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Workplace atmospheres — Pumps for personal sampling of chemical and biological agents — Requirements and test methods

Air des lieux de travail — Pompes pour le prélèvement individuel des agents chimiques et biologiques — Exigences et méthodes d'essai

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Foreword

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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, www.iso.org/directives.

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The committee responsible for this document is ISO/TC 146, *Air quality*, Subcommittee SC 2, *Workplace atmospheres*.

Introduction

Many different methods are used to determine the concentration of chemical and biological agents in workplace air. Many of these methods involve the use of a pump and sampler connected by a flexible tube. Air is drawn through the sampler and chemical and biological agents are trapped, e.g. on a filter, sorbent tube or long-term detector tube, or in a gas washing bottle. In personal sampling, the pump and sampler are attached to the worker so as to collect chemical and biological agents in the breathing zone.

The volume of air drawn by the pump during the sampling period is one of the quantities in the calculation of the concentration of the chemical and biological agents in air. Therefore, the volume of air sampled should be determined accurately and, in order to facilitate this, the flow rate should be maintained within acceptable limits throughout the sampling period. For particle size selective sampling, the short-term fluctuation of the flow rate should also be maintained within acceptable limits in order to ensure that the sampler exhibits the required collection characteristics.

EN 482[1] specifies general performance criteria for methods for measuring the concentration of chemical and biological agents in workplace air. These performance criteria include maximum values of expanded uncertainty that are not to be exceeded under prescribed laboratory conditions. In addition, the performance criteria should also be met under a wider variety of environmental influences, representative of workplace conditions. The contribution of the sampling pump to measurement uncertainty should be kept to a minimum.

This International Standard is intended to enable manufacturers and users of personal sampling pumps to adopt a consistent approach to, and provide a framework for, the assessment of the specified performance criteria. Manufacturers are urged to ensure that pumps meet the requirements laid down in this International Standard, including environmental influences which can be expected to affect performance.

Workplace atmospheres — Pumps for personal sampling of chemical and biological agents — Requirements and test methods

1 Scope

This International Standard specifies performance requirements for battery powered pumps used for personal sampling of chemical and biological agents in workplace air. It also specifies test methods in order to determine the performance characteristics of such pumps under prescribed laboratory conditions.

This International Standard is applicable to battery powered pumps having a nominal volume flow rate above 10 ml · min^{-1}, as used with combinations of sampler and collection substrate for sampling of gases, vapours, dusts, fumes, mists and fibres.

This International Standard is primarily intended for flow-controlled pumps.

2 Normative references

The following referenced documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

IEC 61000-6-1, *Electromagnetic compatibility (EMC) — Part 6-1: Generic standards — Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) — Part 6-3: Generic standards — Emission standard for residential, commercial and light-industrial environments*

3 Terms and definitions

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

3.1
biological agent
bacteria, viruses, fungi and other micro-organisms or parts of them and their associated toxins, including those which have been genetically modified, cell cultures or endoparasites which are potentially hazardous to human health

Note 1 to entry: Dusts of organic origin, e.g. pollen, flour dust and wood dust, are not considered to be biological agents and are therefore not covered by this definition.

[SOURCE: EN 1540:2011,[2] definition 2.1.1]

3.2
chemical agent
any chemical element or compound on its own or admixed as it occurs in the natural state or as produced, used, or released, including release as waste, by any work activity, whether or not produced intentionally and whether or not placed on the market

[SOURCE: EN 1540:2011,[2] definition 2.1.2]

3.3
airborne particles
fine matter, in solid or liquid form, dispersed in air

Note 1 to entry: Smoke, fume, mist and fog consist of airborne particles.

[SOURCE: EN 1540:2011,[2] definition 2.2.3]

3.4
air sampler
sampler
device for separating chemical and/or biological agents from the surrounding air

Note 1 to entry: Air samplers are generally designed for a particular purpose, e.g. for sampling gases and vapours or for sampling airborne particles.

[SOURCE: EN 1540:2011,[2] definition 3.2.1, modified — synonyms placed on separate lines]

3.5
personal sampler
sampler, attached to a person, that collects gases, vapours or airborne particles in the breathing zone to determine exposure to chemical and/or biological agents

[SOURCE: EN 1540:2011,[2] definition 3.2.2]

3.6
personal sampling
process of (air) sampling carried out using a personal sampler

[SOURCE: EN 1540:2011,[2] definition 3.3.3]

3.7
breathing zone
space around the nose and mouth from which breath is taken

Note 1 to entry: Technically the breathing zone corresponds to a hemisphere (generally accepted to be 30 cm in radius) extending in front of the human face, centred on the midpoint of a line joining the ears. The base of the hemisphere is a plane through this line, the top of the head and the larynx. This technical description is not applicable when respiratory protective equipment is used.

[SOURCE: EN 1540:2011,[2] definition 2.4.5]

3.8
sorbent tube
device, usually made of metal or glass, containing a collection substrate such as a sorbent or a support impregnated with reagent

Note 1 to entry: Some sorbent tubes are intended for use as active samplers and some as passive samplers.

[SOURCE: EN 1540:2011,[2] definition 3.2.5]

3.9
pressure drop
<sampling train> difference between ambient pressure and the pressure at the inlet of the pump, for a constant volume flow rate setting

Note 1 to entry: The pressure drop, sometimes referred to as back pressure, is measured across the sampler, the collection substrate and the tubing.

3.10
flow-controlled pump
pump with nominally constant flow rate provided by an automatic flow control system

3.11
nominal flow rate range
range of volume flow rate values, adjustable at the pump, at which the manufacturer claims that the pump can operate at a constant flow rate up to the maximum value of the required pressure drop range for the operating time

3.12
operating time
period during which the pump can be operated at specified flow rate and pressure drop without recharging or replacing the battery

3.13
pulsation
short-term relative variation of volume flow rate at a given flow rate

4 Types of pump

Sampling pumps are classified according to their intended use as follows:

— type P: pumps for personal sampling of airborne particles;

— type G: pumps for personal sampling of gases and vapours.

NOTE 1 Type P pumps can be used for personal sampling of gases and vapours as long as they comply with the type G pump requirements.

NOTE 2 For types of pump mechanism and control system. see Annex A.

5 Requirements

5.1 Features

The pump shall have the following features:

a) an automatic control which keeps the volume flow rate nominally constant;

b) a means to reduce the likelihood of unintentional or unauthorized adjustment of any pump control, such that it is concealed beneath a cover, can only be actuated with the aid of a tool or requires specialized knowledge for operation;

c) either a malfunction indicator which, following completion of sampling, indicates that the air flow has been reduced or interrupted during sampling, or an automatic cut-out which stops the pump if the flow rate is reduced or interrupted;

d) a fuse or resettable breaker which interrupts the current in the electrical circuit of the pump in the case of excessive current drain;

e) a filter which prevents particles from being drawn into the mechanism of the pump;

f) a means to secure the pump on a person (integrated or available as an accessory).

NOTE Some pumps use internal sensors to provide atmospheric, pressure and air flow data. Information on the use of these sensors is given in Annex B.

5.2 Mass

The mass of the pump, including batteries and integral holders, shall not exceed 1,2 kg for sampling pumps with a flow rate of less or equal than 5 l · min^{-1} and 2,5 kg for sampling pumps with a flow rate above 5 l · min^{-1}.

5.3 Design safety

The outer case of the pump shall be so designed that there are no sharp corners or other uncomfortable protruding parts.

5.4 Operating time

The operating time shall be at least 1 h and should preferably be greater than 8 h. This applies to the complete nominal flow rate range against the pressure drops as specified in Table 4 at (5 ± 2) °C.

NOTE The capacity of a battery increases with temperature. Therefore, the test is performed towards the lower end of the temperature range in which the pump is likely to be used.

For the duration of the operating time, the flow rate shall not deviate by more than 5 % from the initial value.

The manufacturer shall report, in the instructions for use, the operating time at the specified pressure drop according to 5.10 for the flow rates given in Table 1 at (5 ± 2) °C.

Table 1 — Flow rates for reporting by the manufacturer of the operating time

Pump type	Nominal flow rate range ml · min^{-1}	Flow rate setting ml · min^{-1}
P	≤5 000	2 000
		Maximum value of the nominal flow rate range of the pump
	>5 000	Minimum value of the nominal flow rate range of the pump
		Maximum value of the nominal flow rate range of the pump
G	≤300	50
		Maximum value of the nominal flow rate range of the pump
	>300	300
		Maximum value of the nominal flow rate range of the pump
NOTE For regular user tests to maintain pumps and flow meters, see Annex C.		

5.5 Start-up and long-term performance

During operation of the pump at (5 ± 2) °C and in the range from 20 °C to 25 °C, the flow rate shall not deviate by more than 5 % from the value measured at the start of the determination of the long-term performance.

5.6 Short-term interruption of air flow

When the air flow is fully blocked, the pump shall cut out or the malfunction indicator activate. The pump may try to restart automatically after the airflow is becoming blocked. If the air flow is blocked for more than (120 ± 10) s, the pump shall not restart automatically or the malfunction indicator shall remain activated until reset.

5.7 Temperature dependence

When the flow rate is set within the temperature range from 20 °C to 25°C in accordance with 7.7, it shall not deviate by more than 5 % after cooling down the sampling train to (5 ± 2) °C within about 2 h and running for a period of (60 ± 1) min when the temperature is changed to the next (fixed) value within the range from 5 °C to 40 °C as stated in 7.7.3.

5.8 Mechanical strength

The general function of the pump shall not be impaired by shock treatment (see 7.8). No mechanical damage or electrical defect shall occur.

After shock treatment, the flow rate measured shall not deviate by more than 5 % from the value measured prior to shock treatment.

5.9 Pulsation of flow rate (for type P pumps only)

For type P pumps, the pulsation shall not exceed 10 % of the flow rate.

By recording the time curve of the flow rate the pulsation P is given by Formula (1):

$$P = \frac{\sqrt{\frac{1}{T}\int_0^T \left[f(t) - \bar{f} \right]^2 \mathrm{d}t}}{\bar{f}} \times 100 \qquad (1)$$

where

$f(t)$ is the volume flow rate over time t, in litre per minute ($\mathrm{l} \cdot \mathrm{min}^{-1}$), calculated from the measurement of velocity;

$\bar{f}$ is the mean volume flow rate over time T, calculated in litre per minute ($\mathrm{l} \cdot \mathrm{min}^{-1}$), from the measurement of velocity;

t is the time, in seconds (s);

T is the time period of pulsation, in seconds (s).

The quantity $f(t)$ is not necessarily the absolute air flow, but shall have a direct linear relationship to the flow rate.

NOTE P can be measured in several ways. See 7.9 for examples.

5.10 Flow rate stability under increasing pressure drop

5.10.1 Pumps with a nominal flow rate range less or equal than 5 000 ml · min^{-1}

When set within the nominal flow rate range of the pump, the flow rate shall not deviate by more than ±5 % from the initial value on changing the pressure drop within the range specified in Table 2.

5.10.2 Pumps with a nominal flow rate range above 5 000 ml · min^{-1}

When set within the nominal flow rate range of the pump, the flow rate shall not deviate by more than ±5 % from the initial value on changing the pressure drop within the nominal pressure drop range specified by the pump manufacturer.

5.11 Timer accuracy

If the pump has an internal timer, the indicated time shall not deviate by more than ±0,5 % from that of a calibrated timer.

5.12 Electromagnetic compatibility

The pump shall meet the requirements for electromagnetic compatibility according to IEC 61000-6-1 and IEC 61000-6-3.

5.13 Explosion hazard

If the pump is claimed to be suitable for use in areas subject to explosion hazard, the pump shall comply with the requirements of IEC 60079-0.

Table 2 — Required pressure drop range

Pump type	Adjusted flow rate	Required pressure drop range
	ml · min^{-1}	kPa
P	1 000	0,1 to 4,0
	2 000	0,3 to 4,0
	3 000	0,4 to 4,0
	4 000	0,6 to 5,0
	5 000	0,7 to 6,25
G	10	0,02 to 0,2
	50	0,1 to 1,2
	100	0,2 to 2,6
	200	0,5 to 6,0
	300	1,0 to 10,0
	500	2,0 to 10,0

NOTE The upper and lower values specified for the required pressure drop range for type P pumps are typical for an unloaded and heavily loaded filter. The values specified for required pressure drop for type G pumps are typical for one sorbent tube with low flow resistance up to two sorbent tubes in line. See Annex D.

6 Test conditions

6.1 Number of test objects

The tests given in Clause 7 may be carried out with one pump only unless otherwise stated in the specific test clause.

6.2 Test instruments

The uncertainty of the test instruments shall be in accordance with Table 3.

Table 3 — Uncertainty of test instruments used

Test instrument	Uncertainty
Volume flow meter	within ±2 %
Volume meter	within ±2 %
Pressure gauge	within ±5 %
Timer	within ±0,1 %
Thermometer	within ±1 °C

For a rapidly responding flow meter, e.g. a hot-wire anemometer, the response time shall be less than 4,5 ms from t_{10} to t_{90}.

NOTE 1 Times t_{10} and t_{90} are those at which 10 % and 90 % of the final reading of the anemometer signal is reached when a step signal is applied.

The temperature stability of the climatic chamber used shall be at least ±2 °C.

All test instruments listed in Table 3 shall have calibrations that are traceable to national standards.

NOTE 2 Annex E lists typical test instruments.

6.3 Preconditioning and sequence of tests

Prior to the technical tests (see Clause 7), precondition the pump by performing an appropriate number of charging and operating cycles (see Clause 10 for charger).

For pumps with a nickel–cadmium (NiCd) battery, perform at least five cycles. Wherever possible, the use of this battery type should be avoided for reasons of environmental protection and to avoid problems with battery memory effects.

For pumps with a nickel–metal hydride (NiMH) battery or a lithium-ion (Li-ion) type battery, perform at least three cycles.

Fully charge the battery in accordance with the manufacturer's instructions and run the pump until it automatically shuts down due to low battery status.

To reduce the cycle time, the pump should run at its maximum nominal flow rate and at 80 % of the maximum of the required pressure drop range as in 5.10.

Following completion of the charging and operating cycles, perform tests in the order given in Clause 7.

6.4 Adjustment of volume flow rate and pressure drop

Flow rates shall be adjusted within a maximum deviation of ±5 % of the required value.

Pressure drops shall be adjusted within a maximum deviation of ±10 % of the required value.

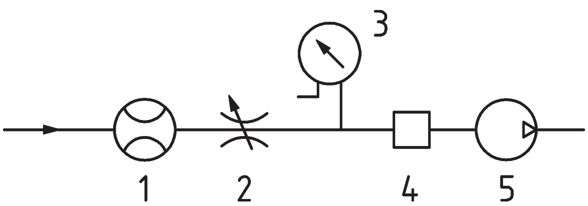
If an integral flow meter is incorporated in the pump this shall not be used to adjust the flow rate.

NOTE 1 The technical tests (see Clause 7) require the pump to be adjusted to specific flow rates and the flow resistor to be adjusted to give specific pressure drops at the inlet of the pump. The required flow rates and pressure drops are specified in the individual test clauses.

NOTE 2 The pressure drop settings for the technical tests include the flow resistance of the connected volume flow meter or volume meter (Figure 1, label 1).

6.5 Test set-up and performance

The basic test set-up for the technical tests shall be as depicted in Figure 1.



Key

1 volume flow meter or volume meter

2 air flow resistor

3 differential pressure gauge (manometer)

4 pulsation damper (optional)

5 pump

Figure 1 — Test set-up for pumps operating with a variable flow resistance

Air is drawn through a volume flow meter or volume meter. The flow resistor, adjusted depending on the test to be performed, is connected by one end to the outlet of the volume flow meter, and by the other end to the inlet of the pump. The pressure drop relative to ambient pressure is measured using a differential pressure gauge (manometer), connected to the line, and in between the flow resistor and the inlet of the pump. The pump inlet is connected to the flow resistor and the differential pressure gauge.

NOTE 1 Where pulsation of the air flow prevents accurate reading of the volume flow meter and differential pressure gauge, a pulsation damper of low flow resistance (up to 200 Pa at 2 l · min^{-1}) can be inserted downstream of the differential pressure gauge.

All connections shall be leak tight. The diameter and length of the tubing used should be as low as possible with a maximum total length of (80 ± 5) cm and a nominal internal diameter of 6 mm. For higher flow rates, larger diameter tubing may be used to limit pressure restriction. For the pulsation test given in 7.7, special requirements for the tubing and test set-up shall be fulfilled.

Tests shall be performed with fully charged batteries.

Unless otherwise specified, the tests shall be carried out at a range from 20 °C to 25 °C, and the temperature shall be measured and recorded in the test report.

NOTE 2 If the measurement of the pressure drop is not necessary for a test, the differential pressure gauge can be omitted.

7 Test methods

7.1 Features

Make a visual inspection and check the manufacturer's specifications to determine that the pump incorporates all of the features specified in 5.1.

7.2 Mass

Check the mass by weighing and compare the result with the requirement given in 5.2.

7.3 Design safety

Determine whether the design safety requirements specified in 5.3 are met by visual inspection of the pump.

7.4 Operating time

Carry out the operating time tests at (5 ± 2) °C in conjunction with the tests for start-up and long-term performance (see 7.5).

Check whether the requirement specified in 5.4 is met.

7.5 Start-up and long-term performance

7.5.1 Test set-up

Perform all the tests using the basic set-up given in 6.5 and carry out the tests at (5 ± 2) °C in a climatic chamber.

7.5.2 Flow rate and pressure drop adjustment

Carry out the test at two flow rates and pressure drop conditions as specified in Table 4.

Table 4 — Flow rate and pressure drop settings for the start-up and long-term performance test

Pump type	Maximum value of the nominal flow rate range of the pump	Flow rate setting	Resistor pressure drop setting
	ml · min^{-1}	ml · min^{-1}	kPa
P	≤5 000	2 000	1,6[a]
		Maximum value of the nominal flow rate range of the pump	Maximum pressure drop for this flow rate as specified in Table 2
	>5 000	Minimum value of the nominal flow rate range of the pump	0,4 Times maximum pressure drop for this flow rate as specified by the manufacturer
		Maximum value of the nominal flow rate range of the pump	Maximum pressure drop for this flow rate as specified by the manufacturer
G	≤300	50	0,5[a]
		Maximum value of the nominal flow rate range of the pump	Maximum pressure drop for this flow rate as specified in Table 2
	>300	300	4,0[a]
		Maximum value of the nominal flow rate range of the pump	Maximum pressure drop for this flow rate as specified by the manufacturer

[a] 0,4 Times the maximum pressure drop specified in Table 2.

If the required flow rate setting falls between the values stated in Table 2, determine the required pressure drop setting by linear interpolation.

7.5.3 Procedure

Perform the test for each flow rate and pressure drop condition specified in 7.5.2, once at a temperature in the range from 20 °C to 25 °C and once at (5 ± 2) °C.

Prior to each test, fully charge the battery and then condition the complete test set-up (see 6.5) by storing at the required temperature for at least 16 h. Switch on the pump and adjust the flow rate and pressure drop to the required values. Start the timer and measure the flow rate continuously. Continue the test until the measured flow rate falls outside the ±5 % criterion set in 5.5, a malfunction is registered or the pump cuts out automatically (see 5.1).

7.6 Short-term interruption of air flow

7.6.1 Test set-up

The basic set-up is as given in 6.5.

7.6.2 Flow rate and pressure drop adjustment

The test is carried out at the flow rate and pressure drop as specified in Table 5.

Table 5 — Flow rate and pressure drop settings for the short-term interruption of airflow test

Pump type	Maximum value of the nominal flow rate range of the pump	Flow rate setting	Resistor pressure drop setting
	ml · min^{-1}	ml · min^{-1}	kPa
P	≤5 000	2 000	0,5
	>5 000	Mean value of the nominal flow rate range of the pump	For this flow rate, 1,5 times the minimum value of the nominal pressure drop range, but not exceeding the mean value of the nominal pressure drop range
G	≤300	50	0,2
	>300	300	1,5

7.6.3 Procedure

Adjust the pump and resistor to the required flow rate and pressure drop as specified in 7.6.2. Fully block the air flow by fixing a hose clamp on the tubing at the inlet of the pump. Measure the time taken for the pump to react to the blockage (e.g. automatic cut out, activation of malfunction indicator) using a timer. Afterwards remove the clamp and check whether the requirements specified in 5.6 are met.

7.7 Temperature dependence

7.7.1 Test set-up

The basic set-up is as given in 6.5. The complete test set-up is located in a climatic chamber.

7.7.2 Flow rate and pressure drop adjustment

The test is carried out at the flow rate and pressure drop as specified in Table 6.

Table 6 — Flow rate and pressure drop settings for the temperature dependence test

Pump type	Maximum value of the nominal flow rate range of the pump	Flow rate setting	Resistor pressure drop setting
	ml · min^{-1}	ml · min^{-1}	kPa
P	≤5 000	2 000	0,5
	>5 000	Mean value of the nominal flow rate range of the pump	For this flow rate, 1,5 times the minimum value of the nominal pressure drop range, but not exceeding the mean value of the nominal pressure drop range
G	≤300	50	0,2
	>300	300	1,5

7.7.3 Procedure

Prior to the test, fully charge the battery and then condition the complete test set-up (see 6.5) by storing at the temperature range from 20 °C to 25 °C for at least 16 h. Switch the pump on and adjust the flow rate and pressure drop to the required values. Place the complete test set-up in the climate chamber at (5 ± 2) °C for about 2 h with the pump running, then measure the flow rate. Then increase the temperature to 10 °C, 20 °C, 30 °C, and 40 °C and keep constant for periods of (60 ± 1) min at each temperature. Measure the flow rate at the end of each 1 h period.

Pumps with operating times less than about 8 h shall not be run over the entire test period. Once each required temperature is reached, switch on the pump and run for (15 ± 1) min prior to flow rate measurement, then switch off the pump upon completion of flow rate measurement.

Check whether the requirement specified in 5.7 is met.

If the temperature range specified by the manufacturer exceeds the range from 5 °C to 40 °C the test should be performed over this extended temperature range. In this case, the temperature steps should be adjusted accordingly but should not exceed 10 °C.

7.8 Mechanical strength

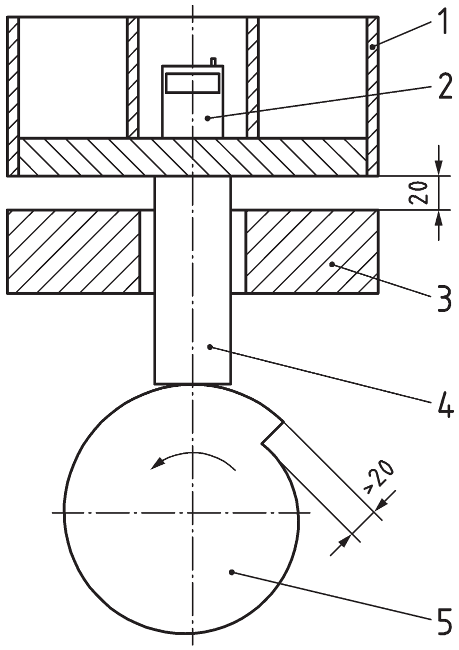
7.8.1 Test set-up

The basic set-up is as given in 6.5.

For the shock treatment a test set-up as shown schematically in Figure 2 shall be used.

The apparatus consists of a steel case which is fixed on a vertically moving piston, capable of being lifted up 20 mm by a rotating cam and dropping down on to a steel plate under its own weight as the cam rotates. The mass of the steel case shall be more than 10 kg. The mass of the steel plate on to which the steel case falls should be at least 10 times the weight of the steel case. This may be achieved by bolting the base plate to a hard solid floor.

Dimensions in millimetres



Key

1 steel case

2 pump

3 steel plate

4 vertically moving piston

5 rotating cam

Figure 2 — Test set-up for shock treatment

7.8.2 Flow rate and pressure drop adjustment

The test is carried out at the flow rate and pressure drop as specified in Table 7.

Table 7 — Flow rate and pressure drop settings for the mechanical strength test

Pump type	Maximum value of the nominal flow rate range of the pump	Flow rate setting	Resistor pressure drop setting
	ml · min^{-1}	ml · min^{-1}	kPa
P	≤5 000	2 000	3,2
	>5 000	Mean value of the nominal flow rate range of the pump	For this flow rate, 0,8 times the maximum value of the nominal pressure drop range
G	≤300	50	1,0
	>300	300	8,0

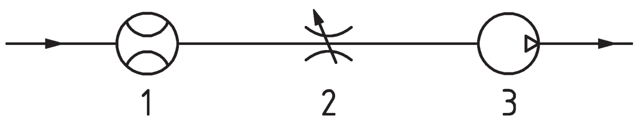
7.8.3 Procedure

Adjust the pump and resistor to the required flow rate and pressure drop as specified in 7.8.2. Measure the flow rate. Switch off the pump and subject the pump to the shock treatment. Secure the pump on its rear face in a steel case (see Figure 2). Operate the shock equipment with about 2 000 shocks. After the shock treatment, switch on the pump and measure the flow rate again. Check whether the requirements specified in 5.8 are met.

7.9 Pulsation of flow rate (for type P pumps only)

7.9.1 Test set-up

The test set-up shall be as specified in Figure 3.



Key

1 rapidly responding flow meter or anemometer

2 air flow resistor

3 pump

Figure 3 — Test set-up for pulsation of flow rate test

A rapidly responding flow meter or anemometer (response time from t_{10} to t_{90} of 4,5 ms or less) is used to measure a signal proportional to the flow rate. The flow resistor, adjusted as specified in 7.9.2, is connected by one end to the outlet of the rapidly responding flow meter, and by the other end to the inlet of the pump (see Figure 3).

All connecting tubing is made from rigid material [e.g. polyvinyl chloride (PVC) tubing with a wall thickness of at least 1 mm] that has no damping effect and with an internal diameter of 6 mm. The tubing length between the pump and the resistor is (600 ± 10) mm, and (200 ± 10) mm between the resistor and the inlet of the rapidly responding flow meter.

The rapidly responding flow meter measurement values are recorded continuously over at least one pulsation period, e.g. by using a data logger or memory oscilloscope. Alternatively, a voltage meter can be used to determine the alternating and continuous components of the air flow.

7.9.2 Flow rate and pressure drop adjustment

The test is carried out at the flow rate and pressure drop as specified in Table 8.

Table 8 — Flow rate and pressure drop settings for the pulsation of the flow rate test

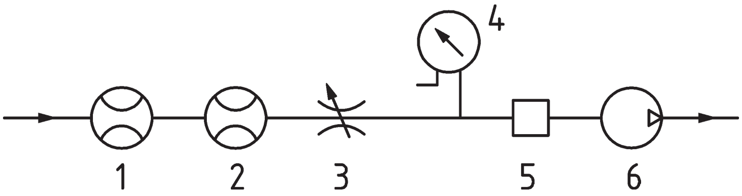
Maximum value of the nominal flow rate range of the pump	Flow rate setting	Resistor pressure drop setting
ml · min^{-1}	ml · min^{-1}	kPa
≤5 000	2 000	0,75
>5 000	Mean value of the nominal flow rate range of the pump	2

7.9.3 Procedure

Calibrate the rapidly responding volume flow meter. To obtain an unbiased linear relationship between the flow rate and the output signal of the flow meter, auxiliary linearization equipment should be used.

NOTE 1 It is not necessary to achieve an absolute calibration which connects the output signal of the flow meter with the flow rate.

NOTE 2 For calibration of a hot wire anemometer and for the adjustment of the flow rate and resistor pressure drop before the pulsation test, a slowly responding volume meter or volume flow meter connected to the inlet of the anemometer, in order to have the lowest pressure drop in the first position, and a differential pressure gauge (manometer) connected between the flow resistor and the pump inlet, are added to the test set-up (see Figure 4).



Key

1 slowly responding volume flow meter or volume meter
2 rapidly responding volume flow meter or anemometer
3 air flow resistor
4 differential pressure gauge (manometer)
5 pulsation damper (optional)
6 pump

Figure 4 — Setting of flow rate and pressure drop prior to pulsation measurement

Adjust the pump and resistor to the required flow rate and pressure drop as specified in 7.9.2.

If the pulsation of the air flow prevents accurate reading of the slowly responding volume flow meter or volume meter and differential pressure gauge when setting the flow rate and pressure drop prior to the pulsation test, a pulsation damper of low flow resistance is inserted downstream of the flow resistor during the setting of the flow and the resistance pressure drop. After setting and adjusting the flow rate and the resistor pressure drop, remove the slowly responding volume flow meter or volume meter and pulsation damper, if used.

If the measurements are to be carried out with a rapidly responding anemometer, calibrate the average reading of the rapidly responding anemometer relative to the slowly responding volume flow meter by using non-pulsating air flows. Determine a relation between the linearized output of the rapidly responding anemometer (voltage U in volt) versus the flow rate in litres per minute as measured by the slowly responding volume flow meter (q_V in l · min^{-1}) according to Formula (2):

$$q_V = A + BU \quad (2)$$

Determine the coefficients A and B by regression analysis.

Measure the rapid variation of the flow rate by one of the following methods.

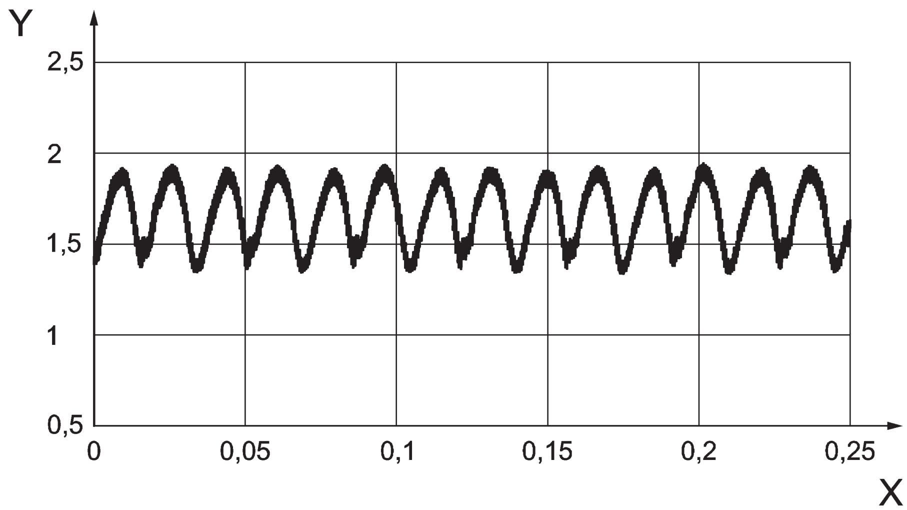
a) Record the output signal of the rapidly responding flow meter (at least 60 readings per period) over a number of cycles of the pulsating volume flow and calculate the flow rate values. Determine the value of pulsation by numerical integration according to Formula (1) over five typical single pulsation periods (see Figure 5). All five cycles investigated shall meet the requirement specified in 5.9.

b) Measure the direct current (DC) and alternating current (AC) voltages, U_{DC} and U_{AC} of the rapidly responding flow meter at the adjusted flow rate.

NOTE This can also be carried out with currents, depending on the output of the flow meter, but is here only showed for voltages.

The pulsation P is directly obtained from Formula (3):

$$P = \frac{BU_{AC}}{A + BU_{DC}} \times 100 \qquad (3)$$



Key

Y q_V l · min⁻¹ flow rate

X t s time

Figure 5 — Example of pulsation cycles

7.10 Flow rate stability under increasing pressure drop

7.10.1 Test set-up

The basic set-up is as given in 6.5.

7.10.2 Flow rate adjustment

The tests are carried out at the flow rate settings as specified in Table 9.

Table 9 — Flow rate settings for the flow rate stability under increasing pressure drop

Pump type	Maximum value of the nominal flow rate range of the pump ml · min^{-1}	Test flow rate setting ml · min^{-1}
P	≤5 000	Minimum value of the nominal flow rate range of the pump Maximum value of the nominal flow rate range of the pump
	>5 000	Minimum value of the nominal flow rate range of the pump Maximum value of the nominal flow rate range of the pump
G	≤300	Maximum value of the nominal flow rate range of the pump
	>300	Maximum value of the nominal flow rate range of the pump

7.10.3 Procedure

Adjust the pump to one of the test flow rates given in Table 9 and the resistor to the minimum pressure drop setting at this flow rate as given in 5.10. Allow to stabilize for (30 ± 1) min. Increase the pressure drop, in at least five steps, up to the maximum value as specified in 5.10. For values of the adjusted flow rate which are between those given in 5.10, the required pressure drop is obtained by linear interpolation. At each step, after varying the pressure drop, wait (120 ± 10) s before recording flow rate and pressure drop. Repeat this procedure for the second test flow rate (type P pumps only).

The test shall be continued at pressure drops above the maximum, as given in 5.10, until the pump cuts out automatically or the flow rate deviates by more than ±5 % from the test flow rate.

7.11 Timer accuracy

To check whether the requirement specified in 5.11 is met, the timer of the pump and a timer which has calibration traceable to the national time standard are compared over a period of at least 1 h.

NOTE This test can be carried out over the entire operating time in conjunction with the test of the start-up and long-term performance at a range from 20 °C to 25 °C (see 7.5).

7.12 Electromagnetic compatibility

Verify by means of a test certificate whether the requirement specified in 5.12 is met.

7.13 Explosion hazard

Verify by means of a test certificate whether the requirement specified in 5.13 is met.

8 Test report

The test report shall include at least the following information:

a) full identification of the pump;

b) reference to this International Standard (ISO 13137:2013);

c) identification of the test laboratory;

d) test conditions and test results;

e) whether the features and results comply with the values or limits specified therein;

f) any unusual features noted during the determinations;

g) any operation not included in this International Standard that could have an influence on the results.

9 Instructions for use

The instructions for use supplied with the pump shall be in the language(s) required by regulations of the countries where the pump is to be marketed. It shall contain at least the following information:

a) name and address of the manufacturer;

b) designation of series or type;

c) serial number, if any;

d) statement of conformance with this International Standard (ISO 13137:2013);

e) intended use (type P and/or G);

f) nominal flow rate range;

g) nominal range of pressure drop;

h) operating time according to 5.4;

i) temperature range for operating;

j) type designation of charger to be used for charging the battery;

k) notes and recommendations required for operation and setting of the flow rate of the pump and charge and discharge of the battery;

l) notes with respect to maintenance and trouble-shooting;

m) notes with respect to special safety requirements. If the pump can be used in an area subject to explosion hazard, the certificate number provided by the appropriate certification body;

n) information concerning the adjustment of flow rate; this should also include information pertinent to the use of low resistance pulsation dampers, if required;

o) information that the flow rate given by an integral flow meter, if included, is not considered a calibration traceable to national or international standards;

p) information concerning the equilibrium time to reach a stable air flow rate.

10 Charger

10.1 Requirements

A compatible type of charger shall be unambiguously assigned to the pump for charging its battery.

10.2 Testing

Verify in accordance with instructions for use of the pump.

11 Marking

The pump shall bear all markings which are necessary for its unambiguous identification, in order to indicate its compliance with mandatory requirements, if any, and for its safe use. The label shall contain at least the following:

a) manufacturer's name;

b) type;

c) serial number;

d) number of this International Standard (ISO 13137:2013);

e) If the pump can be used in an area subject to hazard by explosion, add the relevant certification number and a warning "**Do not charge in a hazardous area**". This text shall be in the language(s) of the countries where the pump is to be marketed.

Annex A
(informative)

Types of pump mechanism and control system

A.1 Types of pump mechanism

A.1.1 General

Pumps for personal sampling of chemical agents in general incorporate one of two types of pump mechanism: diaphragm pump mechanism (see A.1.2) or rotary vane pump mechanism (see A.1.3).

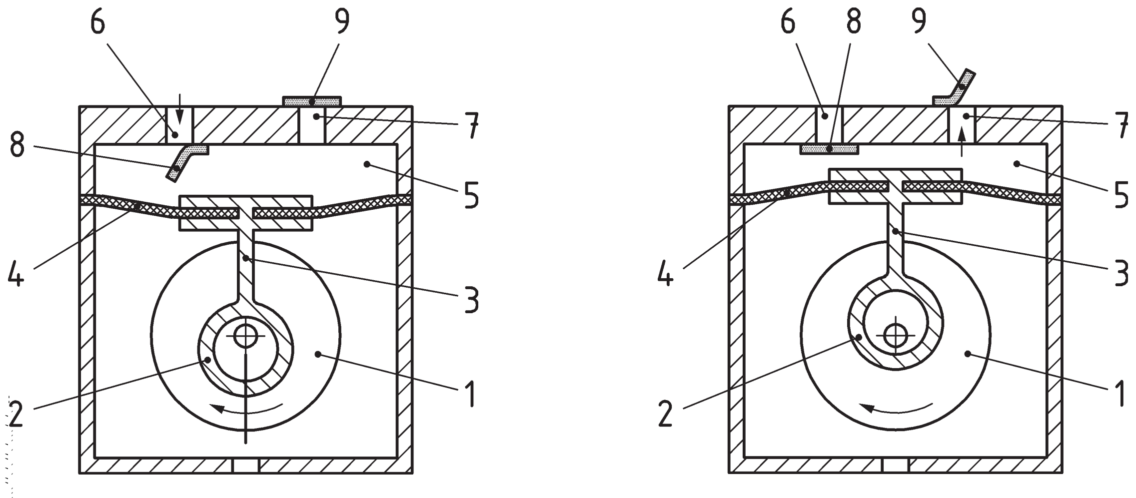
A.1.2 Diaphragm pumps

Diaphragm pumps comprise a chamber sealed on one side by a flexible diaphragm. The chamber is provided with inlet and outlet ports sealed by valves. The flexible diaphragm is driven in a reciprocating motion by the action of an electric motor, generally via an eccentric and connecting rod. See Figure A.1.

On the inlet stroke the diaphragm is flexed to increase the volume of the chamber, thus creating a vacuum within the chamber, which draws air through the inlet port valve and into the chamber, while the outlet port valve is maintained closed by the vacuum in the chamber.

On the outlet stroke, the diaphragm is flexed to decrease the volume of the chamber, thus creating a positive pressure within the chamber, which forces the air out of the chamber via the outlet port valve, while the inlet port valve is maintained closed by the positive pressure in the chamber.

The air flow rate is adjusted by varying the speed of the driving motor.



a) inlet stroke   b) outlet stroke

Key

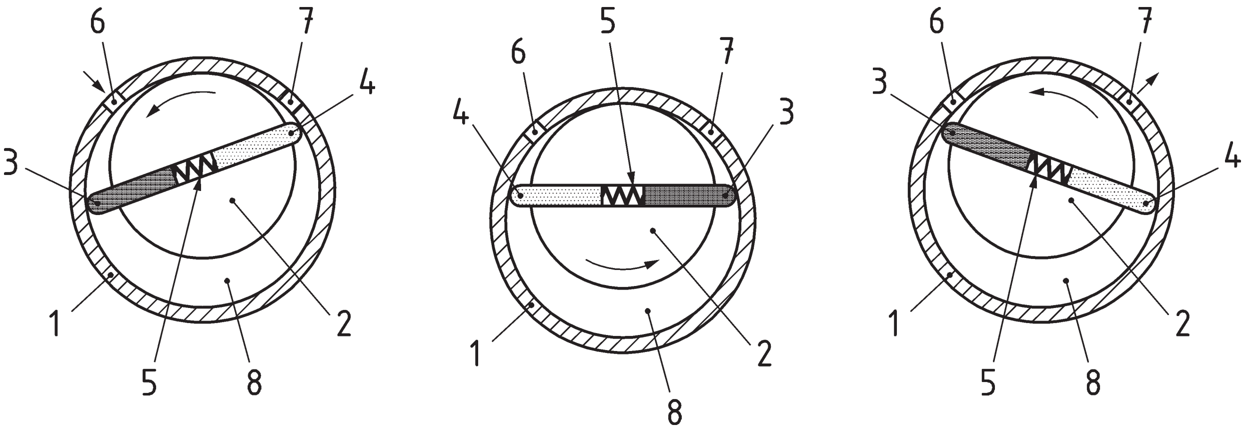
1 motor
2 eccentric
3 connecting rod
4 diaphragm
5 chamber
6 inlet port
7 outlet port
8 inlet valve
9 outlet valve

Figure A.1 — Diaphragm pump

Current examples of diaphragm pumps for air sampling applications comprise single and twin diaphragm mechanisms. The twin mechanisms provide higher air flow rates and lower pulsation of the airflow.

A.1.3 Rotary vane pumps

Rotary vane pumps comprise a set of two vanes affixed to a rotor driven directly by an electric motor. The vanes and rotor are housed in a fixed volume, sealed, cylindrical chamber. The rotor is positioned offset to the centreline of the chamber. The chamber is provided with inlet and outlet ports. See Figure A.2.



a) inlet **b) transfer** **c) outlet**

Key

1 chamber	3 vane 1	5 spring	7 outlet port
2 rotor	4 vane 2	6 inlet port	8 partition

Figure A.2 — Rotary vane pump

The vanes may be rigid and free to slide in the rotor, such that the outer tip of the vane remains in contact with the circumference of the chamber. A spring may be used to maintain the tips of the vanes in contact with the circumference of the chamber or alternatively the centrifugal force created by the rotation of the rotor may be used to maintain the tips of the vanes in contact with the circumference of the chamber.

Alternatively, the vanes may be flexible and rigidly fixed to the rotor. Flexing of the vanes maintains the tips of the vanes in contact with the circumference of the chamber.

The vanes and rotor create three separate partitions within the chamber, one connected to the inlet port, one connected to the outlet port, and the third isolated from both inlet and outlet ports.

As vane 1 passes the inlet port and continues its rotation the volume of the partition connected to the inlet port increases, thus creating a vacuum in the partition, which draws air through the inlet port valve into the chamber.

As vane 2 rotates past the inlet port, the partition is isolated from the inlet port.

As vane 1 rotates past the outlet port, the partition is connected to the outlet port.

As vane 2 rotates towards the outlet port, the volume of the partition decreases, thus creating a positive pressure within the partition, which forces the air out of the chamber via the outlet port.

The air flow rate is adjusted by varying the speed of the motor driving the rotor.

Variants of this principle may also incorporate additional vanes.

A.2 Types of control system

A.2.1 Constant flow control

Pumps designed to this International Standard are of the constant flow control type. In this type of control, the control system adjusts the operation of the pump mechanism to maintain a constant volume flow rate within a specified tolerance.

The pump control system incorporates sensors to determine the performance of the pump mechanism. The performance of the pump mechanism can be determined from the voltage and current drawn by the pump motor or the pump control system can incorporate an air flow sensor to measure the air flow rate directly.

The pump controls may also incorporate additional sensors to monitor environmental conditions, e.g. ambient temperature and atmospheric pressure, and adjust the performance of the pump mechanism based on these for greater accuracy.

A.2.2 Constant pressure control

In this type of control, the control system adjusts the operation of the pump mechanism to maintain a constant pressure drop at the sample media outlet, within a specified tolerance.

The pump control system incorporates a pressure sensor at the pump inlet to derive a pressure drop signal. This signal plus the required pressure drop setting form the feedback and input signals of a closed loop control system.

An alternative method of constant pressure control is the incorporation of an internal (or the addition of an external) pneumatic pressure regulating valve.

When this type of control system is utilized, the sampler should include a throttle valve to set the required flow rate through the sample media.

Annex B
(informative)

Internal sensors of sampling pumps

B.1 General

Sampling pumps very often have several internal sensors, e.g. for measurement of temperature, pressure, and flow rate, and the pump can be connected to a computer.

These internal sensors can be used to provide sampling data as long they meet the minimum requirements given in 6.2.

B.2 Measurement of ambient conditions

B.2.1 General

Occupational exposure limit values are in many cases related to specified atmospheric conditions (e.g. 20 °C and 101,3 kPa or 25 °C and 100 kPa). To convert the volume of the sampled air to these conditions, the pressure and temperature of the sampled atmosphere during sampling are recorded.

The ambient conditions are measured at the beginning and end of the measurement, and for measurement related to the work shift, a minimum of one time in between.

Normally calibrated thermometers and barometers are used for the measurement of the ambient conditions during sampling.

B.2.2 Temperature

For temperature measurement, use a thermometer (e.g. glass or electrical) with a tolerance of 1 °C traceable to the national standard (see 6.2).

The data given by an internal thermometer of a sampling pump can only be used to calculate the specified atmospheric conditions when its accuracy meets the requirement given in 6.2 and can be calibrated traceable to the national standard.

B.2.3 Atmospheric pressure

For pressure measurement, use a pressure meter (e.g. barometer) with a tolerance of 0,5 kPa traceable to the national standard.

B.3 Flow rate measurement

For flow rate measurement, use a flow meter (e.g. mass flow meter, rotameter) with a measurement uncertainty better than ±2 % of the measured flow rate traceable to the national standard (see 6.2).

The data given by an internal flow meter of a sampling pump can only be used to measure the flow rate when its accuracy meets the requirement given in 6.2 and can be calibrated traceable to the national standard.

NOTE Some sampling pumps are equipped with an internal rotameter. These rotameters are highly inaccurate and cannot be used for flow rate adjustment.

B.4 Interface to a computer (internal data logger)

Pumps that have an interface to transfer the sample related data (e.g. air flow, sampling time) should ensure that the data stored in an internal data logger can easily be transferred to a computer.

Annex C
(informative)

User tests for pumps and flow meters

C.1 General

Always check sampling pumps and flow meters for correct function before each use. In particular, this includes flow rate stability and flow rate adjustment.

In order to ensure a long life for most battery types, perform a complete discharge and charge cycle before each use. For further information see the manufacturer's instructions for use.

C.2 Regular verification of pump performance

As a result of regular use, it is possible that the performance of the battery and the pump no longer satisfies the requirements of this International Standard. Therefore, the performance of a pump should be verified regularly, and at least annually. This verification can be carried out by the pump user or by an external service (e.g. the pump manufacturer).

For regular verification of pump performance, the basic test set-up given in 6.5 and the test procedure described in 7.10 can be used. Always test pumps in relation to the specific application. Therefore, the test should be carried out at a flow rate at which the pump is commonly operated.

Record the results and keep the documentation. The latter should include at least the date of the last verification, the date of the next verification and the document with the results of the verification.

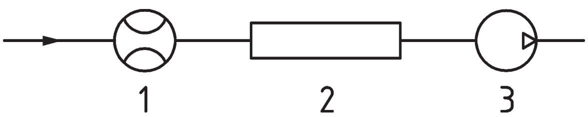
C.3 Verification of pump flow stability

Fully charge the pump in accordance with the manufacturer's instructions. Connect an upstream flow resistor, e.g. a sampler and collection substrate, and set the pump to the desired flow rate. If the set flow rate is kept constant over a short period (e.g. 5 min), the pump can be used.

C.4 Setting and checking the pump during sampling

Before each use, connect the sampling train (pump plus sampler selected for sampling) to a suitable flow meter. Set the flow rate to the required value. After sampling, check the flow rate again; it shall not deviate by more than ±5 % from its initial value. See Figure C.1.

NOTE Pumps very often show a starting behaviour where the air flow is not constant over a short period. The time can vary up to approximately 30 min, especially when the pump is not adapted to the environmental conditions.



Key

1 volume flow meter or volume meter

2 sampler

3 pump

Figure C.1 — Flow rate measurement of sampling pumps

C.5 Pump maintenance

C.5.1 Battery

Pumps with older designs usually have NiCd batteries, while pumps with more recent designs have NiMH or Li-ion batteries.

With NiCd batteries there is a risk of the so-called memory effect. If the batteries are not fully discharged and not fully charged several times in succession, battery performance is permanently impaired. Batteries should always be fully discharged before charging. In the event of prolonged disuse, they should be stored in their discharged state or in their current state (partially discharged). Before being used again, the pumps should undergo a complete discharge and charge cycle.

For further information, see the manufacturer’s instructions for use.

C.5.2 Checking battery performance

Regularly used pumps normally do not need to be checked regarding their battery performance. However, pumps which are not used regularly should be checked before use, as follows.

First perform a complete discharge and charge cycle. Then operate the pump at the usually set flow rate with a sampler typical for this flow rate until it switches off or the low battery indicator displays an error. Replace the battery, if the runtime is not sufficient.

C.5.3 Power consumption

The power consumption can be easily tested by running the pump at a high flow rate and a high pressure drop, and measure the running time until the pump stops or signals a malfunction. A record of this shows if something is wrong with the pump engine and flow system, provided a good battery is used.

C.6 Flow meters

The flow meters used according to this International Standard to set the flow rate for sampling should be regularly calibrated. It is not necessary to traceably calibrate every flow meter. Therefore, it is sufficient to test the flow meters used against a single traceably calibrated laboratory standard.

For typical flow meter measurement ranges and measurement uncertainties see Table C.1.

Table C.1 — Typical flow meter measurement ranges and measurement uncertainties

Type (measurement principle)	Measurement range	Measurement uncertainty	Remarks
	l · min^{-1}	%	
Soap bubble tube (replaceable measurement cell)	0,005 to 0,5 0,1 to 4,0	±1	Clean regularly
Soap bubble tube (replaceable measurement cell)	0,001 to 0,250 0,02 to 6,0 2,0 to 30,0	within ±1 within ±1 within ±1	Clean regularly
Rotameter accuracy class 2,5	various	within ±5 to ±2,5	Measurement in upper third
Rotameter accuracy class 1,6	various	within ±3 to ±1,6	Measurement in upper third
Dry piston	0,01 to 12,0	within ±1 to ±4	At ≥10 l · min^{-1}, about 4 % deviation. Piston stroke systems have low inherent resistance
Dry piston (replaceable measurement cell)	0,015 to 0,3 0,1 to 7,0 0,5 to 30,0	±1 ±1 ±1	Piston stroke systems have low inherent resistance
Thermal mass flow meter	0,005 to 15,0	within ±1 to ±4	at ≤0,05 l · min^{-1}, about 4 % deviation
Gas meter	6,0 to about 150,0	±2	Laboratory use only

Annex D
(informative)

Pressure drop due to collection substrates

For the measurement of pressure drop, install a sampling train consisting of a pump and a sampler on a benchmark test equipped with a volume flow meter or volume meter and a differential pressure gauge. Adjust the flow rate to the desired value, in relation with the sampler type, and record the pressure drop.

All pressure drops listed in Tables D.1 to D.4 are measured values of typical collection substrates. For more detailed information see Reference [4].

Table D.1 — Pressure drop of sampling tubes

Sorbent	Tube size		Filling		Flow rate		Pressure drop	
	mm		mg		l · min^{-1}		kPa	
	length	d_i[a]	S_1[b]	S_2[c]	min.	max.	min.	max.
Charcoal	125	7	300	600	0,033	0,333	0,2	3,4
Charcoal	110	8	200	400	0,05	0,2	0,2	0,7
Charcoal	110	8	200	400	0,5	2,0	0,6	3,5
Charcoal	70	6	50	100	0,05	0,2	0,2	0,7
Silica gel	125	7	500	1000	0,033	0,333	0,1	2,4
Silica gel	125	7	300	300	0,067	0,333	0,2	2,2
Silica gel	110	8	260	520	0,05	0,2	0,1	0,4
Silica gel	110	8	260	520	0,5	2,0	0,9	9,3
XAD-2[d]	110	8	50	100	—	1,0	—	2,8
XAD-4[d]	75	6	40	80	—	1,0	—	1,9
XAD-7[d]	110	6	50	100	—	0,166	—	1,2
Chromosorb 104[d]	70	6	35	75	0,05	0,2	1,0	4,8
Carbotrap[d]	110	7	175	350	0,05	0,2	0,4	1,6
Carbotrap 349[d]	89	6,4	—	355	0,05	0,2	0,9	3,7
Tenax TA™[d]	100	8	50	100	—	0,5	—	2,3
Tenax TA™[d]	89	4,9	—	200	0,05	0,2	0,8	4,7
Porapack Q[d]	70	6	39	78	0,05	0,2	1,1	4,3
Silica gel impregnated with DNPH	43	10	—	350	—	0,333	—	0,3
Silica gel impregnated with DNPH	74	—	—	350	—	1,0	—	4,6
Silica gel impregnated with DNPH	—		150	300	0,05	0,2	0,4	1,9
Charcoal impregnated with KOH	70	6	50	100	—	0,2	—	0,3
Charcoal impregnated with H_2SO_4	150	8	100	500	—	0,333	—	0,6
Charcoal impregnated with 4-*t*-butyl catechol	70	6	55	10	—	0,1	—	0,5

a Internal diameter.

b Section 1.

c Section 2.

d Product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

For pressure drop measurements, the filters have been mounted in different inhalable or respirable sampler, e.g. GSP sampler,1) Button sampler,1) IOM sampler,1) IFA 2-l-cyclone,1) IFA 10-l-cyclone,1) and BGI cyclone GK 2.69,1) PGP-EA sampler.1)

See Tables D.2 to D.4.

1) Product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Table D.2 — Pressure drop of unloaded filters

Filter material	Diameter	Pore size	Flow rate		Pressure drop	
	mm	µm	$l \cdot min^{-1}$		kPa	
			min.	max.	min.	max.
Glass fibre[a]	37	—	1	10	0,2	4,6
Glass fibre[b,c]	25	1	2	4	1,0	1,5
Quartz fibre[a]	37	—	1	10	0,2	2,4
Polytetrafluoroethylene[a]	37	10	1	10	0,3	2,7
Polytetrafluoroethylene[a]	37	0,45	1	10	0,8	8,8
Polyvinyl chloride[c]	37	0,8	1	10	0,5	4,4
Polyvinyl chloride[b,c]	25	0,8	2	4	2,9	5,8
Polyvinyl chloride[b,c]	37	5	2	3,5	0,5	0,7
Mixed cellulose ester[b]	25	0,8	—	2,0	—	2,8
Mixed cellulose ester[b]	25	1,2	—	2,0	—	2,1
Mixed cellulose ester[b]	25	1,2	—	2,0	—	2,7
Mixed cellulose ester[b]	25	5,0	—	2,0	—	1,5
Mixed cellulose ester[b]	25	8,0	—	2,0	—	1,4
Mixed cellulose ester[c]	25	0,8	—	4,0	—	7,2
Mixed cellulose ester[c]	25	1,2	—	4,0	—	5,8
Mixed cellulose ester[c]	25	5,0	—	4,0	—	4,0
Mixed cellulose ester[c]	25	8,0	—	4,0	—	3,8
Mixed cellulose ester[a]	37	8	1	10	0,1	1,1
Mixed cellulose ester[a]	37	0,8	1	10	0,7	9,7
Silver	25	0,8	—	4	—	3,1

a Filter mounted in GSP sampler.[1)]

b Filter mounted in an old IOM cassette.[1)]

c Filter mounted in Button sampler.[1)]

Table D.3 — Pressure drop of loaded filters

Filter material	Diameter	Pore size	Loading	Flow rate	Pressure drop
	mm	µm	mg	$l \cdot min^{-1}$	kPa
Glass fibre[a]	25	1	2,52[b]	4	3,1
Glass fibre[a]	25	1	3,32[b]	4	3,4
Glass fibre[a]	25	1	3,62[b]	4	6,4
Glass fibre[a]	25	1	3,92[b]	4	5,2
Silver[c,f]	25	0,8	5	4	6,3
PVC[d,f]	37	5	10	10	4,1
PVC[e,f]	37	5	9	8	4,1
MCE[g,h]	25	5,0	1,4	2	2,8

a Filter mounted in a Button sampler,1) loaded with welding fume.

b Average of six samples.

c Filter mounted in modified (25 mm filters) BGI cyclone GK2.69,1) loaded with fine Arizona road dust.

d Filter mounted in an IFA 10-l-cyclone,1) loaded with fine Arizona road dust.

e Filter mounted in a PPI impactor,1) loaded with fine Arizona road dust.

f Data taken from Reference [5].

g Filter mounted in a filter cassette, loaded with welding fume.

h Mixed cellulose ester.

Table D.4 — Pressure drop of other collection substrates

Sampling device	Diameter	Pore width	Filling or impregnation	Flow rate	Pressure drop
	mm	µm		$l \cdot min^{-1}$	kPa
PU-foam[a]	20, height: 16	480 µm cell diameter	—	3,5	0,1
PU-foam + glass fibre filter[a]	20, 37	—	—	3,5	0,5
B 70 impinger	—	—	water 15 ml	1,166	3,6
B 70 impinger	—	—	toluene15 ml	1,166	1,0
B 70 impinger	—	—	2-propanol 15 ml	1,166	1,1
Glass fibre MN 85/90 BF1) **impregnated**	37	—	impregnated with 500 µl 1 mol · l^{-1} KOH	3,5	0,7
Glass fibre MN 85/90 BF1) **impregnated**	37	—	impregnated with 250 µl 0,1 mol · l^{-1} NaOH	3,5	0,7

a Mounted in a PGP-EA sampler.1)

Annex E
(informative)

Test instruments

E.1 **Volume meter**: e.g. gas meter or soap bubble meter.

E.2 **Flow meter**, e.g. dry piston flow meter, mass flow meter.

E.3 **Volume flow meter** or **hot wire anemometer**, rapidly responding (response time from t_{10} to t_{90} of 4,5 ms or less).

E.4 **Differential pressure gauge**.

E.5 **Flow resistor**, e.g. needle valve.

E.6 **Timer** of known accuracy, e.g. stopwatch.

E.7 **Pulsation damper**: e.g. buffer volume.

E.8 **Climatic chamber**.

E.9 **Auxiliary pump** (pulsation free).

E.10 **Temperature meter**: e.g. glass or electrical thermometer.

E.11 **Air pressure meter**: e.g. barometer.

E.12 **Shake machine**.

E.13 **Recorder** for rapid effects. e.g. memory oscilloscope or data logger, or AC/DC voltmeter or ampere meter.

E.14 **Connecting hoses** and **accessories**.

E.15 **Tubing** of rigid material without damping effect on pulsation.

E.16 **Linearizator** for the output signals of the rapidly responding flow meter or hot wire anemometer, if required.

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