INTERNATIONAL STANDARD

ISO 8573-4

Second edition
2019-02

Compressed air — Contaminant measurement —

Part 4: Particle content

Air comprimé — Mesurage des polluants —

Partie 4: Teneur en particules

Reference number
ISO 8573-4:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 4 *Compressed air treatment technology*.

This second edition cancels and replaces the first edition (ISO 8573-4:2001), which has been technically revised. It also incorporates the Technical corrigendum ISO 8573-4:2001/Cor.1:2002.

A list of all parts in the ISO 8573 series can be found on the ISO website.

Introduction

Particles are a common contaminant in compressed air and this document details the correct sampling methodology and assists the user in selecting equipment and instrumentation and the determination of particle size and concentration.

In addition, it is to be used to assess compressed air purity such that the purity class can be stated in accordance with ISO 8573-1 for particles of Class 1, 2, 3, 4 and 5, and can be used only by agreement between consenting parties when measurements to purity Class 0 are to be performed.

This document does not detail the methods to be used to determine the mass concentration of particles as required for the particle purity Classes of 6, 7 and *X* as detailed in ISO 8573-1 of the series, for which ISO 8573-8 is required.

Historically it was the intention to only consider solid particles for the purposes of the particle purity class measurement. The detection methods detailed here however are not substance selective and thus this standard reports all particles present in the compressed air within the size ranges measured.

By reference to the other standards in the ISO 8573 series the component parts of the particle concentration can be assessed e.g. oil, water or solid particles. Solid particles may also include debris, carbonaceous matter and viable microorganisms.

The annexes of this document provide general guidance to the types of equipment available to the user for the measurement of particle concentration in compressed air.

Compressed air — Contaminant measurement —

Part 4: Particle content

1 Scope

This document provides a method for sampling compressed air and a guide for choosing suitable measuring equipment to determine its particle size and concentration by number (to be referenced as "concentration" throughout this document). It also describes the limitations of the various measurement methods and describes the evaluation and uncertainty considerations.

This document will report the particle size and concentration of all types of particle combined and does not aim to be able to segregate the separate solid and liquid particle fractions. When it is required that the concentration of a specific fraction is to be determined then recourse to the relevant standard method from the ISO 8573 series is recommended.

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

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

NOTE 3 This document does not address instances where non-isothermal conditions exist, and separate arrangements should be made where particles may be formed by vapour condensation or lost through evaporation.

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. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3857-4, *Compressors, pneumatic tools and machines — Vocabulary — Part 4: Air treatment*

ISO 8573-1, *Compressed air — Part 1: Contaminants and purity classes*

ISO 21501-1, *Determination of particle size distribution — Single particle light interaction methods — Part 1: Light scattering aerosol spectrometer*

ISO 21501-4, *Determination of particle size distribution — Single particle light interaction methods — Part 4: Light scattering airborne particle counter for clean spaces*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3857-4 and ISO 8573-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
optical aerosol spectrometer
OAS
light scattering aerosol spectrometer used for measuring the size, number concentration and number/size distribution of particles suspended in a gas

Note 1 to entry: This device is described in ISO 21501-1.

3.2
optical particle counter
OPC
light scattering airborne particle counter used for measuring the size and particle number concentration of particles suspended in air

Note 1 to entry: This device is described in ISO 21501-4.

4 Units

General use of SI units (see ISO 80000-1) as given throughout this document is recommended. However, in agreement with accepted practice in the pneumatic industry sector, some non-preferred SI units, accepted by ISO, are also used.

1 bar = 100 000 Pa

NOTE bar(e) is used to indicate effective pressure above atmospheric.

1 l (litre) = 0,001 m^3

5 Reference conditions

Reference conditions for volume statements are as follows:

— air temperature: 20 °C

— absolute air pressure: 100 kPa [1 bar (a)]

— relative water vapour pressure: 0

6 Particle type

6.1 General

Particles are characterized by their properties of material, particularly their size, density, shape, transparency, colour, vapour pressure and hardness. A particle may be in the solid or liquid phase. Solid particles may also comprise microbiological viable and non-viable particles.

NOTE Agglomerates may be comprised of all types of particles.

6.2 Liquid particles

Liquid particles are sized, counted and their concentration determined using this document. If it is necessary to determine the fraction which comprises oil by mass, then ISO 8573-2 should be applied. Where liquid water content is to be determined by mass then ISO 8573-9 should be applied.

6.3 Solid particles

6.3.1 General

Solid particles are sized, counted and their concentration determined using this document. On occasion that the concentration by mass is to be determined then ISO 8573-8 should be applied.

6.3.2 Microbiological particles

The compressed air may include in its composition microorganisms of a viable and/or non-viable nature which will be counted as part of the total concentration reported by this document. Viable particles include pollen, bacteria, fungi and their spores. If it is necessary to determine the fraction which comprises viable particles, then ISO 8573-7 should be applied.

7 Selection of method

7.1 General

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

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

Table 1 — Guidance to selection of method

Method	Applicable particle diameter d µm
Sampling disc sampling and sizing/counting by light optical microscopy (LM) (BS 3406-4)[7][a][b]	≥5,0
Sampling disc sampling and sizing/counting by scanning electron microscope (SEM) (BS 3406-4)[7][a][b]	≥0,005
Optical particle sizing and counting instrument	≥0,06 to ≤100

[a] Manual full sampling disc surface counting, sizing and classifying is a laborious process, therefore an automated technique to perform these tasks is recommended.

[b] Determination of mass concentration is also possible by pre-weighing the sampling discs and calculating their weight increase after the test followed by elemental analysis if required.

7.2 Sampling on sampling disc surface in conjunction with a microscope

This system employs a sampling disc with a classification suitable for the intended measurement range, in conjunction with a microscope. It is not as fast as light scattering methods in that detection is carried out after the sampling has taken place. The range of particle sizes that can be counted and sized depends on the type of microscopic technique applied, further guidance is given in Annex B. To determine particle size and number by microscopy, the method described in BS 3406-4 should be applied.

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, taking into account pressure and temperature, to determine the volume of air used during the test, whichever method is adopted. Take precautions to prevent shock depressurization, which may damage the test equipment, or ingress of atmospheric contamination. Guidance for the recording of parameters, e.g. temperature, pressure, sampling time and flowrate, and their presentation in the test report is given in Clause 10.

Sampling disc sampling may be unsuitable for the sizing of liquid particles in compressed air due to evaporation effects. One advantage of this method is its ability to determine a particle's elemental or chemical composition by other analytical means such as energy dispersive X-ray spectroscopy often coupled to an SEM.

Once the particles collected on the sampling disc have been counted and sized their concentration can be determined using Formula (2).

7.3 Sampling using particle sizing and counting instruments

7.3.1 General

There are many types of particle sizing and counting instruments. An instrument with the capability to measure the size and concentration of the particles in air shall be selected. Instrument sample air flow rates are typically low and thus it is likely that sizing and counting using an instrument-based approach will be performed on a representative sample of the air obtained using isokinetic sampling principles.

There are particle sizing and counting instruments that can be operated at the same pressure as that of the compressed air. These are preferable to instruments that only operate at atmospheric pressure but may be limited in sensitivity due to the detection method. When sampling from a compressed air system using an instrument that cannot withstand the system pressure, a compressed air diffuser shall be used (see Annex E). Pressure regulators shall not be used in place of a compressed air diffuser to reduce the pressure and obtain a sample of air.

7.3.2 Instrument selection

The instrument used shall be based upon the light scattering measurement principle for single particle measurements. It may either be an optical aerosol spectrometer (OAS) described as a light scattering aerosol spectrometer in ISO 21501-1, or an optical particle counter (OPC) described as a light scattering airborne particle counter in ISO 21501-4. For more information see Annex B.

Take care to ensure that the instrument selected is suitable for the particle size and concentration range to be measured (see Table 2).

Table 2 — Guidance to particle size and concentration by number OAS and OPC counters

Instrument type	Typical particle size range µm	Typical maximum particle concentration particles/m^3
Optical aerosol spectrometer (OAS)	≥0,06 to ≤100	1×10^{12}
Optical particle counter (OPC)	≥0,1 to ≤10	5×10^{7}

7.3.3 Instrument calibration

The instrument selected shall have a valid calibration certificate, wherein the calibration has been performed using certified and NIST traceable polystyrene latex microspheres (PSL), selected to cover the size range or ranges in which the particle size measurement will be performed. Calibration of the OAS or OPC shall have been conducted in accordance with ISO 21501-1 or ISO 21501-4 respectively, in the range of interest and be no more than 12 months old.

When using instruments supplied with a test dust for the purposes of checking calibration and performance, the dust shall have a valid calibration certificate from the manufacturer and be not more than 12 months old.

7.3.4 Coincidence and dilution

Take care to ensure when operating the particle counting instrument that the maximum concentration is not exceeded. If the maximum concentration is exceeded this would result in coincidence. Particle coincidence would result in the instrument reporting a larger particle size than actually present and a lower total number of particles counted per unit of volume. Where concentrations are present that exceed the allowable limits of the instrument in use, a particle dilution system shall be used (see Annex F). Consult the instrument manufacturer to identify a suitable particle dilution system for performing this task. The dilution ratio shall remain constant over the operating concentration range of the equipment.

8 Sampling techniques

8.1 General

The sampling equipment measurements can be carried out at full or partial flow.

a) Full flow — sampling of total airflow.

b) Partial flow — a representative sample taken from a percentage of the airflow.

In both cases to determine the concentration of the particles in the air sampled, the total volume of air sampled shall be known. This can either be recorded directly by a totalising flowmeter or as the product of the set flow rate and the period the air was being sampled.

The sample air flow rate shall not exceed the operating limits of the sampling device. The air flow rate should be constant.

8.2 Full flow sampling

For full flow sampling procedures refer to Annex C. Full flow sampling is likely to only be practical when applying the principle to sizing and counting using sampling discs due to the small sample flowrates generally in use with particle counting instruments.

8.3 Partial flow sampling

Where partial flow sampling is required then refer to Annex D.

The sample shall be collected at isokinetic conditions relative to the flow of the air being sampled. Isokinetic sampling devices shall exhibit the following characteristics;

a) The probe entrance shall be a minimum distance of 10 pipe diameters from upstream bends or restrictions and 3 diameters from downstream bends or restrictions.

b) The probe shall be inserted to an approximate central position across the pipe diameter

c) The probe entrance shall be tapered at an angle ≤30° to prevent the probe from influencing the flow at the sampling point and should be of the same cross-sectional shape as the pipe inside which it is situated. The nozzles may vary in shape and construction (see Figure D.2).

d) The probe shall be checked visually internally and cleaned, if necessary, before and after use and any impaction onto the internal surface of the probe during sampling shall be taken into account.

e) Turbulent flow conditions within the main air stream are required (Reynolds number, R_e, 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 in Formula (1):

$$\left(q_w + q_p\right) > D/20 \tag{1}$$

where

q_w is the waste discharge, in l/s (at reference conditions);

q_p is the probe discharge, in l/s (at reference conditions);

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

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

9 Evaluation of test results

9.1 Influence of humidity, temperature and pressure

The air flow rate used to calculate the concentration of particles in the sampled air shall be corrected to the reference conditions. See Clause 5.

9.2 Number concentration

Once the size and number, N_d, of particles has been measured the concentration, $C_{n(x)}$, can be calculated from Formula (2);

$$C_{n(d)} = N_d \times (Q \cdot t)^{-1} \tag{2}$$

where

$C_{n(d)}$ is the number concentration for a given particle size or range, in particles/m^3;

N_d is the total number of particles counted of a given particle size or range;

d is the corresponding particle size or range;

Q is the flowrate of the analysed compressed air through the sampling equipment, in m^3/s;

t is the total time (s) for which compressed air has been sampled through the sampling equipment.

10 Test report

The test report shall identify the location and conditions under which the particle size and concentration was determined.

The test report used to declare particle concentration determined in accordance with this document shall contain the following additional information as a minimum:

a) details of the company and location at which the test was performed;

b) a reference to this document, e.g. ISO 8573-4:2019;

c) a description of the point in the system at which the measurements were taken;

d) a record of the particle concentration, volume flow rate, temperature, pressure and sampling time for each measurement;

e) a description of the sampling and measuring system including instrument names and serial numbers;

f) the date at which the particle sizing and counting instrument was last calibrated;

g) the words "Declared particle concentration in accordance with ISO 8573-4:2019”, followed by the concentration relating to the size or range over which the measurement was made corrected to reference conditions in Clause 5;

h) a statement regarding the applicable uncertainty of the measured values.

An example test report is given in Annex A.

Annex A
(informative)

Example test report on determination of particle content in compressed air

The compressed air system at Optical Industries Inc consists of four air compressors, aftercoolers 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).

Samples were collected for 60 s at 1 h intervals over an 8 h period on 14/06/2018 using a partial flow sampling method.

Company:	Optical Industries Inc		
Location of measurement:	Spray shop B, Booth 7, compressed air feed to gun		
Particle counter manufacturer:	XYZ Industries		
Model:	Partsense OPC		Serial Number 098765
Instrument Flow:	28 l/min	Measuring range:	0,1 µm to 5,0 µm
Date of last calibration:	23/11/2017		
Calibration Certificate:	AB12345	Sampling technique:	Isokinetic
Compressed air diffuser:	Yes	Sample Dilution:	No

Declared particle concentration in accordance with ISO 8573-4:2019

Date and time stamp	$C_{n(d)}$ number of particles per cubic metre as a function of particle size, d				System flow rate	Pressure	Tempera-ture	Pressure Dewpoint
	Particle size $0,10 \leq d$ <0,5 µm	Particle size $0,5 \leq d$ <1,0 µm	Particle size $1,0 \leq d$ <5,0 µm	Particle size >5,0	m^3/h	bar(e)	°C	°C
23/04/18 08:16:40 08:16:23	32 400	4 860	81	0	1 166,4	6,61	16,8	−37,5
23/04/18 09:16:40 09:16:23	25 200	3 780	63	0	907,2	6,58	17,4	−34,2
23/04/18 10:16:40 10:16:23	35 600	5 340	89	0	1 281,6	6,59	18,6	−33,8
23/04/18 11:16:40 11:16:23	28 000	4 200	70	0	1 008,0	6,63	19,6	−33,1
23/04/18 12:16:40 12:16:23	27 200	4 080	68	0	979,2	6,61	20,4	−28,6

Date and time stamp	$C_{n(d)}$ number of particles per cubic metre as a function of particle size, *d*				System flow rate	Pressure	Tempera-ture	Pressure Dewpoint
	Particle size 0,10 ≤ *d* <0,5 µm	Particle size 0,5 ≤ *d* <1,0 µm	Particle size 1,0 ≤ *d* <5,0 µm	Particle size >5,0	m³/h	bar(e)	°C	°C
23/04/18 13:16:40 13:16:23	30 000	4 500	75	0	1 080,0	6,60	19,7	−28,0
23/04/18 14:16:40 14:16:23	33 200	4 980	83	0	1 195,2	6,52	19,3	−29,2
23/04/18 15:16:40 15:16:23	34 800	5 220	87	0	1 252,8	6,57	18,8	−30,3
Declared particle concentration (particles/m³) in accordance with ISO 8573-4.								
Average	30 800	4 620	77	0	1 108,9	6,59	18,8	−31,8
The uncertainty of the measurement system has been determined to be ±10 %.								

Annex B
(informative)

Description of measurement methods and particle sizing

B.1 Sampling on a sampling disc surface in conjunction with an optical microscope

This system is not as fast as particle sizing and counting with an online instrument, in that the detection is carried out after the sampling has taken place. The detection process itself can be a labour-intensive task, as the sample size needs to be sufficiently large and statistically verified to ensure accuracy. The sizing and counting process is usually semi or fully automated, thus reducing counting errors and improving repeatability. They can typically be used to measure particles from ≥0,005 µm to ≤1,000 µm depending on chosen method. The advantage is the relatively high sampling rate, allowing full flow measurements to be taken in some cases. The method does not distinguish between different species of particles; however, imagery collected can show additional information such as shape and colour not available from online counting systems.

The selection of the method of measurement depends on the concentration range and the sizes of particles in the compressed air. Table B.1 provides guidance for choosing the method most suitable for the sizes of particles estimated to be present in the sample.

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

Table B.1 — Guidance to selection of method

Method	Applicable particle diameter *d* µm
Sampling disc sampling and sizing/counting by light optical microscopy (LM) (BS 3406-4)[a][b]	≥5,0
Sampling disc sampling and sizing/counting by scanning electron microscope (SEM) (BS 3406-4)[a][b]	≥0,005

[a] Manual full sampling disc surface counting, sizing and classifying is a laborious process and for this reason an automated technique to perform these tasks is recommended.

[b] Determination of mass concentration is also possible by pre-weighing the sampling disc and calculating their weight increase after the test and elemental analysis if required.

Furthermore, when using microscopes based upon the scanning electron principle, the ability to perform elemental analysis using energy dispersive X-ray analysis (EDXA) for chemical characterisation of specific particles or areas of the sampling disc is usually available.

The sampling disc used for the collection of the sample should have a rating suitable for the size and type of particles to be measured. Gridded sampling discs are helpful when performing manual optical microscopic sizing but not essential, particularly if the process is performed on an automated microscope stage with counting and size classifying software.

Some sampling disc materials that have been found suitable (but not limited to) are as follows:

— Polytetrafluoroethylene (PTFE);

— Polyvinylchloride (PVC);

— Mixed cellulose ester (MCE);

— Polysulfone;

— Borosilicate glass fibre;

— Vinyl/acrylic copolymer.

B.2 Sampling using particle counting instruments

Many particle counting instruments have the capability to measure the size range and concentration of particles carried in an air stream. Seek advice from the manufacturer or manufacturer's representative in selecting the correct instrument. Instrument sample air flow rates are typically very low and thus it is likely that sizing and counting using an instrument-based approach will be performed on a representative sample of the air obtained using isokinetic sampling principles.

In some cases, particle sizing and counting instruments are available that can be operated at the same pressure as that of the compressed air. These are preferable to instruments that only operate at atmospheric pressure, because the rapid expansion of the sampled air through a high-pressure gas diffuser can lead to sampling errors and requires the separate validation of the diffuser but may be limited in sensitivity due to the detection method.

B.2.1 Particle counters based upon light scattering techniques

Particle counting instruments based upon single particle light interaction techniques pass a beam of light through air of a known refractive index which then encounters particles of a different refractive index and results in light becoming scattered. Particle counting instruments employ highly polished mirrors and lenses to focus the scattered light on to a detector which converts the scattered light in to electrical pulses. The pulse represents the presence of a particle and its magnitude represents the size of the particle. By knowing the rate of air flow and the period over which the number of particles was counted, a particle size and number concentration is determined. The ability of the instrument to resolve changes in the scattered light intensity determines the resolution of the counter. The minimum count rate efficiency relates to the counter, usually referenced at 50 % count rate efficiency for a given size.

There are two main classes of optical particle counters based on single particle scattered light detection techniques:

— optical aerosol spectrometer (OAS) described as a light scattering aerosol spectrometer in ISO 21501-1, or

— optical particle counter (OPC) described as a light scattering airborne particle counter in ISO 21501-4.

B.2.1.1 Optical aerosol spectrometer (OAS)

OAS instruments count pulses of scattered light from a single particle that passes through a defined optical measurement volume illuminated with a focused light beam. The shape of individual particles measured are assumed to be spherical. The amount of light scattered depends upon the light reflection, refraction and diffraction properties of the particle. Thus, the size reported is substance specific and expressed as an equivalence to a reference calibration substance usually as spheres of polystyrene latex (PSL) with known refractive index and nominal density.

These instruments are broadly defined by two types of construction which defines the way in which the particle is illuminated. They either employ an intracavity laser, or more commonly, a polychromatic light source. Both constructions benefit from substantially improved particle size resolution over that of OPC instruments. They typically have up to 64 size channels per decade in the size range being measured.

Intracavity laser instruments have a sample flow range of typically 0,01 l/min to 0,1 l/min whereas polychromatic light instruments can typically flow 5 l/min and thus larger sampling volumes can be measured in a shorter sampling time period. Intracavity laser instruments are also generally limited in the range of particle size (≥0,06 µm to ≤10 µm) and maximum concentration that can be measured but benefit from their capability in measuring low concentrations of particles.

OAS instruments based on polychromatic light are generally more tolerant to high concentrations of particles, typically up to 1×10^{12} particles/m^3, and a larger size range spanning typically 0,12 µm to 100 µm. Variants of this type of instrument are available to measure particles directly in the compressed air with the need for a compressed air diffuser and losses due to the diffuser do not need to be accounted for in the measurement.

For OAS instruments the size of the particle that can be measured is directly related to the defined optical volume of the sensor. As this optical volume increases they are less tolerant to high concentrations of particles in the sampled stream. Further details relating to single particle light interaction methods can be found in ISO 21501-1:2009, Annex A.

B.2.1.2 Optical particle counter (OPC)

Optical particle counters (OPC) count pulses of scattered light from single particles, or in some cases, they count the shadows cast by backlit particles through a defined optical measurement volume. Generally, the particle to be measured is illuminated by a monochromatic light source such as a He-Ne laser.

Individual particles measured are assumed to be spherical in shape. The amount of light scattered depends upon the light reflection, refraction and diffraction properties of the particle. Thus, the size reported is substance specific and expressed as an equivalence to a reference calibration substance such as spheres of polystyrene latex (PSL) with known refractive index and nominal density.

Laser based OPCs are suited to clean room monitoring sampling at relatively high sample flow rates of typically 28 l/min to 100 l/min because they allow substantially shorter test durations which is particularly useful when measuring such low particle concentration levels.

One disadvantage of using laser light to size a particle is the difficulty in evenly illuminating the optical volume in which the particle is passing through. This is because the centre of the laser beam is brighter than the edge. Consequently, the ability of these instrument to resolve differences in particle size is limited and can result in <10 particle size channels over a range between ≥0,1 µm to ≤10,0 µm in size.

B.3 Particle sizing

B.3.1 General

There are several ways to describe a particle size. Furthermore, a particle may be in a solid or liquid form. Due to the wide variety of sources from which particles are formed, such as those occurring naturally or anthropogenic, particles are rarely of regular shape. This irregularity makes sizing a challenging process.

Particles are typically assessed on the basis of diameter, volume, weight or surface area where these characteristics are often equated to an equivalent spherical diameter.

B.3.1.1 Equivalent spherical diameter

The equivalent diameter of a sphere that has the same properties of the particle being measured. Properties considered may be projected surface area, volume, mass, sedimentation velocity, electrical mobility, scattered light, diffusion etc. In each case the diameter reported is an equivalence to that of the property being measured.

B.3.1.2 Scattered light diameter

The equivalent diameter of a homogeneous sphere of a reference material that has the same scattered light properties as the measured particle when said particle is sized using single particle light interaction techniques. Calibration of such devices is usually undertaken with monodisperse reference materials such as those manufactured from polystyrene latex (PSL) with a defined refractive index and size traceable dimensions.

Annex C
(informative)

Full flow sampling

C.1 General

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

The method detailed here deals with the sampling and analysis of airborne particles at a constant flow rate 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 add 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, take precautions to ensure that the system pressure is maintained, the air is safely expanded to atmosphere and silencers fitted as required. The temperature, pressure and velocity ranges for the apparatus shall be within those specified by the manufacturer.

C.2 Sampling equipment

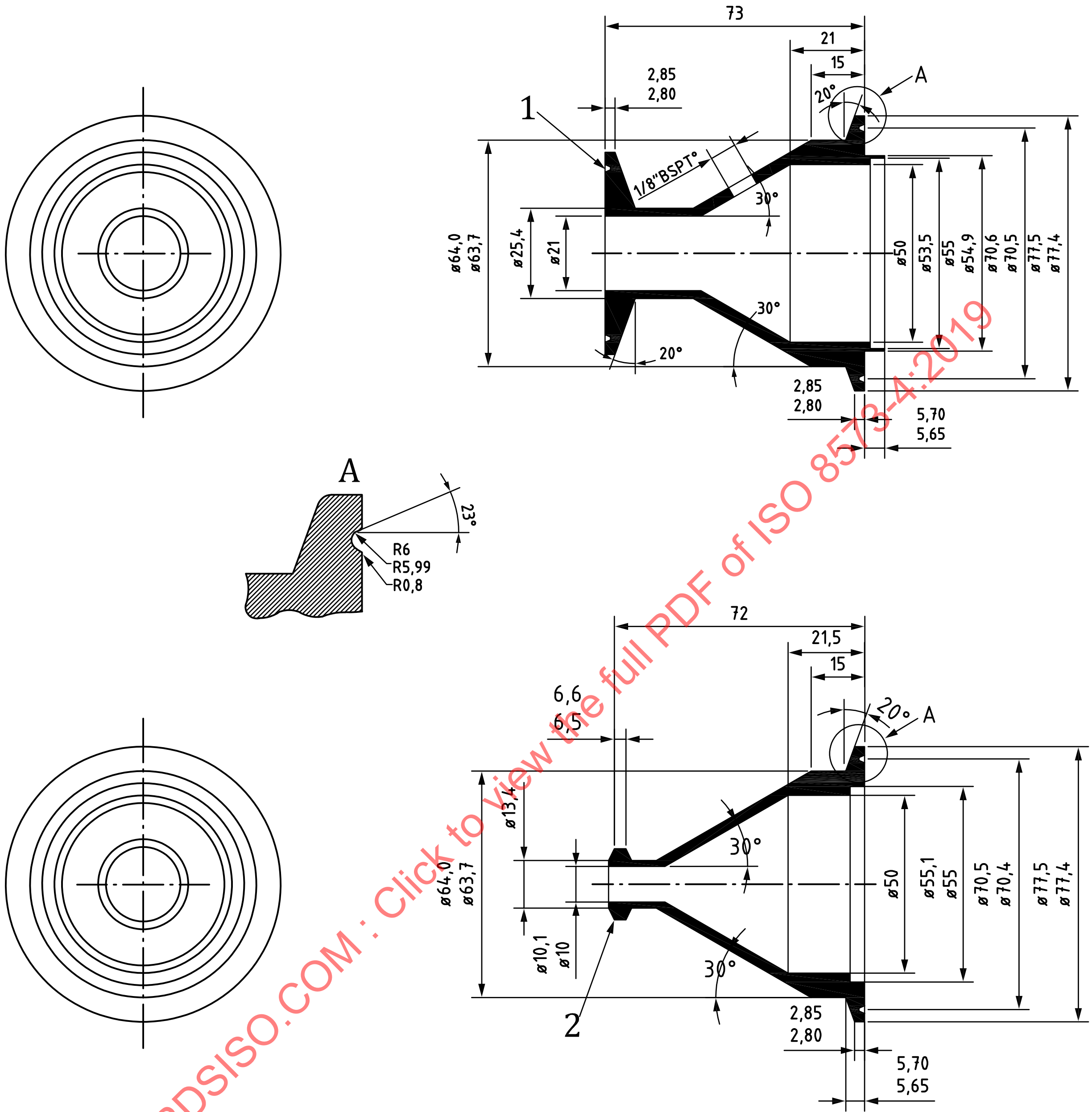
C.2.1 Sampling disc holder

The design of the sampling disc holder shall be such that the air flow is evenly distributed across the surface to prevent jetting which can cause an uneven particle loading or even damage to the sampling disc surface.

The maximum face velocity shall be restricted to 1 m/s. The pore size of the selected collection sampling disc shall be suitable for the minimum size of the particles to be collected and the sampling disc diameter shall be large enough to prevent the particles collected from overlapping, thereby eliminating sizing and counting errors through coincidence.

One such design of sampling disc holder can be seen in Figure C.1.

Dimensions in millimetres



Key

1 typical crevice-free joint

2 crevice-free joint to suit probe

NOTE The example given in Figure C.1 is provided for information purposes only and users shall ensure that any design meets their own safety requirements for the compressed air pressure at which the holder is intended to be used.

Figure C.1 — Example of sampling disc holder

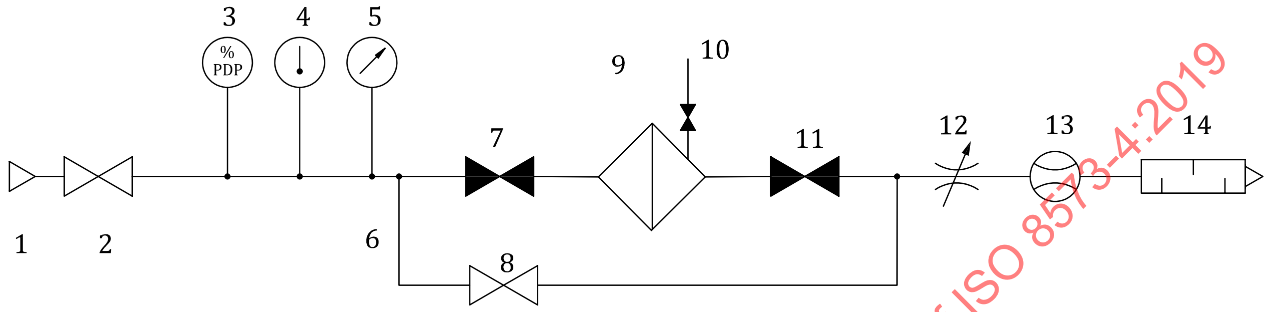
C.3 Sampling equipment arrangement

The general arrangement of the test equipment for full flow sampling is shown in Figure C.2. It is important that the test equipment does not affect the collected sample.

Instruments designed to size and count particles generally operate at relatively low sample flow rates. Hence it is unlikely that full flow sampling of the compressed air can be performed, and thus particle sizing and counting by microscopic analysis will be required.

As the test apparatus is portable, different test locations can be chosen, provided the stated parameters are not exceeded and suitable valve and connection arrangements for insertion of the test equipment into the circuit exists. Take care to prevent cross-contamination of any new location by the previous test yielding falsely high readings.

Where practical the sampled air may be returned to the compressed air system for use.



Key

1 compressed air sampling point
2 full-flow ball valve (open)
3 pressure dewpoint sensing/measuring
4 temperature sensing/measuring
5 pressure sensing/measuring
6 bypass pipe
7 full-flow ball valve (closed)
8 full-flow ball valve (open)
9 sampling disc holder or particle counter (measurement at pressure)
10 sampling disc holder depressurising valve
11 full-flow ball valve (closed)
12 multi-turn flow control valve
13 flow sensing/measuring
14 silencer

Figure C.2 — Typical test equipment arrangement for full flow sampling

Annex D
(informative)

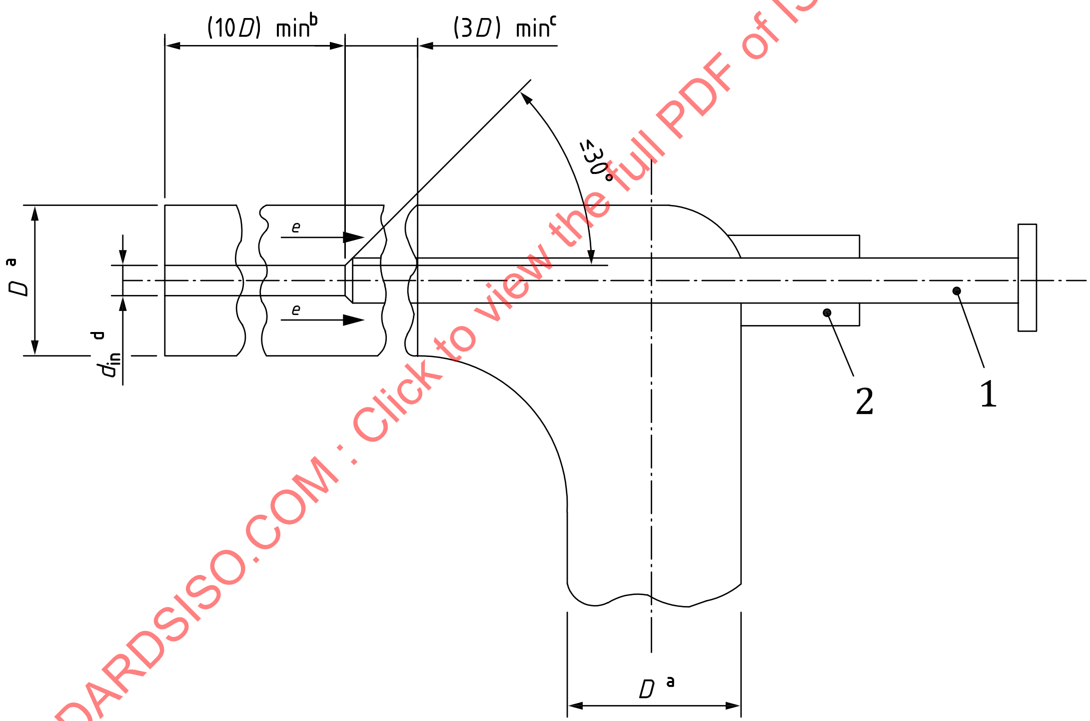
Isokinetic sampling

D.1 General

The set-up for the isokinetic sampling probe at the insertion point of the compressed air system under investigation is shown in Figure D.1.

D.2 Sampling equipment

D.2.1 Equipment set-up for isokinetic sampling



Key

1 isokinetic sampling probe in the main line

2 adjustable gland to allow adjustment of probe

a Main pipe inside diameter.

b Minimum straight length in front of the probe ≥10 × *D*.

c Probe insertion point at minimum of ≥3 × *D*.

d Internal probe diameter d_{in}.

e Direction of flow.

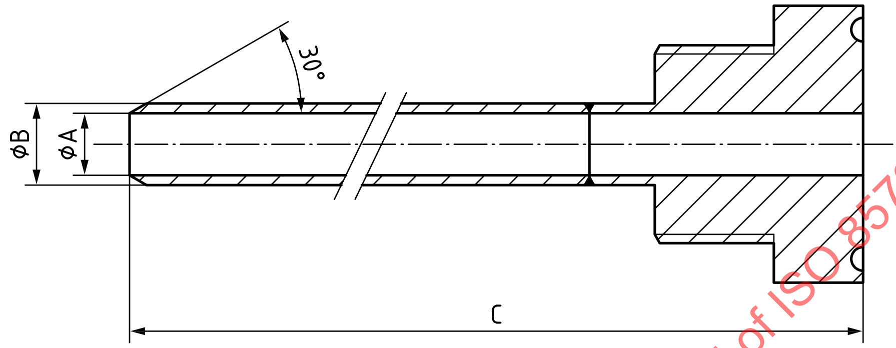
Figure D.1 — Typical set-up of probe insertion for isokinetic sampling (shown for bend insertion of probe)

D.2.2 Design of isokinetic sampling probe

The general construction of the probe is shown in Figure D.2. The probe is intended for use at pressurised conditions to match the velocity of that in the main line for sampling when used with a suitable sampling disc.

The probe should be of circular cross-section, the open end having a thickness of less than 1,5 mm and the internal and external surfaces having an inclination not greater than 30° to the axis of the nozzle.

The angle at the nozzle minimizes the effect of impact onto the end of the probe.



Typical probe sizes	A	B	C
1	7	9,6	200
2	10	12,6	200
3	17	19,6	400

Figure D.2 — Typical isokinetic sampling probes

D.2.3 Probe installation

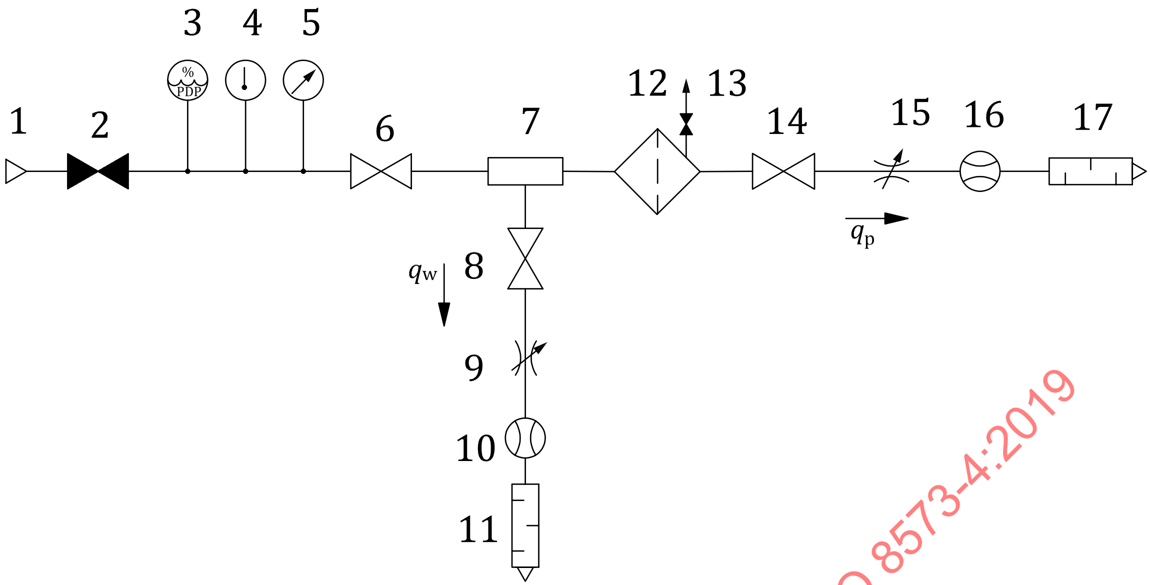
An isokinetic sampling probe should not create a problem, providing the general design in Figure D.2 is used. A simple compression seal may be used, if a fluorocarbon elastomer (or similar) seal is used to prevent contamination during the analysis procedure.

This seal shall be capable of maintaining the probe in the pipe up to the maximum working pressure. Ideally this seal should allow insertion of the probe to differing lengths if necessary.

D.3 Sampling equipment arrangement

D.3.1 Partial flow isokinetic sampling with a sampling disc holder

A typical arrangement for partial flow isokinetic sampling equipment with a sampling disc holder is shown in Figure D.3.



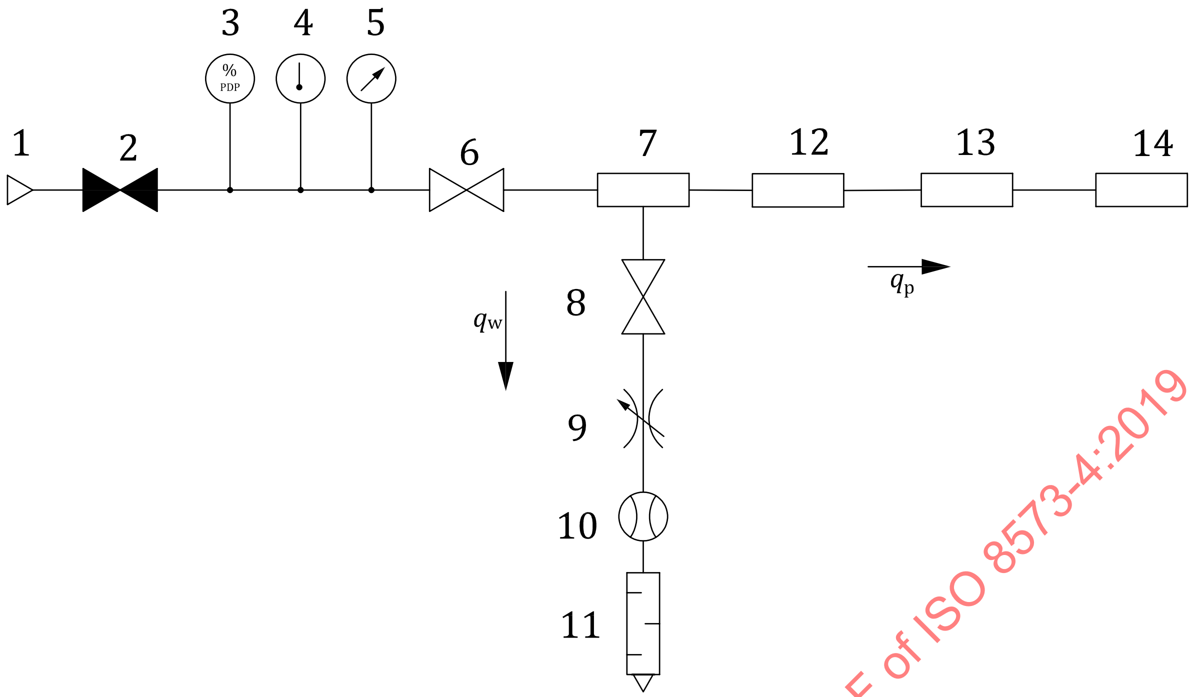
Key

q_w waste discharge flow direction
q_p probe discharge flow direction
1 compressed air sampling point
2 full-flow ball valve (closed)
3 pressure dewpoint sensing/measuring
4 temperature sensing/measuring
5 pressure sensing/measuring
6 full-flow ball valve (open)
7 isokinetic probe insertion point — see Figure D.1
8 full-flow ball valve (open)
9 multi-turn flow control valve
10 flow sensing/measuring
11 silencer
12 sampling disc holder
13 sampling disc holder depressurising valve
14 full-flow ball valve (open)
15 multi-turn flow control valve
16 flow sensing/measuring
17 silencer

Figure D.3 — Typical test equipment arrangement for partial flow isokinetic sampling with a sampling disc holder

D.3.2 Partial flow isokinetic sampling with a particle counter

A typical arrangement for partial flow isokinetic sampling equipment with a particle counter is shown in Figure D.4.



Key

q_w	waste discharge flow direction	7	isokinetic probe insertion point — see Figure D.1
q_p	probe discharge flow direction	8	full-flow ball valve (open)
1	compressed air sampling point	9	multi-turn flow control valve
2	full-flow ball valve (closed)	10	flow sensing/measuring
3	pressure dewpoint sensing/measuring	11	silencer
4	temperature sensing/measuring	12	compressed air diffuser
5	pressure sensing/measuring	13	dilution system (optional)
6	full-flow ball valve (open)	14	particle counter

Figure D.4 — Typical test equipment arrangement for partial flow isokinetic sampling at atmospheric pressure with a particle counter

D.4 Flow and pressure requirements

D.4.1 Compressed air flow rates

The air velocities within the main pipeline and within the probe shall be identical (isokinetic) throughout the sampling period. This is achieved by adjusting the flow controllers to provide appropriate readings on the flowmeters.

Both q_w and q_p shall be measured and maintained.

Identical pipe and probe velocities exist when the pressure is constant and occurs when the following conditions are met as expressed in Formula (D.1) i.e.:

$$\left(q_w + q_p\right)/q_p = D^2/d^2 \tag{D.1}$$

where

q_w is the waste discharge, in l/s;

q_p is the probe discharge, in l/s;

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

d is the internal probe diameter, in mm.

Generally, it is accepted that when the sample velocity is within ±10 % of the main line velocity the sample can be considered as having been collected at an isokinetic condition.

D.4.2 Reducing system pressure before measurement

A standard flow control or ball valve should not be used to reduce the pressure in the measuring equipment prior to the point of measurement. Particles within the compressed air stream may become impacted and deposited within the valve, and thus causing a lower measured particle count and resultant concentration to be reported.

If the system pressure is to be reduced before the measurement equipment, the reduction method shall employ a gas diffuser suitable for use with the measurement equipment and test pressure. Further information relating to pressure diffusers can be found in Annex E.