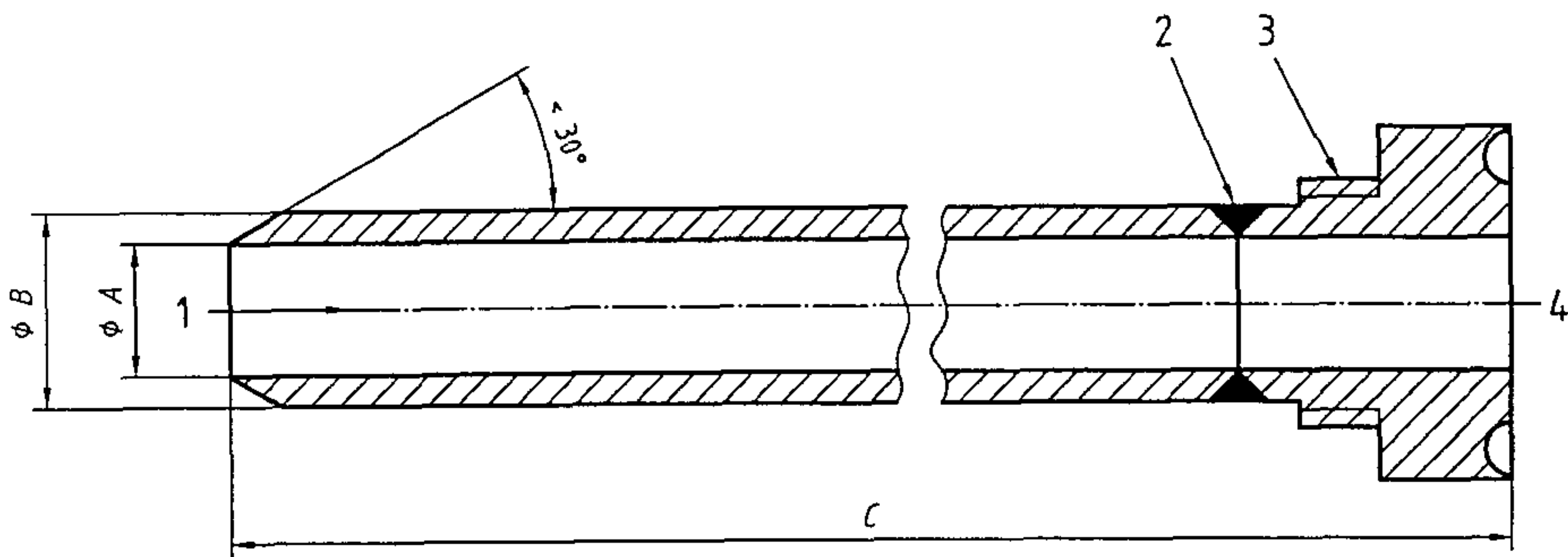
7.3.3 Design of the isokinetic sampling probe

The general construction of the probe is shown in Figure 3.

The probe shall be of circular cross-section, the open end of the tube having a wall thickness of less than 1,3 mm and the internal and external surfaces having an inclination not greater than 30° (see Figure 2).

The angle at the nozzle minimizes the effect of impact onto the end of the probe. The probe dimension shall be selected to give the appropriate flow for the measurement device applied, based on prevailing flow conditions in the main pipe.

The probe should be designed to be compatible with the measuring instrument being used. If the sampling is carried out in stages, isokinetic conditions should be maintained where possible. If isokinetic sampling is not possible, then this shall be agreed.



- Key**
- 1 Direction of flow
 - 2 Crevice-free joint
 - 3 Suitable pressure-tight thread connection
 - 4 To membrane holder

Probe size	A mm	B mm	C mm
1	7	9,6	200
2	10	12,6	200
3	17	19,6	400

Figure 3 — Isokinetic sampling probe

7.3.4 Compressed air flowrates

The air velocities within the main pipeline Q and within the probe q shall be identical throughout the sampling period. This is accomplished through adjustment of the flow controllers to provide appropriate readings on the flow meters.

Both Q and q shall be measured and maintained.

Identical pipe and probe velocities exist when the pressures are constant and identical, i.e.:

$$\frac{Q}{q} = \frac{D^2}{d^2}$$

where

Q is the total pipe discharge, in litres per second;

q is the probe discharge, in litres per second;

D is the internal actual main pipe diameter, in millimetres;

d is the internal probe diameter, in millimetres.

7.4 Reducing system pressure before measurement

If the system pressure is reduced before the measurement, the reduction method shall not influence the resulting particle count and particle distribution.

7.5 Average values

Depending on the reproducibility of the method, the measurement facility and the experience of the parties involved in the provision of the measurement facility, the average value of consecutive measurements at the sampling point shall be used.

7.6 Operating conditions

Actual operating conditions shall be described in the test report.

8 Measurement methods

8.1 General

Below are listed a number of preferred methods for measurement of solid particle content by counting. This list is not exhaustive and other methods are available for use by agreement.

Consideration shall be given to the calibration requirements of the measurement equipment used as described in manufacturers' instructions.

Estimated particle concentration shall be within the measurement limits of the equipment, as given by the equipment manufacturer.

The sampling and test equipment shall not influence the particle distribution being measured.

For more detailed information see annex B.

8.2 Laser particle counting

A Laser Particle Counter (LPC) is suitable for measuring particles with aerodynamic diameters between 0,1 µm and 5 µm.

8.3 Condensation nucleus counting

The Condensation Nucleus Counter (CNC) enlarges the particle to an optically detectable size by condensing a supersaturated vapour onto the particle nucleus. It is suitable for counting particles in the diameter range 0,01 µm to 3 µm.

Pressure and temperature limits of the method are provided in the equipment manufacturer's specifications. This method is used in conjunction with a Scanning Mobility Particle Sizer.

8.4 Differential mobility analysis

The Differential Mobility Analyser (DMA) is used as a particle band-pass filter. The size selection is based on the electrical mobility of charged particles.

8.5 Scanning mobility particle sizing

The Scanning Mobility Particle Sizer (SMPS) combines both the DMA and CNC instruments. Particles entering the DMA are classified by size and sent to the CNC for concentration measurement. The SMPS is best for relatively high concentrations of 100 to 10^8 particles per cubic metre. It is the only size-discriminating detector that can accurately count particles of diameter below 0,1 µm.

8.6 Sampling on membrane surface in conjunction with a microscope

This system employs a gridded membrane, with a classification suitable for the intended measurement range, in conjunction with a microscope. It is not as fast as the previous two methods in that detection is carried out once the sampling has taken place. The method is used to measure particles of diameter in the range 0,5 µm to 5 µm. To determine particle concentration by microscopy, the method described in BS 3406-4 should be employed.

The optimum duration of a test measurement may be determined after an initial test to determine the approximate particle concentration present. When carrying out full-flow tests, it is possible to route the air back into the compressed air systems, preventing loss of the product. Conversely, it is also possible to vent the flow to the atmosphere. Flow measurement is required to determine the volume of air used during the test, whichever method is adopted. Obvious precautions to prevent shock depressurization, which may damage the test equipment, or ingress of atmospheric contamination, are necessary. Appropriate physical parameters, e.g. temperature, pressure, volume and flowrate, shall be recorded as in 11.2.

9 Evaluation of test results

9.1 Reference conditions

Reference conditions for volume statements are given in Table 2.

Table 2 — Reference conditions

Air temperature	20 °C
Air pressure	1 bar ^a absolute
Relative water vapour pressure	0
^a 1 bar = 0,1 MPa	

9.2 Influence of humidity

The measured particle concentration shall be corrected to refer to the dry air volume as given by the partial pressure of the air at the sampling point.

9.3 Influence of pressure

Particle concentration shall be corrected to reference pressure conditions.

Particle concentration will vary in direct proportion to the variation in the ratio of system to sample absolute pressures.

9.4 Influence of temperature

Solid particle concentration shall be corrected to reference temperature conditions.

Temperature may also affect particle measurement results if the particles are unstable at the measurement temperature or the rated temperature of the sampling equipment is exceeded.

9.5 Influence of other contaminants

The influence of liquids other than water shall be given due consideration when selecting a test method.

10 Uncertainty

Due to the very nature of physical measurements, it is impossible to measure a physical quantity without error or, in fact, to determine the true error of any one particular measurement. However, if the conditions of the measurement are sufficiently well known, it is possible to estimate or calculate a characteristic deviation of the measured value from the true value, such that it can be asserted with a certain degree of confidence that the true error is less than the said deviation. The value of such a deviation (normally 95 % confidence limit) constitutes a criterion of the accuracy of the particular measurement.

It is assumed that all systematic errors that may occur in the measurement of the individual quantities and of the characteristics of the air may be compensated for by corrections. A further assumption is that the confidence limits in errors in reading and integration errors may be negligible if the number of readings is sufficient.

The (small) systematic errors that may occur are masked by the inaccuracy of measurements.

Quality classifications and limits of error are often invoked for ascertaining the uncertainty of individual measurement because, apart from the exceptions such as electrical transducers, they constitute only a fraction of the quality class or the limit of error.

The information concerning the uncertainty of measurement of the individual quantities and the confidence limits of the gas properties is an approximation. Such approximations can only be improved at a disproportionate expense. See ISO 2602 and ISO 2854 for further information.

NOTE A calculation of the probable error in accordance with this clause is not always necessary.

11 Test report

11.1 Statements

Statements of the number of particles in the compressed air shall be made in such a manner that the values can be verified in accordance with the procedures of this part of ISO 8573. The influence of any liquids present in the sample which may affect the particle count shall be recorded.

11.2 Statement format

The test report used to declare solid particle concentration determined in accordance with this part of ISO 8573 shall contain the following information:

- a) description of the compressed air system and its working conditions, with sufficient detail to determine the applicability of the declared values of
 - volume flowrate,
 - sampling time,
 - pressure,
 - temperature,
 - other contaminants (including water/oil).
- b) description of the point at which the samples were taken;
- c) description of the sampling and measurement system that was used, particularly materials used, and details of its calibration record;
- d) the words "Declared solid particle concentration in accordance with ISO 8573-4", followed by:
 - the actual, average measured value evaluated in accordance with clause 9 above, corrected to **reference** conditions;
 - the actual, average measured value evaluated in accordance with clause 9 above, citing the **actual** conditions;
 - the solid particle concentration, expressed as the number of solid particles in respective size classes, at sampling and reference conditions;
 - the pressure and temperature to which the measurement refers;
 - a statement regarding the applicable uncertainty of the measured value;
 - the date of calibration.
- e) the date of the sampling and measurements.

A sample of a test report is given in annex A.

Annex A (informative)

Sample test report on determination of solid particle content in compressed air

The compressed air system at OSI Industries consists of four air compressors, after-coolers and refrigerant-type dryers, with one stand-by compressor, two compressors working full load and one compressor loaded to approximately 50 %. The system working pressure is set at 7 bar(e); measurements on the solid particle contaminants were made in the system where the supply pipe enters the B-shop.

Samples were taken regularly at 1-h intervals during 8 h on 1996-01-23.

The pressure at the sampling point was 6,6 bar(e).

The measurements were made using a gridded membrane and microscope having a lower limit of observation of 0,5 μm . If the measurement was outside a particular range, it was identified as being "not measured".

The system was calibrated on 1995-11-30 as per record.

Table A.1 — Example of declared solid particle concentration in accordance with ISO 8573-4

Conditions	Solid particle concentration particles/m ³				Uncertainty	Pressure bar(e)	Temperature °C
	Particle size $\leq 0,10 \mu\text{m}$	Particle size $0,10 < d \leq 0,5$ μm	Particle size $0,5 < d \leq 1,0$ μm	Particle size $1,0 < d \leq 5,0$ μm			
Reference conditions			8×10^3			0	20
Actual conditions	not measured	not measured	$7,54 \times 10^3$	not measured		6,6	26

Annex B (informative)

Description of measurement methods

B.1 Laser particle counting

A Laser Particle Counter measures light scattered from a cloud of particles that passes through a focused light beam. The signal most closely relates to the mass, or more exactly the volume, of the particles and depends on the refractive index and shape of the particles. Laser Particle Counters are suitable for measuring particles with aerodynamic diameters between 0,1 μm and 5 μm and have some advantages in their low cost and low maintenance.

The sampling rate of most particle detection equipment is relatively low, typically 1 cm^3/s . The main problem is the introduction of contamination in the sampling network.

B.2 Condensation nucleus counting

The Condensation Nucleus Counter (CNC) is used in conjunction with the Scanning Mobility Particle Sizer.

A CNC is suitable for measuring particles in the range 0,01 μm to 3 μm .

The CNC enlarges the particle to an optically detectable size by condensing a super-saturated vapour, typically butanol, onto the particle nucleus. The relatively large droplets are counted in a simple optical particle detector. All particles grow to approximately the same droplet diameter, independent of original particle size, so the CNC detects all particles equally well but does not discriminate their size.

The droplets produce a relatively large signal, and therefore the CNC has a high signal-to-noise ratio with a negligible false-count rate. Because of their extremely wide concentration range and low false count rate, CNCs are commonly used to test particle content of compressed air after high and ultra-high efficiency filters.

B.3 Differential mobility analysis

The Differential Mobility Analyser (DMA) can be thought of as a particle band-pass filter. The DMA extracts a narrow range of particle sizes from a poly-disperse aerosol. The size selection is based on the electrical mobility of charged particles. The DMA consists of concentric cylindrical electrodes; a grounded outer electrode and an inner electrode held at a high voltage potential. The aerosol enters the outer annular ring between electrodes and flows, along with an inner ring of clean sheath air, through the DMA. Particles of opposite polarity migrate towards the inner electrode, their trajectory governed by the air flowrate and the particles' electrical mobility (which is inversely proportional to particle size). By changing the voltage potential, the concentration of particles of different sizes can be measured.

B.4 Scanning mobility particle sizer (SMPS)

The Scanning Mobility Particle Sizer combines both the DMA and CNC instruments. Particles entering the DMA are classified by size and sent to the CNC for measurement of concentration. A computer controls the voltage scan of the DMA, records concentration data from the CNC, and converts the raw data into a usable size distribution. The SMPS is best for relatively high concentrations of 100 to 10^8 particles/ m^3 . It is the only size-discriminating detector that can accurately measure the concentration of particles of diameter below 0,1 μm .

B.5 Sampling on gridded membrane surface in conjunction with an optical microscope

This system is not as fast as the previous two, in that the detection is carried out once the sampling has taken place. This in itself can be a labour-intensive task, as the sample needs to be statistically verified to ensure accuracy. It is used to measure particles of diameter in the range 0,5 μm to 5 μm . The advantage is the relative high sampling rate, allowing full-flow measurements to be taken in some cases. The method does not distinguish between different species of particles; however as the count process is often by eye, some differentiation is possible.

Bibliography

- [1] ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*.
- [2] ISO 2854, *Statistical interpretation of data — Techniques of estimation and tests relating to means and variances*.
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- [4] BS 3406-4, *Methods for determination of particle size distribution. Guide to microscope and image analysis methods*.



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