
**Respiratory protective devices —
Methods of test and test equipment —**

Part 8:

**Measurement of RPD air flow rates of
assisted filtering RPD**

*Appareils de protection respiratoire — Méthodes d'essai et
équipement d'essai —*

Partie 8: Mesurage des débit d'air des APR filtrants à ventilation assistée





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Foreword

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

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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword — Supplementary information](#).

The committee responsible for this document is ISO/TC 94, *Personal safety — Protective clothing and equipment*, Subcommittee SC 15, *Respiratory protective devices*.

ISO 16900 consists of the following parts, under the general title *Respiratory protective devices — Methods of test and test equipment*:

- *Part 1: Determination of inward leakage*
- *Part 2: Determination of breathing resistance*
- *Part 3: Determination of particle filter penetration*
- *Part 4: Determination of gas filter capacity and migration, desorption and carbon monoxide dynamic testing*
- *Part 5: Breathing machine/metabolic simulator/RPD headforms/torso, tools and verification tools*
- *Part 6: Mechanical resistance/strength of components and connections*
- *Part 7: Practical performance test methods*
- *Part 8: Measurement of RPD air flow rates of assisted filtering RPD*
- *Part 9: Carbon dioxide content of the inhaled air*
- *Part 10: Resistance to ignition, flame, radiant heat and heat*
- *Part 11: Determination of field of vision*
- *Part 12: Determination of volume-averaged work of breathing and peak respiratory pressures*
- *Part 13: RPD using regenerated breathable gas and special application mining escape RPD: Consolidated test for gas concentration, temperature, humidity, work of breathing, breathing resistance, elastance and duration*
- *Part 14: Measurement of sound level*

Introduction

This part of ISO 16900 is intended as a supplement to the respiratory protective devices (RPD) performance standards. Test methods are specified for complete devices or parts of devices that are intended to comply with the performance standards. If deviations from the test method given in this part of ISO 16900 are necessary, these deviations will be specified in the performance standards.

Respiratory protective devices — Methods of test and test equipment —

Part 8:

Measurement of RPD air flow rates of assisted filtering RPD

1 Scope

This part of ISO 16900 specifies the methods for measuring air flow rates delivered to the wearer by an assisted filtering RPD.

2 Normative references

The following referenced documents, in whole or in parts, are indispensable for the application 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 16972, *Respiratory protective devices — Terms, definitions, graphical symbols and units of measurement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16972 and the following apply.

NOTE Within the definitions listed in 3.2 to 3.7, the flow rates are deemed to be volumetric flow rates.

3.1

assisted filtering RPD

filtering RPD where breathable gas is actively supplied to the wearer by the RPD

3.2

interactive flow rate

flow rate through the filters of an *assisted filtering RPD* (3.1) resulting from the combined action of the assisted filtering RPD and the breathing pattern generated by the breathing machine

3.3

averaged interactive flow rate

interactive flow rate averaged over 10 consecutive breathing cycles of the breathing machine

3.4

averaged maximum interactive flow rate

average of the highest flow rate within each breathing cycle of 10 consecutive breathing cycles of the breathing machine

3.5

averaged minimum interactive flow rate

average of the lowest flow rate within each breathing cycle of 10 consecutive breathing cycles of the breathing machine

3.6

measured maximum flow rate

volumetric flow rate of an *assisted filtering RPD* (3.1), determined in a laboratory test, when the RPD is in the condition which results in the highest air flow rate, where this condition takes into account the influences of temperatures, settings of RPD, pre-conditionings, use of accessories and others

3.7 measured minimum flow rate
volumetric flow rate of an *assisted filtering RPD* (3.1), determined in a laboratory test, when the RPD is in the condition which results in the lowest air flow rate, where this condition takes into account the influences of temperatures, settings of RPD, pre-conditionings, use of accessories, and others

4 Prerequisites

In order to implement this part of ISO 16900, at least the following parameters need to be specified in the relevant performance standard:

- a) number of test specimens;
- b) operating conditions of the RPD, e.g. possible air flow settings, charging status of batteries, influences from the temperature of operation;
- c) designated operational temperature range;
- d) appropriate RPD headform(s) and, if necessary, torso;
- e) any pre-conditioning.

5 General test requirements

Unless otherwise specified, the values stated in this International Standard are expressed as nominal values. Except for temperature limits, values which are not stated as maxima or minima shall be subject to a tolerance of $\pm 5\%$. Unless otherwise specified, the ambient conditions for testing shall be between 16 °C and 32 °C and $(50 \pm 30)\%$ RH. Any temperature limits specified shall be subject to an accuracy of ± 1 °C.

Where the assessment of the pass/fail criterion depends on a measurement, an uncertainty of measurement as specified in [Annex A](#) shall be given.

6 Principle

The complete RPD is fitted to an appropriate headform and, if necessary, torso and the RPD operated in accordance with the manufacturer's instructions for use, unless prescribed otherwise by the performance standard. The air flow supplied by the RPD is measured as the air flow rate.

Depending on the prerequisites given it might be required to determine the air flow rate at conditions which result in the minimum flow rate or the maximum flow rate of the RPD. Depending on the design of the RPD, these air flow rates may be determined by possible flow settings of the RPD, initialization time, the charging status of the battery, different filter types, alarm settings, the temperature of the RPD, including the temperature range for use, use of accessories, hose length, supply pressure, and other factors.

Where it is necessary to manipulate the RPD in order to achieve, during subsequent tests, a constant flow equivalent to either the measured maximum or minimum flow, the procedure that has to be adopted will depend on the design of the RPD. Possible ways of achieving such adjustments are substituting the battery by an external variable controlled power supply, artificially increasing the pressure drop of the filters used, or artificially adjusting the air flow control system of the RPD.

All results of measured air flow rates are deemed to be volumetric flow rates and shall be corrected to 20°C, 1013 hPa according to Formula (1)

$$Q_{cor} = Q_m \cdot k \cdot \left(\frac{P_m}{T_m} \right) \quad (1)$$

where

Q_{cor} is the corrected air flow;

Q_m is the measured air flow;

k is a constant 0,289 [K/hPa], i.e. 293 K divided by 1,013 hPa (20°C);

P_m is the pressure during measurement in hPa;

T_m is the temperature during measurement in K.

7 Test method

7.1 General

This part of ISO 16900 describes two test methods: measurement of flow rate using zero back pressure method and measurement of the interactive flow rate.

7.2 Measurement of flow rate using zero back pressure method

7.2.1 General

This test is suitable for RPD, where the interactive flow rate is constant, e.g. RPD with Respiratory Interface class L (loose fitting).

7.2.2 Test equipment

The test equipment consists of the following:

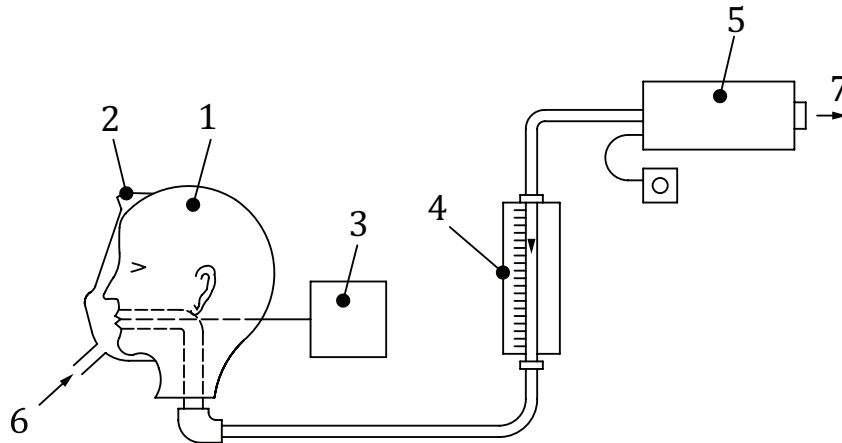
- appropriate **RPD headform**, of the appropriate size;
- **torso**, where necessary;
- **blower** or **suction device** with the air flow capacity to blow or draw an appropriate amount of air. The required air flow capacity shall be greater than the maximum airflow supplied by the RPD under test. The capacity usually needs to be above the flow rate which corresponds to the peak flow rate of the designated work rate class of the device. The air flow rate of the blower or suction device shall be controllable;
- **suitable flow meter**, calibrated in the range of air flow to be measured;
- **differential pressure sensor**, with a precision of better than ± 5 Pa at 0 Pa;
- **airtight box** or **lightweight bag** of a volume between 10 l and 30 l with necessary airtight connections.

7.2.3 Test procedure for RPD with a respiratory interface class T

The respiratory interface shall be fitted to the appropriate headform and, if necessary, a torso. Respiratory interfaces of class T shall be fitted in a leaktight manner to the headform. A sealant might

be necessary for this. The differential pressure sensor, the flow meter, and the suction device shall be arranged as shown in [Figure 1](#).

The RPD shall be activated. The controllable suction device of the test equipment used to draw air from the mouth opening of the head form shall be switched on and adjusted such that the differential pressure sensor shows a constant value of 0 ± 5 Pa, when compared to the ambient pressure. The air flow rate measured by the flow meter is the average interactive flow rate.



Key

- | | | | |
|---|-------------------------------|---|---|
| 1 | headform | 5 | controllable suction device |
| 2 | respiratory interface class T | 6 | air flow of the RPD |
| 3 | differential pressure sensor | 7 | air flow from controllable suction device |
| 4 | air flow meter | | |

Figure 1 — Typical test arrangement for air flow rate measurement of RPD with Respiratory Interface of class T

7.2.4 Test procedure for RPD with a respiratory interface class L

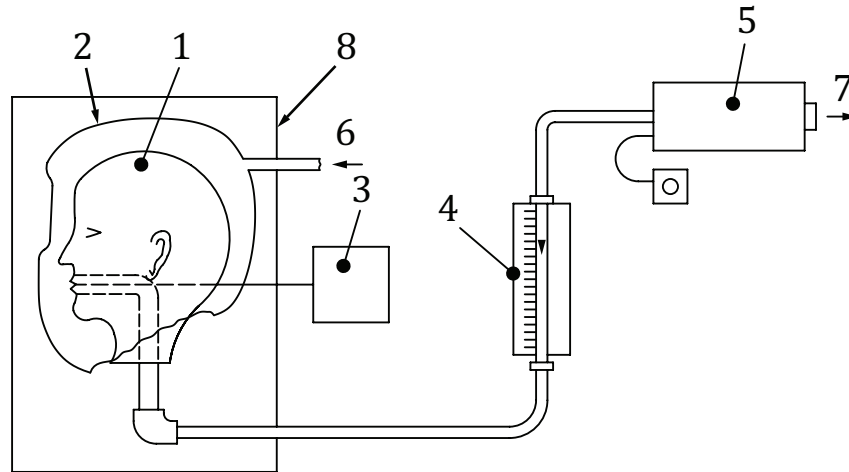
The loose fitting respiratory interface shall be fitted to the appropriate headform and, if necessary, a torso. The differential pressure sensor, flow meter, the blower, and the box or lightweight bag shall be arranged as shown in [Figure 2](#) or [Figure 3](#). All connections to and from the box or lightweight bag shall be leak tight.

For RPD with a Respiratory Interface of class L, [Figure 2](#) shows an appropriate test setup.

For RPD where the blower of the RPD is integrated in the Respiratory Interface of class L, [Figure 3](#) shows an appropriate test setup.

The RPD shall be activated. The adjustable blower device of the test equipment shall be switched on and adjusted so that the lightweight bag does not inflate, nor deflate. A pressure sensor might be helpful to find the exact adjustment of the blower.

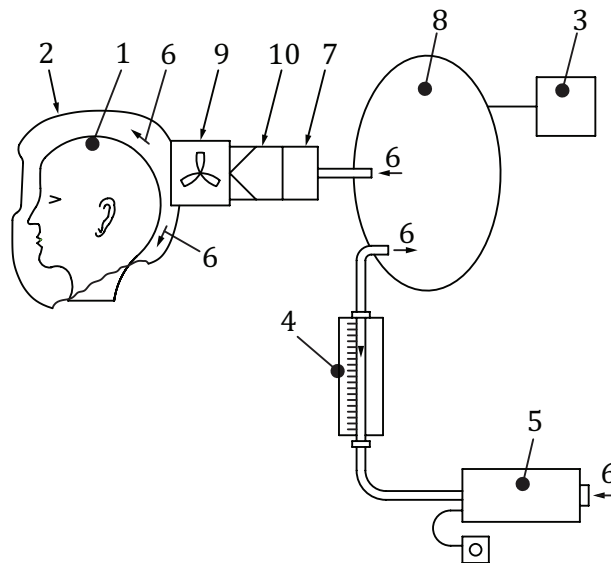
If a box is used, the blower device shall be adjusted such that the pressure sensor shows a constant value of (0 ± 5) Pa when compared to the ambient pressure. The air flow rate measured by the flow meter is the averaged interactive flow rate.



Key

- | | |
|---------------------------------|--|
| 1 headform | 5 controllable suction device |
| 2 respiratory interface class L | 6 air flow supplied by the RPD |
| 3 differential pressure sensor | 7 air flow from controllable suction device |
| 4 air flow meter | 8 box or lightweight bag, either may be used |

Figure 2 — Typical test arrangement for air flow rate measurement of RPD with Respiratory Interface class L where the air flow to the respiratory interface is supplied via a hose



Key

- | | |
|---------------------------------|--|
| 1 headform | 6 air flow |
| 2 respiratory interface class L | 7 leak tight connector between filter and breathing bag or box |
| 3 differential pressure sensor | 8 box or lightweight bag |
| 4 air flow meter | 9 blower of RPD |
| 5 controllable blower | 10 filter of RPD |

Figure 3 — Typical test arrangement for air flow rate measurement of RPD, where the blower of the RPD is integrated in the Respiratory Interface class L

7.3 Measurement of the interactive flow rate

7.3.1 General

This method is used to measure the maximum, the minimum, and the average interactive flow rate of RPD. It is suitable for all RPD, but especially where the blower unit is breath responsive. It measures the variation of air flow rate within each breath as indicated by the variation of the differential pressure, measured between the outlet of the filter and the blower part of the RPD.

In order to use this method, a correlation needs to be established between air flow through the RPD and the pressure drop across the filter system of the RPD as described in 7.3.3.

The maximum of the interactive flow rate (Q_{\max}) is the air flow rate passing through the RPD when the respiratory interface fitted on the appropriate headform and, if necessary, torso, is subject to the peak maximum inhalation flow rate of a breathing machine set to the relevant work rate as appropriate.

The minimum of the interactive flow rate (Q_{\min}) is the air flow rate passing through the RPD when the respiratory interface fitted on the appropriate headform and, if necessary, torso, is subject to the maximum exhalation air flow rate of a breathing machine set to the relevant work rate as appropriate.

The average of the interactive flow rate (Q_{av}) is the averaged air flow rate through the RPD when the respiratory interface fitted on the appropriate headform and, if necessary, torso, is subjected to a breathing machine set to the relevant work rate, as appropriate, and measured or calculated and averaged over 10 breathing cycles.

Values of Q_{\max} , Q_{\min} , and Q_{av} can be calculated from the recorded pressure data by using the air flow pressure characteristic of the RPD as given in Formula (2)

$$Q = a \cdot (\Delta P)^b \quad (2)$$

where

a and b are constants;

Q is the air flow rate [l/min];

ΔP is the differential static pressure [Pa] measured at a suitable point;

a and b can be calculated by linear regression analysis from the regression model in Formula (3)

$$\log Q = \log a + \log b(\Delta P) \quad (3)$$

7.3.2 Test equipment for calibration

The test equipment consists of the following:

- **pressure sensor**, able to measure at frequencies up to 50 Hz with less than 3 dB damping;
- **recording equipment** to record the dynamic pressure measurements, recording at the minimum of 100 Hz;
- **flow meter** capable of measuring within the range of the interactive air flow rates supplied by the RPD. This depends on the performance of the RPD and the designated work rate class;
- **controllable suction device**, capable of drawing more than the interactive maximum air flow rate.

7.3.3 Calibration of the test system

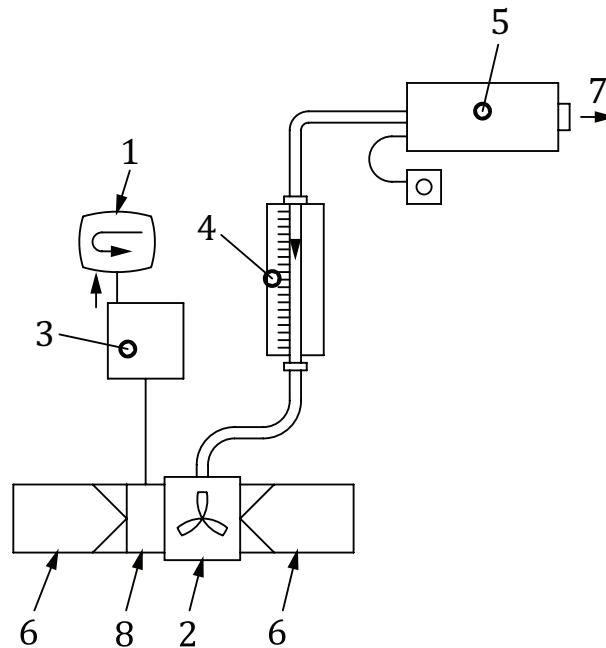
A measuring point for the pressure sensor is introduced in the RPD between the outlet of one filter and the inlet of the blower unit of the RPD (see [Figure 4](#)). At this point of the RPD, the pressure is negative compared to the environment when the RPD is switched on. The point shall be chosen so that there is only minimum interference to the air flow rate of the RPD when it is switched on.

An adapter or spacer between the filter outlet and the inlet of the blower unit may be used, provided it can be demonstrated that the results are unaffected.

NOTE This is the case when the pressure drop across the spacer is negligible when compared to the pressure drop across the filter and blower unit.

The outlet of the blower unit shall be connected to the inlet of the flow meter. The outlet of the flow meter shall be connected to the controllable suction device. The pressure sensor is connected to the measuring point. With the blower unit switched off, the pressure drop (ΔP) at the measuring point is measured at air flow rates between 0 l/min and the maximum expected air flow rate, e.g. 0 l/min, 30 l/min, 50 l/min, 70 l/min, 95 l/min, 120 l/min, 150 l/min, and 180 l/min. A typical arrangement is shown in [Figure 4](#).

From the measured values of pressure drop (ΔP), and flow rate (Q), the values of a and b in Formula (2) and Formula (3) are determined.



Key

- | | | | |
|---|------------------------------|---|---|
| 1 | recording equipment | 5 | controllable suction device |
| 2 | blower unit of RPD | 6 | filter of RPD |
| 3 | differential pressure sensor | 7 | air flow from controllable suction device |
| 4 | air flow meter | 8 | spacer (if inserted) |

Figure 4 — Typical test arrangement for calibration

7.3.4 Test equipment for measurement of interactive flow rate

The test equipment consists of the following:

- **breathing machine;**
- **pressure sensor**, able to measure at frequencies up to 50 Hz with less than 3dB damping;

- **recording equipment** to record the dynamic pressure measurements, recording at the minimum of 100 Hz;
- appropriate **RPD headform** of the appropriate size;
- **torso**, if necessary;
- **flow meter** capable of measuring within the range of the interactive air flow rates supplied by the RPD. This depends on the performance of the RPD and the designated work rate class;
- **controllable suction device**, capable of drawing more than the interactive maximum air flow rate.

7.3.5 Test procedure for measurement of averaged interactive flow rate

To measure the averaged interactive flow rate, the respiratory interface of the RPD shall be fitted on the appropriate headform and, if necessary, torso. The headform shall be connected to the breathing machine set to the relevant work rate. If the Respiratory Interface is class T (tight fitting), it shall be fitted in a leaktight manner to the headform. A sealant may be necessary for this. A typical test arrangement is shown in [Figure 5](#).

The RPD shall be activated, after which the breathing machine shall be switched on. The time-dependent pressure between the pressure measuring point and the ambient atmospheric pressure shall be measured and recorded. Using only the differential pressure values (ΔP) with the sign corresponding to an air flow through the filter into the blower, the air flows shall be calculated from the recorded data according to Formula (2) and Formula (3).

After the flow rates have been calculated from the differential pressures, the averaged interactive flow rate Q_{av} shall be calculated using the data of 10 consecutive breathing cycles.

7.3.6 Test procedure for measurement of averaged maximum interactive flow rate

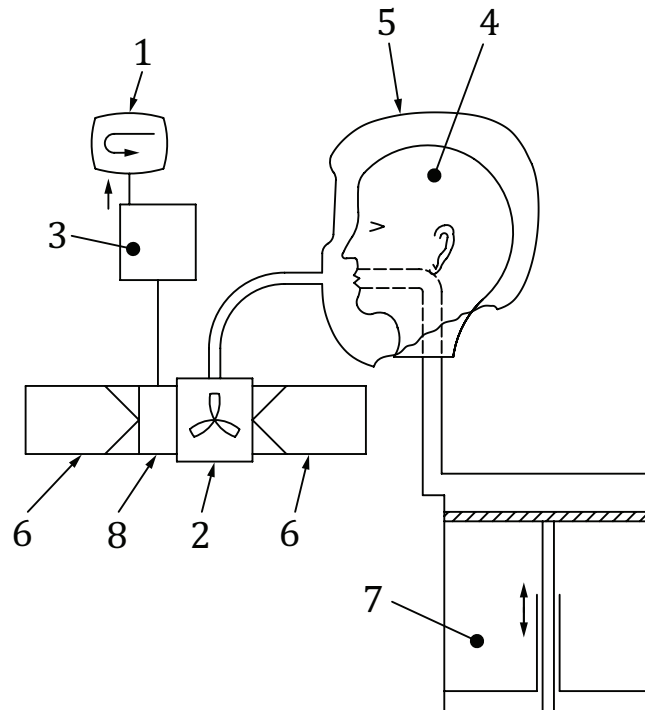
7.3.6.1 General

The maximum interactive flow rate can be measured with the dynamic test method or the static test method.

7.3.6.2 Dynamic test method

To measure the maximum interactive flow rate, the respiratory interface of the RPD shall be fitted on the appropriate headform. If the Respiratory Interface is class T, it shall be fitted in a leaktight manner to the headform. A sealant may be necessary for this. The headform shall be connected to the breathing machine set to the relevant work rate. A typical test arrangement is shown in [Figure 5](#).

The RPD shall be activated, after which the breathing machine shall be switched on. The time-dependent differential static pressure between the pressure measuring point and the ambient atmospheric pressure shall be measured and recorded. Maximum interactive flow rates shall be calculated from the maximum differential static pressures using Formula (2) and Formula (3). After the flow rates have been calculated from the differential pressures, the averaged maximum interactive flow rate Q_{max} shall be calculated using the data of 10 consecutive breathing cycles.



Key

- | | | | |
|---|------------------------------|---|-----------------------|
| 1 | recording equipment | 5 | respiratory interface |
| 2 | blower unit of RPD | 6 | filter of RPD |
| 3 | differential pressure sensor | 7 | breathing machine |
| 4 | headform | 8 | spacer (if inserted) |

Figure 5 — Typical test arrangement to measure the averaged interactive flow rate, the averaged maximum interactive flow rate or the averaged minimum interactive flow rate with the dynamic test method

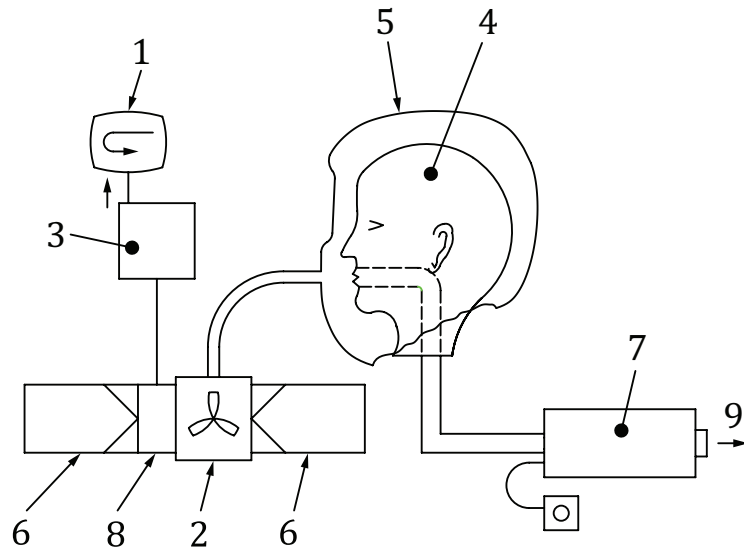
7.3.6.3 Static test method

The breathing machine as described in 7.3.4 is replaced by a controllable suction device. The suction device is adjusted to a constant air flow rate corresponding to the equivalent peak flow rate of the RPD class W1, W2, W3, or W4, respectively, i.e. 110 l/min for W1, 205 l/min for W2, 330 l/min for W3, or 425 l/min for W4.

The configuration for the static test method is shown in Figure 6.

NOTE The peak air flow rates for the suction device for this test are derived from the average air flow rates for W1, W2, W3, and W4 and the sinusoidal breathing pattern of the breathing machine. The peak air flow rates are therefore different from the peak air flow rates for W1, W2, W3, and W4 based on other breathing patterns, e.g. human breathing.

The measured pressure drop is ΔP_{\max} . Q_{\max} shall be calculated from ΔP_{\max} using Formula (3).



Key

- | | | | |
|---|------------------------------|---|------------------------------|
| 1 | recording equipment | 6 | filter of RPD |
| 2 | blower unit of RPD | 7 | controllable suction device |
| 3 | differential pressure sensor | 8 | spacer (if inserted) |
| 4 | headform | 9 | air flow from suction device |
| 5 | respiratory interface | | |

Figure 6 — Typical test arrangement to measure the maximum interactive flow rate with the static test method

7.3.7 Test procedure for measurement of the averaged minimum interactive flow rate

The averaged minimum interactive flow rate can be measured with the dynamic test method.

To measure the averaged minimum interactive flow rate, the respiratory interface of the RPD shall be fitted on the appropriate headform. If the Respiratory Interface is class T, it shall be fitted in a leaktight manner to the headform. A sealant may be necessary for this. The headform shall be connected to the breathing machine set to the relevant work rate. A typical test arrangement is shown in [Figure 5](#).

The RPD shall be activated, after which the breathing machine shall be switched on. The time-dependent differential static pressure between the pressure measuring point and the ambient atmospheric pressure shall be measured and recorded. Minimum interactive flow rates shall be calculated from the minimum differential static pressures using Formula (2) and Formula (3). After the flow rates have been calculated from the differential pressures, the averaged minimum interactive flow rate Q_{min} shall be calculated using the data of 10 consecutive breathing cycles.

8 Test report

The test report shall include information regarding those parameters specified in [Clause 4](#), together with the following, as a minimum:

- a) the method used according to this part of ISO 16900, i.e. ISO 16900-8;
- b) the flow rate in l/min, including the uncertainty of the measurement;
- c) the type of flow rate:
 - 1) flow rate using the zero back pressure method;

- 2) averaged interactive flow rate (see [3.3](#));
 - 3) averaged maximum interactive flow rate (see [3.4](#));
 - 4) averaged minimum interactive flow rate (see [3.5](#));
- d) the information if the RPD was tested for the measured maximum or measured minimum flow conditions (see [3.6](#) and [3.7](#));
- e) any deviation from the test method.

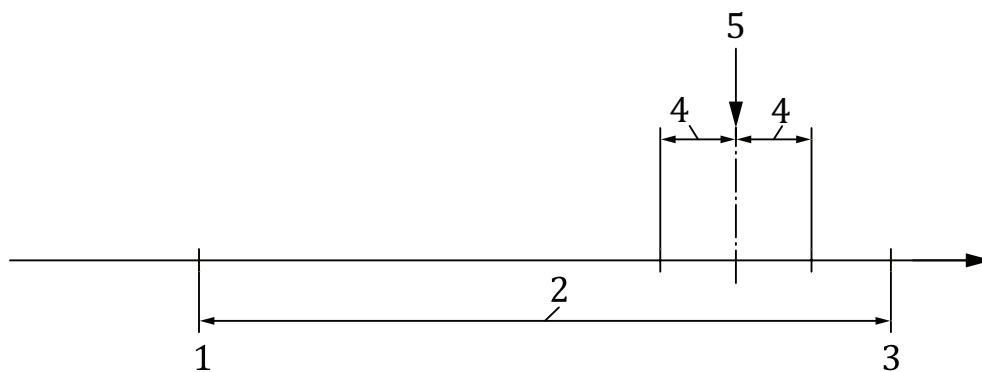
Annex A (normative)

Application of uncertainty of measurement

A.1 Determination of compliance

In order to determine compliance or otherwise of the measurement made in accordance with this test method, when compared to the specification limits given in the performance standard, the following protocol shall be applied.

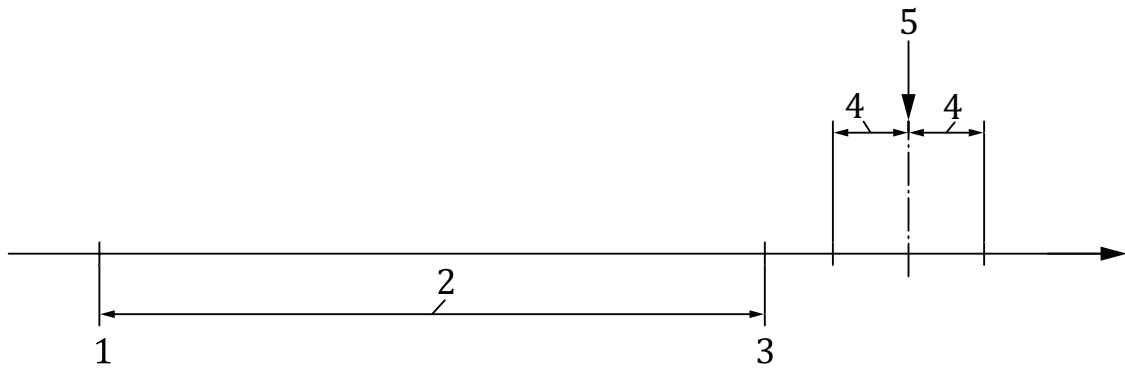
If the test result \pm the uncertainty of measurement, U , falls completely inside or outside of the specification zone for the particular test given in the performance standard, then the result shall be deemed to be a straightforward pass or fail (see [Figures A.1](#) and [A.2](#)).



Key

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement, U
- 5 measured value

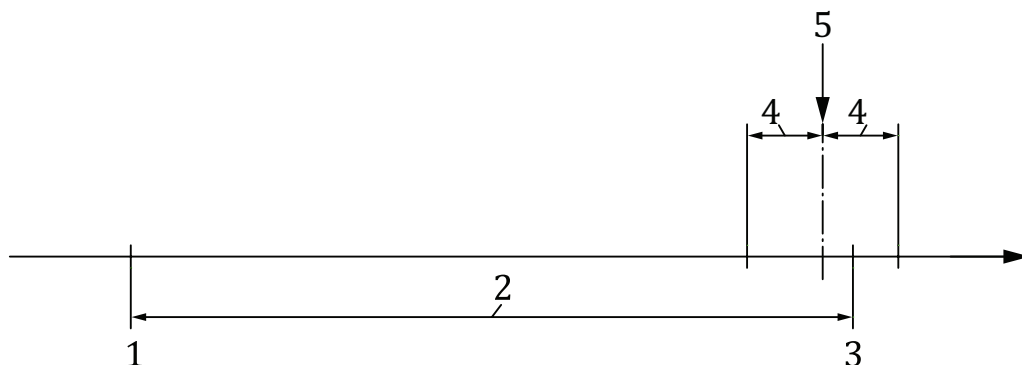
Figure A.1 — Result pass

**Key**

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement, U
- 5 measured value

Figure A.2 — Result fail

If the test result \pm the uncertainty of measurement, U , overlaps a specification limit value (upper or lower) for the particular test given in the performance standard, then the assessment of pass or fail shall be determined on the basis of safety for the wearer of the device; that is, the result shall be deemed to be a fail (see [Figure A.3](#)).

**Key**

- 1 lower specification limit
- 2 specification zone
- 3 upper specification limit
- 4 uncertainty of measurement, U
- 5 measured value

Figure A.3 — Result fail

