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Introduction

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| | 3.1 | Definition 1 | ed | Definition is ambiguous and needs clarifying. | Amend to read '... so that the mains connector to which no connection ... | |
| | 6.4 | Paragraph 2 | te | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer. | |

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Foreword

This document (prEN 14143:2010) has been prepared by Technical Committee CEN/TC 79 “Respiratory protective devices”, the secretariat of which is held by DIN.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 14143:2003.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

In this European Standard the annex A is informative.

Introduction

A given self-contained re-breathing diving apparatus can only be approved when the apparatus or apparatus sub-assemblies satisfy the requirements of the tests specified in this standard, and practical performance tests have been carried out successfully on the complete apparatus where specified in the standard.

1 Scope

This European Standard specifies minimum requirements for self-contained re-breathing diving apparatus to ensure a minimum level of safe operation of the apparatus. It applies to the following:

- a maximum depth of 6 m for apparatus using pure oxygen;
- a maximum depth of 40 m for apparatus using oxygen in nitrogen gas mixtures;
- a maximum depth of 100 m for apparatus using oxygen and helium or oxygen, nitrogen and helium gas mixtures;
- water temperatures from 4 °C to 34 °C.

The requirements of this standard are intended to take account of the interaction between the wearer, the apparatus, and where possible the environment in which the apparatus is likely to be used. See annex ZA.

2 Normative references

The following referenced documents 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.

EN 132, *Respiratory protective devices – Definitions of terms and pictograms*

EN 134, *Respiratory protective devices – Nomenclature of components*

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EN 144-1, *Respiratory protective devices – Gas cylinder valves – Part 1: Thread connections for insert connector*

EN 144-3, *Respiratory protective devices – Gas cylinder valves – Part 3: Outlet connections for diving gases nitrox and oxygen*

EN 148-1, *Respiratory protective devices – Threads for facepieces – Part 1: Standard thread connection*

EN 148-2, *Respiratory protective devices – Threads for facepieces – Part 2: Centre thread connection*

EN 148-3, *Respiratory protective devices – Threads for facepieces – Part 3: Thread connection M 45 x 3*

EN ISO 10297, *Transportable gas cylinders – Cylinder valves – Specification and type testing*

EN 12021, *Respiratory protective devices – Compressed air for breathing apparatus*

EN ISO 12209-1, *Gas cylinders – Outlet connections for gas cylinder valves for compressed breathable air – Part 1: Yoke type connections*

EN ISO 12209-2, *Gas cylinders – Outlet connections for gas cylinder valves for compressed breathable air – Part 2: Threaded connections*

EN ISO 12209-3, *Gas cylinders – Outlet connections for gas cylinder valves for compressed breathable air – Part 3: Adapter for 230 bar valves*

ISO/IEC 12207, *Information technology – Software life cycle process*

IEC 60300-3-6, *Dependability management – Part 3: Application guide – Section 6: Software aspects of dependability*

EN 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

EN 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3 : Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

EN 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

EN 61000-4-5, *Electromagnetic Compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

EN 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

EN 61000-4-8, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

EN 61000-4-11, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*

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

3 Terms and definitions

For the purpose of this European Standard the terms and definitions given in EN 132:1998 and the nomenclature given in EN 134:1998 apply together with the following:

3.1

self-contained re-breathing diving apparatus

apparatus that has a supply of gas carried by the diver, allowing the diver to breathe under water

The apparatus is designed and constructed to enable the diver to inspire gas from a facepiece connected to a counterlung and to pass exhaled gas through a carbon dioxide absorption material before it is re-breathed from the counterlung. The inspired partial pressure of the gases within the apparatus remain within acceptable physiological limits. The gas is thus re-circulated within the apparatus.

A self-contained re-breathing diving apparatus may also be called a diving Re-breather.

3.2

high pressure

the pressure inside the gas cylinder(s) and between the gas cylinder(s) and any pressure reducer

3.3

medium pressure

the pressure between the pressure reducer and a gas control system

NOTE This is sometimes referred to as intermediate pressure.

3.4

low pressure

the pressure within the facepiece, breathing hoses, counterlung and absorbent canister, i.e. approximately ambient pressure

3.5

respiratory pressure

the differential pressure at the mouth relative to the no flow pressures at the end of inhalation and exhalation (see Figure 1)

3.6

rated working pressure

the maximum working pressure of the respective components

3.7

hydrostatic imbalance

the difference at end exhalation "no flow" between the pressure at the mouth (see Figure 1) and that at the reference point which could either be the suprasternal notch or the lung centroid of the diver (see Figure 2)

3.8

displaced (tidal) volume

the volume of respirable gas displaced by the breathing simulator during one half cycle (inhalation or exhalation) measured in litre

3.9

breathing frequency

the setting of the breathing simulator measured in cycles per minute

3.10

respiratory minute volume (RMV)

the product of the tidal volume and breathing frequency measured in litre per minute

3.11

pressure volume diagram

the diagram generated during one breathing cycle by plotting the respiratory pressure against the displaced volume (see Figure 1)

3.12

work of breathing

the work expended during one breathing cycle measured in Joule per litre. This work is proportional to the area bounded by the pressure volume diagram (see Figure 1)

3.13

breathing hose

flexible low pressure hose(s) connecting the facepiece to either the counterlung(s) or absorbent canister

3.14

counterlung

variable volume container for the diver to inhale from and exhale to

3.15

absorbent canister

container of absorbent materials which will remove carbon dioxide from the gas passing through them

3.16

dead space

the volume of the cavity formed between the mouth and the inhalation and exhalation parts

3.17

body harness

component of the re-breather to attach the apparatus to the body of the diver

3.18

facepiece

device for connecting the apparatus to the wearer's respiratory tract and isolates the respiratory tract from the environment.

NOTE It may be a mouthpiece assembly, a half mask, a full face mask or a helmet.

3.19

oxygen and nitrogen gas mixture

gas comprising a specified mixture of oxygen and nitrogen, capable of supporting human life under appropriate diving or hyperbaric conditions

NOTE 1 This includes manufactured gas mixtures made up from combinations of pure oxygen and pure nitrogen, with or without compressed air.

NOTE 2 This definition differs from that in EN 13949:2003 in that it covers all oxygen and nitrogen gas mixtures irrespective of oxygen content.

3.20

Trimix

gas comprising a specified mixture of oxygen, helium and nitrogen, capable of supporting human life under appropriate diving or hyperbaric conditions

NOTE This includes manufactured gas mixtures made up from combinations of pure oxygen, pure helium and pure nitrogen, with or without compressed air.

3.21

Heliox

gas comprising a specified mixture of oxygen and helium, capable of supporting human life under appropriate diving or hyperbaric conditions

3.22

active warning device

device that informs the diver of an adverse event without the diver having to take any action to receive the warning. The information is typically audible, visual or tactile

4 Minimum equipment

The apparatus shall comprise at least the following components:

- breathing circuit comprising e.g. facepiece, breathing hose(s), counterlung(s), exhaust valve, absorbent canister;
- gas control or supply system;
- gas supply gas cylinder(s);
- safety device(s);
- body harness.

It shall also be delivered with information supplied by the manufacturer.

The apparatus may also include an emergency breathing system.

5 Requirements

5.1 Design

The manufacturer shall support the apparatus design by the provision of a failure mode effect and criticality analysis (FMECA).

Testing shall be done in accordance with 6.2.

The apparatus shall be designed and its components and parts located to provide protection against mechanical damage caused by external influence and to ensure that it is possible to perform the required pre-dive functional checks. It shall not be possible to assemble or combine the components or parts in such a way that may affect the safe operation and use of the apparatus, e.g. by incorrect connection of the hoses to the breathing circuit. The apparatus shall not have any sharp edges or protrusions that can injure the diver.

Testing shall be done in accordance with 6.2 and 6.15.

All parts, which have to be actuated by the diver during use, shall be accessible and controllable even when wearing protective gloves (three fingers, with 6 mm to 7 mm padding on either side). They shall be designed such that their setting cannot be altered inadvertently during use.

Testing shall be done in accordance with 6.15.

The apparatus shall function satisfactorily out of the water and in all orientations in the water. The apparatus shall be designed to prevent any chemicals used within the apparatus, saliva, condensation or ingress of water from adversely affecting the operation of the apparatus or causing harmful effect to the diver when used according to the information supplied by the manufacturer.

Testing shall be done in accordance with 6.2 and 6.15.

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Any part of the equipment intended for high pressure gas with an oxygen content greater than air as specified in EN 12021 shall be designed and selected for use with high pressure oxygen.

Testing shall be done in accordance with 6.2 and 6.16.

If the apparatus is intended for use in water temperatures less than 4 °C or above 34 °C the manufacturer shall state the minimum and maximum temperatures and its performance shall be tested at those temperatures.

Testing shall be done in accordance with 6.2, 6.3, 6.7, 6.8 and 6.15.

Any gas supply within the apparatus shall have a minimum oxygen content of 5 %.

Testing shall be done in accordance with 6.2.

5.2 Materials

The parts used shall have adequate mechanical strength, durability and resistance to wear and feature sufficient resistance to changes caused by the effect of temperature individually and when assembled.

Testing shall be done in accordance with 6.2, 6.8, 6.9, 6.13 and 6.15.

Materials that come into direct contact with the wearer's skin and the respirable gas shall not be known to be likely to cause irritation or any other adverse effect to health.

Testing shall be done in accordance with 6.2 and 6.15.

5.3 Gas cylinder(s)

The gas cylinder(s) shall comply with regulations appropriate to the country of use and shall be approved and tested with respect to the rated working pressure and the use of elevated oxygen content if appropriate.

The gas cylinder(s) shall be marked with the appropriate neck thread designation according to EN 144-1 where the preferred versions are M 18 x 1,5 and M 25 x 2.

Cylinder(s) shall be designed for use at the maximum diving depth.

Testing shall be done in accordance with 6.2.

5.4 Cylinder valve(s)

Cylinder valves(s) shall comply with EN ISO 10297 and shall be tested and approved for use at the rated working pressure and gas.

Testing shall be done in accordance with 6.2 and 6.16.

The threads for connecting the gas cylinder(s) and the cylinder valve(s) shall comply with EN 144-1 where the preferred versions are M 18 x 1,5 or M 25 x 2.

The connections between the cylinder valve(s) and the gas control or supply system shall be constructed according to:

- EN ISO 12209-1, EN ISO 12209-2 and EN ISO 12209-3 for gas cylinders intended for compressed air;
- EN 144-1 for gas cylinders intended for use with gases with an oxygen content greater than air as specified in EN 12021.

Testing shall be done in accordance with 6.2.

The opening of the valve orifice shall be progressive. Complete opening shall require more than one rotation of the operating mechanism. For valves, in which it is technically difficult to limit opening in this way (for example diaphragm valves) other means shall be provided to delay full gas flow.

The valve(s) shall be designed and located so that it cannot be closed inadvertently e.g. by requiring at least two full turns from fully open to fully closed position.

The function of a cylinder valve shall not be impaired by the ingress of water.

Testing shall be done in accordance with 6.2 and 6.15.

The cylinder valve(s) shall be protected against the entrainment of dirt, solid particles and water from inside the gas cylinder e.g. by means of a protective tube with a length of at least 30 mm and an inside diameter of at least 2,5 mm.

Testing shall be done in accordance with 6.2.

5.5 High and medium pressure parts and connections

5.5.1 General

All metallic high pressure tubes, valves and couplings shall be capable of withstanding a pressure 50 % above the working pressure of the gas cylinder.

All metallic medium pressure parts, valves and couplings shall be capable of withstanding a pressure of 50 % above their rated working pressure.

Non-metallic high pressure tubes, valves and couplings shall be capable of withstanding a pressure of twice the rated working pressure of the gas cylinder.

Non-metallic medium pressure parts, valves and couplings shall be capable of withstanding a pressure of twice their rated working pressure.

Testing shall be done in accordance with 6.2 and 6.9.

It shall not be possible to connect a low or medium pressure subassembly to a high pressure outlet or connection.

Testing shall be done in accordance with 6.2 and 6.15.

5.5.2 Pressure reducer (if fitted)

On the pressure reducer any adjustable medium pressure setting shall be reliably secured against accidental alteration and adequately sealed so that any unauthorised adjustment can be detected.

Testing shall be done in accordance with 6.2 and 6.15.

If fitted, any pressure reducer which is pressurized above 25 bar absolute and may be used with a respirable gas having an oxygen content greater than that of air as specified in EN 12021, shall withstand the oxygen pressure surge test.

Testing shall be done in accordance with 6.2 and 6.16.

5.5.3 Pressure relief system(s)

All medium pressure supplies shall be fitted with a pressure relief system. The manufacturer shall specify the relief pressure and flow based on the failure mode effect and criticality analysis (FMECA). In any case the maximum relief pressure shall not exceed 50 % of the burst pressure as specified by the manufacturer.

Testing shall be done in accordance with 6.10.5.

5.6 Breathing circuit

5.6.1 Performance requirements

5.6.1.1 General

For any facepiece intended for use with the apparatus the requirements shall be fulfilled.

The breathing performance shall be measured using a sinusoidal waveform from a breathing machine with simulated RMV up to 75 l min⁻¹ (BTPS; Body Temperature and Pressure Saturated (see Table 4)). The performance of the apparatus shall be determined using an oxygen in nitrogen gas mixture at an ambient pressure of 5 bar and where appropriate using an oxygen in helium based mixture at an ambient pressure of 11 bar or a reduced pressure specified by the manufacturer.

When the apparatus is intended to be used with Trimix having a gas density greater than that of Nitrox at 40 m, the breathing performance test shall be performed with the highest intended gas density at the maximum intended diving depth.

The apparatus shall provide sufficient volume of respirable gas for the diver at all phases of a dive. In the event of a failure of an automatic volume addition system an alternative means shall be provided to add respirable gas to the breathing circuit or the diver.

The manufacturer shall supply to the test house ideal values in x, y and z from a reference point on the apparatus to the suprasternal notch. For details see Figure 2.

If an automatic volume addition system is fitted, the breathing performance testing shall include the operation of this system.

Testing shall be done in accordance with 6.3.5.

5.6.1.2 Work of breathing (WOB)

Work of breathing shall not exceed a value of:

$$\text{WOB} = 0,5 + 0,03 * \text{RMV} \quad [\text{J l}^{-1}] \text{ related to an RMV from } 15 \text{ l min}^{-1} \text{ to } 75 \text{ l min}^{-1}$$

NOTE The WOB specified is considered to be a physiological maximum level and the manufacturers should endeavour to keep the WOB as low as possible.

Testing shall be done in accordance with 6.3.2.

5.6.1.3 Respiratory pressures

Peak to peak respiratory pressure shall be determined as shown in Figure 1. The peak to peak respiratory pressure shall not exceed 50 mbar (measure as on Figure 1). The compliance of the system (determined as shown on Figure 1) shall not exceed 10 mbar l⁻¹ tidal volume.

Testing shall be done in accordance with 6.3.2.

The peak to peak respiratory pressure for an automatic volume addition system shall not exceed 60 mbar (measure as on Figure 1).

Testing shall be done in accordance with 6.3.5.

5.6.1.4 Hydrostatic imbalance

The hydrostatic imbalance shall not exceed the values specified in Table 1 under the following conditions:

- with 0° diver roll and diver pitch from + 180° to - 90°;
- with 0° diver pitch and diver roll from + 90° to - 90°.

Diver roll and pitch angles are defined in Figures 3 and 4 respectively.

Table 1 — Hydrostatic imbalance

| Pitch (degrees) (roll at 0 degrees) | Lung centroid | | Suprasternal notch | |
|---|---------------|-------|--------------------|-------|
| | +mbar | -mbar | +mbar | -mbar |
| 180,0 | 20,0 | -20,0 | 27,0 | -13,0 |
| 90,0 | 20,0 | -20,0 | 33,5 | -6,5 |
| 45,0 | 20,0 | -20,0 | 24,6 | -15,4 |
| 0,0 | 20,0 | -20,0 | 13,0 | -27,0 |
| -45,0 | 20,0 | -20,0 | 5,5 | -34,5 |
| -90,0 | 20,0 | -20,0 | 6,5 | -33,5 |
| 90,0 | 20,0 | -20,0 | 20,0 | -20,0 |
| 45,0 | 20,0 | -20,0 | 15,1 | -24,9 |
| 0,0 | 20,0 | -20,0 | 13,0 | -27,0 |
| -45,0 | 20,0 | -20,0 | 15,1 | -24,9 |
| -90,0 | 20,0 | -20,0 | 20,0 | -20,0 |

Testing shall be done in accordance with 6.4.

5.6.1.5 Maximum inspired partial pressure of carbon dioxide

The volume-weighted average inspired partial pressure of carbon dioxide shall not exceed 20 mbar. This shall be fulfilled during the full endurance time of the apparatus specified by the manufacturer.

NOTE The full endurance time as specified by the manufacturer includes the maximum carbon dioxide level exhausting from the canister during this period.

Testing shall be done in accordance with 6.3.3.

5.6.2 Inhalation and exhalation valves

The facepiece shall include inhalation and exhalation valves to reduce dead space and ensure gas circulation through the apparatus. Valve assemblies shall be designed so as to be easily assembled and maintained.

A method to check the correct assembly of the valves shall be described in the information supplied by the manufacturer.

Where necessary to ensure the safe working of the apparatus it shall not be possible to reverse the breathing circuit. Where the apparatus design permits this the apparatus shall be tested in both directions of flow.

The valve(s) shall not leak or be permanently deformed, when tested in accordance with 6.5.4.

Testing shall be done in accordance with 6.2 and 6.15.

5.6.3 Breathable volume

The apparatus shall be designed so as to provide sufficient breathable volume for the diver whilst in any attitude.

Testing shall be done in accordance with 6.15.

It shall allow a tidal volume of at least 4,5 l.

Testing shall be done in accordance with 6.5.1.

5.6.4 Breathing circuit test pressure

The breathing circuit shall be capable of withstanding a pressure of 200 mbar for at least 60 s. There shall be no leakage, burst indication or failure.

Testing shall be done in accordance with 6.5.2.

5.6.5 Exhaust valve

The apparatus shall have an exhaust valve, operated automatically by excess gas in the breathing circuit.

The exhaust valve shall prevent the pressure in the breathing circuit exceeding 40 mbar.

Testing shall be done in accordance with 6.5.3.1 after the test according to 6.5.3.2.

The operation of the exhaust valve shall not be degraded or leaking after being subjected to

- a) a constant flow of 300 l min^{-1} for a period of 1 min;
- b) a static negative pressure of 80 mbar for a period of 10 s (when in the wetted condition).

The leakage of the exhaust valve (when in the wetted condition) shall not exceed $0,5 \text{ ml (STP) min}^{-1}$ when tested with a negative pressure of 7 mbar for at least one minute.

Testing shall be done in accordance with 6.5.3.2.

5.6.6 Carbon dioxide absorbent canister

The manufacturer shall specify the absorbent materials that may be used with the apparatus. For each absorbent material specified, the endurance of the charged carbon dioxide absorbent canister in water at

(4 ± 1) °C, shall be stated by the manufacturer. It shall maintain an end of inspiration partial pressure of carbon dioxide of less than 5 mbar for the stated endurance.

Ten minutes after the declared endurance the partial pressure of carbon dioxide shall not exceed 10 mbar. The pH value of any water in the facepiece shall not exceed 9.

Testing shall be done in accordance with 6.6.1 and 6.6.2.

5.6.7 Inhalation temperature

The maximum inspired gas temperature shall be less than 45 °C.

Testing shall be done in accordance with 6.3.4.

5.6.8 Ingress of water

The design and configuration of the apparatus shall minimise the ingress of water in all positions.

The maximum ingress of water reaching the facepiece shall not exceed 50 ml. The pH value shall not exceed 9.

The maximum ingress of water in the apparatus shall not exceed 100 ml.

Testing shall be done in accordance with 6.5.5.

5.7 Gas control or supply system

5.7.1 Inspired partial pressure of oxygen

The apparatus shall under all conditions of use specified by the manufacturer maintain an inspired partial pressure of oxygen greater than 0,20 bar. The inspired partial pressure of oxygen shall remain within the limits specified by the manufacturer. The inspired partial pressure of oxygen shall also be maintained at a partial pressure of less than or equal to 1,6 bar; except during the descent phase(s) and initial bottom time of a dive for a period not greater than 1 min where it may increase to a maximum of 2,0 bar.

In the event of a failure of an automatic system provision may be made for the addition of respirable gas by the diver. If fitted this shall also be able to satisfy the inspired partial pressure of oxygen requirements of this clause.

Where the inspired partial pressure of oxygen is not maintained automatically, the following additional requirements shall be fulfilled:

- The system shall have a minimum continuous flow of oxygen into the breathing circuit of 0,6 l min⁻¹ STPD;
- The system shall have at least one inspired partial pressure of oxygen monitor with an alphanumeric display;
- The system shall have at least one active warning device for minimum and maximum permitted oxygen partial pressures. The minimum warning level shall be 0,4 bar or greater. The maximum warning level shall be less than or equal to 1,5 bar;
- Provision shall be made for the addition of gas by the diver at all times during the dive to both increase and decrease the partial pressure of oxygen in the apparatus.

Testing shall be done in accordance with 6.2, 6.7 and 6.15.

5.7.2 Oxygen partial pressure setpoint maintenance

In apparatus with a fixed oxygen partial pressure setpoint the inspired partial pressure of oxygen shall be maintained within $\pm 0,10$ bar during constant depth phases of the dive. This at a ventilation of 40 l min^{-1} and associated oxygen consumption of $1,78 \text{ l min}^{-1}$ Standard Temperature and Pressure, Dry (STPD).

During the ascent phase the inspired partial pressure of oxygen may reduce to a minimum of 0,5 bar below the set point but shall regain steady state set point within 1 min of halting an ascent.

When gas is injected into the breathing circuit the volume of oxygen added in 1 min shall be at least 6 l (STPD).

Testing shall be done in accordance with 6.7.

5.7.3 Alphanumeric display for inspired partial pressure of oxygen (if fitted)

The limit deviation of the oxygen partial pressure display shall be as defined in Table 2.

Table 2 — Limit deviation of oxygen partial pressure display

| Oxygen partial pressure bar | Limit deviation bar |
|--------------------------------|------------------------|
| 0,1 to 0,4 | $\pm 0,03$ |
| > 0,4 to 2,0 | $\pm 0,06$ |

Testing shall be done in accordance with 6.2, 6.10.2 and 6.15.

5.7.4 Gas endurance

The gas endurance of the apparatus shall be specified by the manufacturer.

NOTE Consideration should be given to additional gas consumption due to the conduct of the dive.

Testing shall be done in accordance with 6.6.1 and 6.6.3.

5.8 Hoses

5.8.1 General

The same high pressure or medium pressure hose assembly respectively shall meet the requirements specified in the following sequence: 5.8.2, 5.8.3, 5.8.4 or 5.8.6, respectively.

5.8.2 Tensile strength of high and medium pressure hoses

The unpressurised hose assembly shall be subject to a tensile strength of 1 000 N for a test period of 10 s to 15 s. Serviceability shall be retained.

Testing shall be done in accordance with 6.8.2.

5.8.3 Flexibility of high and medium pressure hoses

The unpressurised hose assembly shall be capable of being bent to an angle of 180° for 8 h. Serviceability shall be retained.

Testing shall be done in accordance with 6.8.3.

5.8.4 High pressure hose assemblies leak test

Any high pressure hose assembly shall withstand the rated working pressure without leaking.

Testing shall be done in accordance with 6.8.4.

5.8.5 High pressure hose assemblies bursting pressure

Any high pressure hose assembly shall withstand a pressure of four times the rated working pressure for at least 20 s. There shall be no burst, leakage or indication of failure.

Testing shall be done in accordance with 6.8.5.

5.8.6 Medium pressure hose assemblies leak test

Any medium pressure hose assembly shall be capable of withstanding twice the operating pressure of a safety valve or at least 30 bar, whichever is the higher. There shall be no leakage.

Testing shall be done in accordance with 6.8.4.

5.8.7 Medium pressure hose assemblies bursting pressure

Any medium pressure hose assembly shall be capable of withstanding four times the rated working pressure or at least 100 bar, whichever is the higher, for at least 20 s without bursting.

Testing shall be done in accordance with 6.8.5.

5.8.8 Breathing hose

The breathing hose shall be flexible and non-kinking. The breathing hose shall permit free head movement and shall not restrict or close off the gas supply during practical performance tests.

Testing shall be done in accordance with 6.15.

The connections at the ends of the breathing hose shall withstand an axial tensile force of 250 N for 10 s.

Testing shall be done in accordance of 6.8.6.

5.9 Safety devices

5.9.1 General

All safety devices that give a visual indication to the diver shall be capable of being read by a person with normal (or appropriately corrected) visual acuity at all pressures and temperature conditions and under the visibility conditions specified in the information supplied by the manufacturer. Safety devices shall provide an appropriate indication for colour blind people.

Testing shall be done in accordance with 6.2 and 6.15.

5.9.2 Pressure indicator

Each gas supply gas cylinder shall be fitted with a pressure indicating system. The apparatus shall be designed and fitted so as to enable the diver to receive the information without difficulty.

Any flexible hose(s) connecting the pressure indicator(s) shall be sufficiently strong so as to provide protection against damage by external mechanical influences occurring during use. If the connection has a cover, which is not permeable to gases, the space enclosed by this cover shall be vented.

The connection point for a pressure indicator hose shall be so constructed that with an upstream pressure of 100 bar it does not permit the passage of more than 100 l min^{-1} of gas measured at STPD.

The display range of a pressure gauge shall extend from zero to a value of at least 20 % in excess of the rated working pressure of the gas cylinder.

Scale divisions or increments shall not exceed 10 bar. The range below 50 bar shall be clearly differentiated to emphasise low gas supply. The accuracy of any indicator shall conform to the following tolerances measured at decreasing pressure:

- at 50 bar ± 5 bar;
- at 100 bar ± 10 bar;
- at 200 bar ± 10 bar;
- at 300 bar ± 15 bar.

Any pressure indicator shall be waterproof to at least twice the intended maximum diving depth specified by the manufacturer for at least 15 min. Any transparent window(s) shall be splinter-proof. A pressure gauge shall feature a pressure relief facility that in the event of a leak protects the diver against injury.

The safety device of a mechanical pressure gauge shall relieve safely at a pressure not higher than 50 % of the burst pressure of the case. The safety device shall also relieve a minimum flow rate of 300 l min^{-1} .

There shall be a marking to show if the indicator is to be used with oxygen concentrations greater than air as specified in EN 12021.

Testing shall be done in accordance with 6.2, 6.10.1 and 6.15.

5.9.3 Monitors for inspired gases

5.9.3.1 Monitor for inspired partial pressure of oxygen

The apparatus may be fitted with a device that is independent of any oxygen control system to measure and provide warning to the user for high and low partial pressure oxygen levels. The partial pressure of oxygen displayed shall be to an accuracy as specified in Table 2. It shall have a maximum response time of 15 s to 90 % of a step change of oxygen partial pressure.

The manufacturer shall demonstrate the independence of the device by the provision of a failure mode effect and criticality analysis (FMECA).

Testing shall be done in accordance with 6.2, 6.7, 6.10.2 and 6.15.

5.9.3.2 Monitor for inspired carbon dioxide (if fitted)

An inspired carbon dioxide monitor shall have a limit deviation under all conditions within ± 3 mbar.

Testing shall be done in accordance with 6.2, 6.10.3 and 6.15.

5.9.4 Active warning devices

In order to prevent the inspired partial pressure of oxygen falling outside acceptable limits the apparatus shall be fitted with an active warning device. These limits shall be specified by the manufacturer but within the range of 0,27 bar and 1,6 bar.

If fitted, an inspired carbon dioxide active warning device shall have a limit deviation under all conditions within ± 3 mbar and warn the diver when inspired carbon dioxide exceeds 5 mbar.

In the event of a failure of any active warning device it shall fail so as to warn the diver. The FMECA shall be used to identify the appropriate device.

Testing shall be done in accordance with 6.2, 6.10.4 and 6.15.

5.10 Facepiece

5.10.1 General

The facepiece shall be a mouthpiece assembly, a half mask, a full face mask or a helmet.

The facepiece shall aid ear clearing by allowing the diver's nasal passages to be occluded.

It shall also minimise the ingress of water during normal use and in the event of a diver falling unconscious or having a convulsion.

If a full face mask or a helmet is used an inner mask or a mouthpiece may be fitted.

The facepiece shall have a system whereby the diver can secure the breathing circuit from atmospheric air or water ingress when it is removed from the mouth and face.

Testing shall be done in accordance with 6.2 and 6.15.

5.10.2 Facepiece harness

The facepiece harness shall be designed so that the facepiece can be donned and removed easily. It shall be adjustable or self-adjusting and shall hold the facepiece assembly firmly and comfortably in position.

Testing shall be done in accordance with 6.2 and 6.15.

Each strap of the facepiece (excluding mouthpiece) shall withstand a pull (force) of 150 N applied for 10 s in direction of pulling when the facepiece (excluding mouthpiece) is donned.

Where the facepiece is a mouthpiece, each strap of the mouthpiece, if fitted, shall withstand a pull of 50 N applied for 10 s in direction of pulling when the mouthpiece is donned.

The permanent linear deformation of each strap shall not be greater than 5 % when tested at a pull of 30 N for 10 s, measured 4 h after the pull.

Testing shall be done in accordance with 6.11.4.

Once fitted the facepiece shall be easily adjustable by the wearer or self-adjusting.

Testing shall be done in accordance with 6.2 and 6.15.

5.10.3 Connection

5.10.3.1 Half mask, full face mask and helmet

The connection between the facepiece and the apparatus may be achieved by a permanent or special type of connection. If a thread connection is used then it shall not be possible to interchange with threads specified in EN 148-1, EN 148-2 and EN 148-3. The connection between the faceblank and the connector shall be sufficiently robust to withstand axially a tensile force of 300 N (see Figure 6).

Testing shall be done in accordance with 6.2 and 6.11.1.

5.10.3.2 Mouthpiece

The mouthpiece shall not degrade the performance of the re-breather when worn during the practical performance test. Particular attention shall be given to the wearer's mouth action on the assembly.

Testing shall be done in accordance with 6.15.

The mouthpiece shall neither be detached nor alter its shape and/or position permanently.

Testing shall be done in accordance with 6.11.5.

It shall be possible to breathe from the re-breather without the mouthpiece if detachable.

Testing shall be done in accordance with 6.2 and 6.15.

5.10.4 Eyepiece and visors

Visors shall be attached in a reliable and tight manner to the facepiece and shall have adequate mechanical strength.

Testing shall be done in accordance with 6.2 and 6.11.3.

Visors shall not distort vision.

Testing shall be done in accordance with 6.15.

The field of vision shall meet the following requirements:

The facepiece shall be designed so that the effective field of vision (in air) shall be not less than 40 %, related to the natural field of vision. The overlapped field of vision related to the natural overlapped field of vision shall be not less than 50 %, when equipped with a single visor and 20 %, when equipped with two or more visors.

Testing shall be done in accordance with 6.11.2

The manufacturer shall provide means to reduce misting of the eyepiece. It shall be assured that the vision is not impaired while diving.

Testing shall be done in accordance with 6.15.

Where anti-fogging compounds are used as intended or specified by the manufacturer they shall not cause irritation to eyes or skin or damage the components of the facepiece.

Testing shall be done in accordance with 6.2.

5.11 Body harness

The apparatus shall be reliably attached to a body harness which may consist for example of a carrying frame and/or straps to attach it to the body of the diver. The harness shall not have a single action buckle which releases the entire body harness from the diver's body when activated.

The body harness shall be so designed that the apparatus remains securely in position. It shall not be possible for the apparatus and parts of it to become accidentally detached from the diver. The body harness shall not impair the diver's freedom of movement any more than is necessary.

It shall be possible to secure loosely suspended parts (e.g. pressure indicator and straps) in position on the apparatus.

The fit of the harness shall be maintained during the use of the apparatus. If adjustment to the harness is possible, for example by adjusting the length of the straps, then it should be possible for this to be achieved easily and at any time.

Testing shall be done in accordance with 6.2 and 6.15.

5.12 Emergency breathing system

The apparatus shall allow the use of a suitable emergency breathing system.

Testing shall be done in accordance with 6.2 and 6.15.

5.13 Electrical systems

5.13.1 Functional safety

The manufacturer shall support the functional safety by the provision of a failure mode effect and criticality analysis (FMECA).

Testing shall be done in accordance with 6.2.

5.13.2 Programmable systems

Any software or firmware used on the apparatus shall satisfy the requirements of ISO/IEC 12207 and IEC 60300-3-6.

Testing shall be done in accordance with 6.2.

5.13.3 Electromagnetic compatibility (EMC)

Out of water the performance or calibration of the apparatus shall not be affected when exposed to electromagnetic fields and shall satisfy the requirements of the following standards, where applicable: EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-8, and EN 61000-4-11.

Testing shall be done in accordance with 6.12.

5.14 Resistance to temperature

5.14.1 Leakage

The apparatus shall not leak or release gas when tested at temperatures of - 20 °C and + 50 °C.

Testing shall be done in accordance with 6.13.1.

5.14.2 Storage

Trouble free operation shall be ensured after storage at temperatures ranging from - 30 °C to + 70 °C.

Testing shall be done in accordance with 6.13.2.

5.15 Cleaning and disinfecting

All parts that on the recommendation of the manufacturer have to be cleaned and/or disinfected shall be easy to clean, insensitive to the cleaning agents and disinfectants recommended by the manufacturer and remain functional after having been cleaned and/or disinfected.

Testing shall be done in accordance with 6.2 and 6.14.

5.16 Connectors

Components shall be easily disassembled for cleaning, testing and examining. Demountable connections shall be readily connected and secured, where possible by hand. Any means of sealing used shall be retained in position when the connection is disconnected during normal use and maintenance.

Testing shall be done in accordance with 6.2, 6.15 and 6.18.

5.17 Practical Performance

In addition to the laboratory tests described, the apparatus shall also undergo practical performance tests under realistic conditions. These practical performance tests serve the purpose to check the apparatus for imperfection that cannot be determined by the tests described in other parts of this standard.

Where, in the opinion of the testing authority, approval is not granted because practical performance tests show the apparatus has imperfections related to wearer's acceptance, the testing authority shall describe the tests that revealed these imperfections. This will enable other testing stations to duplicate these tests and assess the results thereof.

Testing shall be done in accordance with 6.15.

5.18 Oxygen compatibility and cleanliness

High and medium pressure sub-assemblies that can come in contact with a gas with an oxygen content greater than air as specified in EN 12021 shall be oxygen cleaned and identified as such.

Testing shall be done in accordance with 6.2.

Pressure sub-assemblies above 25 bar that can come in contact with a gas with an oxygen content greater than air as specified in EN 12021 shall be oxygen compatible, cleaned and identified as such.

Testing shall be done in accordance with 6.2 and 6.16.

5.19 Pressure resistance of casings and monitors (except pressure indicators)

If casings and monitors are sealed against ambient pressure they shall be waterproof to two times the intended maximum diving depth specified by the manufacturer for at least 15 min.

Testing shall be done in accordance with 6.17 and after the temperature resistance test in accordance with 6.13.

After this test, the apparatus shall be fully functional.

5.20 Sea water resistance

Any material that may come into contact with sea water shall be sea water resistant.

After conditioning in accordance with 6.18 the apparatus shall still be fully functional.

Testing shall be done in accordance with 6.2 and 6.15

6 Testing

6.1 General

6.1.1 Procedure

The apparatus shall be tested and qualified as a complete unit. When testing components or assemblies of the apparatus separately, complimentary components that comply with relevant standards shall be used.

NOTE If no special measuring devices or methods are specified, commonly used methods and devices should be applied.

6.1.2 Nominal values and tolerances

Unless otherwise specified, the values shall be subjected to a limit deviation of $\pm 5\%$. Unless otherwise specified, the room temperature for testing shall be $(22 \pm 5)^\circ\text{C}$ and at a relative humidity of at least 50%. The temperature limits shall be subject to a limit deviation of $\pm 1^\circ\text{C}$.

6.1.3 Test equipment and test procedures

The performance characteristics of the breathing simulator test equipment shall be defined by the use of a calibration test orifice shown in Figure 5. The test orifice shall be inserted into the test rig in place of the re-breathing apparatus and tested with air at $62,5\text{ l min}^{-1}$ (25 cycles min^{-1} , 2,5 l tidal volume) at 6,0 bar absolute. The values for WOB and inhalation/exhalation pressures shall be $3,3\text{ J l}^{-1}$ and $\pm 25\text{ mbar}$ respectively using air.

The test and measurement equipment shall be appropriate for the pressures and frequencies occurring during tests.

The measuring equipment for respiratory pressure variations in the system, shall be capable of measuring at frequencies up to 50 Hz with less than 3 dB damping.

6.2 Visual Inspection

Visual inspection shall be conducted at normal visual acuity by the responsible expert(s) appointed by the accredited test station to test the apparatus.

The visual inspection shall include the assessment of the device marking, information supplied by the manufacturer, any safety data sheets (if applicable), the FMECA, and relevant declarations applicable to its construction.

6.3 Breathing circuit

6.3.1 General test conditions

The apparatus shall be fully rigged on a mannequin according to the information supplied by the manufacturer.

Note the x, y and z coordinates of the reference point of the apparatus, as specified by the manufacturer, in relation to the reference point of the manikin.

The performance of the apparatus shall be determined using a sinusoidal gas flow from a breathing simulator with an allowable variation of $\pm 3\%$ in both the frequency and the amplitude.

The gas supply shall be switched on and any adjustable relief valve set to a mechanical midpoint or the manufacturers recommended setting.

Completely immerse the apparatus in water at a depth sufficiently deep to preclude surface effects.

For apparatus that do not automatically add gas during tests the breathable volume shall be optimised by setting the minimum possible peak to peak respiratory pressure before starting each measurement.

Record the performance of the apparatus at test pressures of 5 bar with oxygen in nitrogen gas mixtures and at 11 bar with oxygen in helium based mixtures or a reduced pressure specified by the manufacturer

Stabilise the temperature of the water in the test chamber at $(4 \pm 1) ^\circ\text{C}$, or lower if specified by the manufacturer.

NOTE For specific tests other temperatures may apply.

6.3.2 Breathing performance

Set the breathing simulator at the ventilation rates in Table 4.

Measure the respiratory pressure at the mouth and determine performance from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced volume. Analyse the pressure-volume diagram in accordance with Figure 1.

Simulate the diver in both the vertical and horizontal orientation ($+90^\circ$ and 0° pitch - see Figure 4).

6.3.3 Volume weighted average inspired carbon dioxide

Determine the volume weighted average inspired carbon dioxide under the conditions in accordance with 6.3.1 with carbon dioxide injected into the exhaled gas from the breathing simulator at the lowest and the highest rate shown in Table 4.

Measure the inspired carbon dioxide at the mouth with an analyser having a response time of less than 150 ms to 95 % of the step change. The monitored carbon dioxide level should then be integrated with respect to the volume of gas inspired rather than the time of inspiration.

6.3.4 Inspired gas temperature

Stabilise the temperature of the water in the test chamber at (34 ± 2) °C.

Completely immerse the apparatus in water at a depth sufficiently deep to preclude surface effects, but not more than 6 m.

This test shall be conducted at a ventilation rate of 40 l min^{-1} and an associated carbon dioxide injection rate as per Table 4.

Measure the temperature at the mouth with a temperature probe having a response time of less than 150 ms to 95 % of the step change. The temperature monitoring shall be continued until steady-state inhaled temperature is achieved.

6.3.5 Breathing performance with automatic volume addition system

Set the breathing simulator at a ventilation rate of 40 l min^{-1} .

Set a flow from the breathing circuit of $1,78 \text{ l min}^{-1}$ STP.

Measure the respiratory pressure at the mouth and determine performance from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced volume. Analyse the pressure-volume diagram in accordance with Figure 1.

Simulate the diver in both the vertical and horizontal orientation ($+90^\circ$ and 0° pitch - see Figure 4).

6.4 Hydrostatic imbalance

Fully rig the apparatus on a rotating mannequin as specified in 6.3.1 and completely immerse in water at a depth sufficiently deep to preclude surface effects, but not deeper than 2 m. This test shall be undertaken at a RMV of $62,5 \text{ l min}^{-1}$ and the mouth pressure recorded at the end of exhalation (see Figure 1).

After breathable volume optimisation by setting the lowest hydrostatic imbalance at a diver position specified by the manufacturer no further adjustment is allowed for roll and pitch variation measurements.

During this test the manikin shall be rotated about the lung centroid.

6.5 Breathable volume

6.5.1 Volume

Secure the apparatus on a mannequin according to 6.3.1, as it would be for diving with the exhaust valve at its maximum setting (if applicable).

Immerse the apparatus and mannequin to a depth not greater than 1 m at a pitch of $+90^\circ$ (see Figure 4).

Fill the apparatus with gas until an internal pressure at the mouthpiece of $+25 \text{ mbar}$ is achieved or the exhaust valve starts to release gas at less than $+25 \text{ mbar}$.

Withdraw $4,5 \text{ l}$ of gas from the apparatus recording the internal pressure. Then inject $4,5 \text{ l}$ of gas into the apparatus recording the internal pressure.

If a breathing simulator is used it shall be set according to the values specified in Table 5.

The internal pressure when withdrawing the gas shall not exceed -25 mbar and when injecting gas $+25 \text{ mbar}$.

6.5.2 Breathing circuit pressure test

The exhaust valve shall be sealed off and the internal pressure shall be increased to 200 mbar and held for at least 60 s.

6.5.3 Exhaust valve

6.5.3.1 Maximum pressure within the breathing circuit

This test shall be performed in dry conditions at surface pressure.

Exhaust valves that are manually adjustable shall be tested at the maximum relief pressure setting. Exhaust valves which incorporate pre-dive and dive controls shall be tested with the controls set to dive position. Inject gas into the breathing circuit at 150 l min^{-1} for 30 s.

If the apparatus is fitted with a means of injecting gas into the counterlung under control of the diver repeat the test with additional gas being injected from each manual injection system in turn at full flow.

If a high or medium pressure relief system releases gas into the breathing circuit the exhaust valve shall be tested with a gas flow as specified by the manufacturer.

Record the pressure within the counterlung.

6.5.3.2 Leak test

The following test shall be carried out with wetted exhaust valve in air.

Preconditioning:

- a) a constant flow of 300 l min^{-1} for a period of 1 min;
- b) a static negative pressure of 80 mbar for a period of 10 s.

The leakage of the exhaust valve shall be tested with a negative pressure of 7 mbar.

A negative pressure of 80 mbar shall be applied at the demand valve without the facepiece for a period of 10 s.

6.5.4 Inhalation and exhalation valves

A negative pressure of 60 mbar shall be applied to each valve for a maximum period of 10 s.

6.5.5 Ingress of water

Fully rig the apparatus on a rotatable mannequin as specified in 6.3.1 and completely immerse in water at a depth sufficiently deep to preclude surface effects, but not deeper than 2 m. This test shall be undertaken in all 5 roll positions mentioned in Table 1 each for a time of 3 min at an RMV of $62,5 \text{ l min}^{-1}$.

Where the design of the apparatus is such, that a ventilation rate of $62,5 \text{ l min}^{-1}$ does not cause gas to be released from the exhaust valve, e. g. closed-circuit breathing apparatus, then inject gas at a rate of 5 l min^{-1} throughout the test.

On completion of the test invert the apparatus in -90° position for 1 min and measure the volume and the pH of any water present in the facepiece.

On completion of the test the apparatus shall be removed from the water, disassembled and any water present within the breathing loop shall be determined by a combination of volumetric and gravimetric analyses.

6.6 Apparatus endurance

6.6.1 General

Conduct all appropriate tests three times at the following depth conditions:

- a) with oxygen or oxygen and nitrogen gas mixtures at a pressure of 1,6 bar;
- b) with oxygen and nitrogen gas mixtures at the maximum dive profile (pressure and bottom time) specified by the manufacturer, if not specified at a constant pressure of 5 bar;
- c) if required, with oxygen and helium or oxygen, nitrogen and helium gas mixtures at the maximum dive profile (pressure and bottom time) specified by the manufacturer.

6.6.2 Carbon dioxide absorption endurance

Maintain the exhaled gas at (32 ± 4) °C and a relative humidity greater than 80 %.

Test the apparatus with the breathing simulator ventilating at 40 l min^{-1} and carbon dioxide injected into the exhaled gas from the breathing simulator at a rate of $1,60 \text{ l min}^{-1}$.

Record the time taken for the end inspired partial pressure of carbon dioxide to reach 5 mbar and 10 mbar.

At a depth of 6 m, test the apparatus with the breathing simulator ventilating at 40 l min^{-1} and carbon dioxide injected into the exhaled gas from the breathing simulator at a rate of $1,60 \text{ l min}^{-1}$ for a period of half the manufacturer's stated endurance. At this point, the breathing simulator ventilation shall be increased to 75 l min^{-1} and carbon dioxide injected into the exhaled gas from the breathing simulator at a rate of $3,0 \text{ l min}^{-1}$ for a period of 5 min.

During this period, the end inspired partial pressure of carbon dioxide shall be less than 5 mbar.

On completion of the test invert the apparatus in -90° position for 1 min and measure the pH value of any water present at the facepiece.

6.6.3 Gas endurance

Test the apparatus with the breathing simulator ventilating at 40 l min^{-1} and oxygen being removed from the exhaled gas from the breathing simulator at a rate of $1,78 \text{ l min}^{-1}$.

Determine the time taken for any gas supply gas cylinder pressure to reach 50 bar, either by testing or a combination of testing and calculation.

6.7 Inspired oxygen level

Prior to testing the test house shall decide with the manufacturer the relevant point(s) on either the facepiece or the inhalation hose from which the sample(s) shall be taken.

Using the conditions identified in 6.6.1 and 6.6.3 record the inspired partial pressure of oxygen at the agreed sample points.

When testing inspired oxygen levels, the dive profile shall be conducted with a descent rate of 30 m min^{-1} and an ascent rate of 20 m min^{-1} .

The apparatus shall be tested immersed at the surface and up to maximum depth for each gas mixture with the maximum and minimum oxygen consumption rates specified in Table 4.

For apparatus fitted with an automatic partial pressure of oxygen control system each work rate shall be continued until a steady state inspired oxygen is achieved. The inspired oxygen partial pressure shall be recorded continuously.

Where the oxygen control of the apparatus is dependent on a diver's ventilation pattern rather than his oxygen consumption, then the apparatus shall be tested at the rates as given in Table 4 and in Table 7.

For apparatus that are not fitted with an automatic partial pressure of oxygen control system, the test shall enable operation of the manual addition from outside the pressure vessel. The tests at each work rate shall be conducted for minimum 15 min and the inspired partial pressure of oxygen shall be recorded continuously. The operator shall follow the instructions in the information supplied by the manufacturer.

6.8 Hoses assemblies

6.8.1 General

Any high and medium pressure hose assemblies shall be subjected to the following tests.

6.8.2 Tensile strength of high and medium pressure hose assemblies

Apply the tensile strength to the hose assembly by screwing the end fittings into an appropriate anchorage point.

6.8.3 Flexibility of high and medium pressure hoses

Bend the hose around a proof gas cylinder ($(65 \pm 2,5)$ mm radius).

6.8.4 Leak test of high and medium pressure hose assemblies

Submerge the hose assembly in freshwater. The test medium shall be the gas intended for use. The testing time shall be 5 min.

6.8.5 Burst pressure of high and medium pressure hose assemblies

The hose assembly shall withstand the hydrostatic pressure for a period of at least 20 s.

The test fluid shall be water.

6.8.6 Tensile load of breathing hose connections

The tensile load is applied to the hose assembly by attaching the end fittings into an appropriate anchorage point.

6.9 Test pressure of high and medium pressure parts

The high and medium pressure parts and connections shall withstand the test pressure for a period of at least 20 s.

There shall be no leakage, hose burst or indication of failure.

The test medium shall be water.

6.10 Safety devices

6.10.1 Pressure indicator

The manufacturer shall supply a statement declaring that the window material does not splinter when broken.

If fitted any pressure gauge should be subjected to a hydraulic test to establish the burst pressure of the case.

6.10.2 Monitor for inspired partial pressure of oxygen

The partial pressure of oxygen in the inhalation hose shall be measured and compared with the indicated value.

Test the oxygen partial pressure monitor by exposure to partial pressures of oxygen in the range 0,1 bar to 2,0 bar in increments of 0,2 bar. The monitor shall read within the limits given in Table 2.

The oxygen partial pressure monitor shall be pressurised to 1,1 times the maximum stated depth with suitable gases to maintain constant partial pressure of oxygen of 0,2 bar and 2 bar respectively. The rate of pressurisation shall be 30 m min^{-1} . The partial pressure of oxygen monitor reading shall be recorded at 10 m intervals.

The partial pressure of oxygen monitor shall be held at 1,1 times of the maximum stated depth for a period of 1,5 times the maximum bottom time specified by the manufacturer.

The oxygen partial pressure of monitor shall be decompressed using the stop depth specified by the manufacturer. The rate of ascent shall be 20 m min^{-1} and the partial pressure of oxygen monitor held at each stop for a period of 2 min. After a period of 1 min the indicated value shall be compared with the partial pressure of oxygen in the inhalation hose.

6.10.3 Monitor for inspired partial pressure of carbon dioxide

Test the monitor for inspired partial pressure of carbon dioxide by exposure to partial pressures of carbon dioxide in the range 0,0 mbar to 30,0 mbar in increments of 5 mbar. The test shall be repeated at pressure increments of 1,0 bar from 1,0 bar to the maximum pressure (depth) of the apparatus. The monitor shall read within ± 3 mbar of the impressed partial pressure of carbon dioxide.

6.10.4 Active warning devices

6.10.4.1 Inspired partial pressure of oxygen

Test the active warning device by exposure to partial pressure of oxygen in the breathing circuit and check that the device activates within $\pm 0,05$ bar of the warning levels.

6.10.4.2 Inspired partial pressure of carbon dioxide

Test the active warning device by exposure to partial pressure of carbon dioxide in the breathing circuit and check that the device activates within ± 3 mbar of the warning levels.

6.10.5 Pressure relief system(s)

Connect an adjustable gas supply to the pressure relief system. Connect a suitable flow device to the outlet of the relief valve. Check that the pressure required to achieve the flow is within the limits specified by the manufacturer.

6.11 Facepiece

6.11.1 Mechanical strength of the facepiece

Support the facepiece on a dummy head which can be adjusted so that the force can be applied axially to the connection. Additionally, fit a system of restraining straps or bands over the faceblank around the connection so that the force is applied as directly as possible to the fitting of the connection in the faceblank and the restraining force is not applied wholly to the head harness (see Figure 6).

Apply the force in accordance with Figure 6 for a period of 10 s.

Note any mechanical distortion.

6.11.2 Field of vision

Measure the field of vision using an apertometer according to Stoll (see Figure 7). A diagram (see Figure 8) shall be used for the evaluation.

- a) Fit the facepiece to the dummy head and with both eyes lit, adjust the facepiece until the outline of the visor is symmetrical on the hemi-spherical shell and the field of vision is a maximum. Adjust the tensions of the straps to obtain a reasonable secure fit;
- b) Map the positions of the field of vision of each eye individually on to the printed diagram, using the grid lines as a guide;
- c) Measure the areas of the total field of vision and the overlapped field of vision with a planimeter. The field of vision is the innermost line at any point of either the field of vision of the facepiece or the natural field of vision according to Stoll as shown on the printed diagram (see Figure 8).

Express the results as a percentage of the area of the natural field of vision according to Stoll (see Figure 8).

6.11.3 Impact resistance of the eyepiece(s) or visor(s)

Impact resistance shall be tested using a completely assembled face piece mounted on a dummy head such that a steel ball (22 mm diameter, 43,8 g approximately) falls normally from a height of 130 cm on the centre of the lens.

For comparing the tightness of the full face mask before and after the test the same dummy head is used and a pressure of -10 mbar created in the cavity of the mask.

Five visors shall be tested.

6.11.4 Facepiece harness

Test three samples; all in the state as received. Apply the force to the free end of the straps. Measure the permanent linear deformation 4 h after the pull test.

6.11.5 Mouthpiece

In wetted condition, attachment to the demand valve shall be tested by pulling the mouthpiece with a force of 80 N for 10 s with an axial force when the device is retained by a teeth garniture.

6.12 Electrical systems, Electromagnetic compatibility (EMC)

Test the apparatus in accordance with IEC 61000-6-1, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61000-4-8, and EN 61000-4-11, where applicable.

Check the performance and oxygen control of the apparatus by observation of displayed readings prior to, during and immediately post exposure to the electromagnetic radiation.

Calibrate the apparatus prior to exposure to the electromagnetic radiation. Check the partial pressure oxygen control post calibration in the electromagnetic field.

6.13 Resistance to temperature

6.13.1 Testing at - 20 °C and + 50 °C

Before performing the following test the apparatus shall, where required, be calibrated and shall be breathed from for a period of 5 minutes.

Place the fully assembled apparatus, with cylinder valves closed and gas cylinders charged to 50 % of the rated working pressure and the electronic control, if fitted, switched off, in an environmental chamber and cool to - 20 °C for a period not less than 3 h.

Open the cylinder valves, ensuring the apparatus is still at - 20 °C.

Repeat the same test at + 50 °C.

6.13.2 Testing after storage at - 30 °C and + 70 °C

Before performing the following test the apparatus shall, where required, be calibrated and shall be breathed from for a period of 5 minutes.

On completion of the above procedure (both - 30 °C and + 70 °C) for a period not less than 3 h allow the temperature of the apparatus to return to standard laboratory conditions.

Switch on the apparatus and calibrate, if required.

Test at a pressure of 1,0 bar and a ventilation rate of 40 l min⁻¹ with an oxygen consumption of 1,78 l min⁻¹ for the duration of the apparatus as specified in the manufacturers information, during which time the performance shall remain within the limits specified.

6.14 Cleaning and disinfection

Use the disinfectant recommended by the manufacturer. The concentrations and immersion times indicated in the instructions for use are to be doubled. Perform the test 30 times. If no other temperatures are indicated, the temperature of the disinfectant solution shall be 40 °C.

6.15 Practical performance

6.15.1 General

For reasons of safety, practical performance tests shall be carried out only after all laboratory tests have been satisfactorily completed.

6.15.2 Test subjects

The apparatus shall be tested by five test subjects practising regularly and familiar with the type of apparatus under test. Their medical history shall be known to be satisfactory. They shall be medically examined and certified fit to undertake the test procedures.

The necessity of a medical examination immediately before tests and medical supervision during the tests shall be decided by the testing authority.

6.15.3 Basic testing

The tests shall be performed using at least three apparatus and made by five test subjects.

The test subjects shall read the information supplied by the manufacturer. They shall set up and operate the apparatus in accordance with the information supplied by the manufacturer.

During the test the apparatus and the information supplied by the manufacturer shall be subjectively assessed by the wearer and the wearer's comments for the following points recorded after the test:

- a) Harness comfort;
- b) Security of fastenings and couplings, including the harness;
- c) Accessibility and where applicable visibility of controls, partial pressure and pressure indicators and active warning devices;
- d) Clarity and field of vision of the visor of the facepiece;
- e) Performance of the apparatus when conducting full range of head and arm movements;
- f) Where there is an adjustable valve the diver shall assess the performance of the apparatus over the full range of adjustment;
- g) Facepiece comfort and security of gas supply;
- h) Any other comments reported by the wearer on request.

6.15.4 Functional testing when diving

Each of the test dives shall be conducted for at least 15 min or the maximum endurance of the apparatus as stated by the manufacturer.

- a) Donning and doffing of the apparatus as well as adjustment of all straps of the apparatus without help on land;
- b) Jumping test (feet first) from the height of 1 m;
- c) Two dives to be conducted by each diver of which at least one dive to be completed deeper than 3 m;
- d) No continuous leakage while swimming in all orientations (front and back);
- e) Checking of partial pressure oxygen and pressure indicators;
- f) Swimming at maximum speed;
- g) Where there is an adjustable valve, the apparatus performance over the full range of adjustment shall be verified;
- h) Changing to and from emergency breathing apparatus;
- i) Performance of the apparatus when conducting full range of head and arm movements;
- j) During practical performance test all diver operated controls shall be tested.

6.15.5 Report

A record with final report of the tests performed with test persons shall be kept. This record shall contain an assessment of the apparatus by the test persons with regard to the requirements made in clause 5 and give details of the test conditions and all equipment worn.

6.16 Oxygen pressure surge test

This test shall be carried out for valves and reducers (device) used in all applications where the gas or gas mixture has an oxidising potential greater than that of air as specified in EN 12021. For all types of device the pressure surge test shall be carried out with pure oxygen at the working pressure of the device.

The purpose of the test is to check whether the device withstands an oxygen pressure surge safely.

The sample devices in the "as received" condition, or lubricated, if a lubricant is used for such a device, shall be tested.

Before the test, the ignition test installation shall be checked for the required pressure rise (for examples of the test installation and pressure cycle specification, see Figures 9 and 10). For this purpose the sample device, at the end of the 1 m length of copper tube, is replaced by a reliable pressure monitor.

The maximum pressure at the dead end of the copper tube (measured by pressure monitor and recorded on an oscilloscope) shall be achieved within (20 ± 5) ms (time necessary to reach p_{vt} starting from atmospheric pressure).

Stabilisation time at p_{vt} is not fixed but shall be greater than or equal 3 s. Before the next pressure surge the system (sample device and copper tube) shall be depressurised down to atmospheric pressure. Stabilisation time at atmospheric pressure is not fixed but shall be greater than or equal 3 s.

The total time of the pressure cycle shall be 30 s, as illustrated in Figure 10, total time is the time between the beginning of two consecutive pressure surges.

For calibration purposes, heated oxygen at (60 ± 3) °C shall be used.

The quality of oxygen shall be:

- minimum purity 99,5 % by volume;
- hydrocarbon content $\leq 0,01$ mg m⁻³.

Each test shall be carried out as follows:

- Supply oxygen at a temperature of (60 ± 3) °C, directly into the connection of the device to be tested, by means of a copper tube having an internal diameter of 5 mm and a length of 1 m. The specified material and dimensions of the tube are essential in order to ensure that a well defined energy input into the device to be tested is achieved.
- Two test sequences shall be carried out in accordance with Table 3.

Table 3 — Test sequence (if applicable)

| Test sequence | Device operating system | Device stem |
|---------------|-------------------------|-------------------------------------|
| 1 | Closed | Open |
| 2 | Open | Sealed with a screwed metallic plug |

- Oxygen is heated up to (60 ± 3) °C, in the oxygen pre-heater. Inlet of oxygen, to the sample device is controlled by a quick opening valve (see Figure 9). The test consists of subjecting the sample device to 20 pressure cycles from atmospheric pressure to 1,2 times the working pressure (p_{vt}) (see Figure 10).

After the tests, the sample device shall be dismantled and carefully checked, including close examination of non-metallic components. It shall not show any traces of ignition.

6.17 Casings and monitors

The casings and monitors shall be immersed in water and pressurized to two times the intended maximum diving depth specified by the manufacturer at a rate of 30 m min^{-1} . After 15 min no ingress of water shall be observed.

6.18 Sea water resistance

The complete apparatus with the gas supply in the "turned off" position shall be submerged for $8 \text{ h} \pm 5 \text{ min}$ in natural sea water or artificial sea water (see annex A) of between 15 °C and 25 °C. Without cleaning in fresh water the apparatus shall stay in air for $16 \text{ h} \pm 30 \text{ min}$ at 15 °C to 25 °C and a relative humidity of not more than 75 %. Apply four complete cycles.

7 Marking

7.1 The manufacturer shall be identified by name, trade mark or other means of identification.

7.2 Type identifying marking and unique serial number.

7.3 The number of this European Standard.

7.4 Where the reliable performance of components may be affected by aging or usage, the date (at least the year) of manufacture shall be marked.

7.5 Sub-assemblies and components with a considerable bearing on safety shall be marked so that they may be easily identified. If sub assemblies with considerable bearing are too small to be marked or where it is impractical to mark them, the information shall be included in the information by the manufacturer.

7.6 Pressure reducers and pressure indicators shall be marked with the rated working pressure.

7.7 Maximum depth and range of water temperatures of certification.

7.8 If the oxygen control system is not automatic, this shall be marked.

7.9 Pictograms maybe used for marking.

8 Information supplied by manufacturer

8.1 On delivery each apparatus shall include information by the manufacturer which shall enable trained and qualified persons to assemble and use the apparatus in a safe manner.

8.2 The information supplied by the manufacturer shall be in the official language(s) of the country of destination.

8.3 The information supplied by the manufacturer shall contain all necessary information for trained and qualified persons on:

- application;

- maximum depth of certification;
- gas mixtures to be employed and maximum depth for each mixture;
- limitations on use;
- assembly:
 - components;
 - connections;
 - safety devices;
- assessment of risk:
 - temperature conditions;
 - work rates;
 - expected inspired gas concentrations;
 - visibility;
 - use of high oxygen content gases;
 - potential long term health effects;
- apparatus checks:
 - prior to use;
 - post dive;
- donning and fitting of the apparatus to a proper position on the diver;
- use;
- maintenance (preferably separately printed instructions);
- storage:
 - conditions;
 - shelf lives (where applicable);
 - precautions;
- inspection intervals.

8.4 The instructions shall include statements on:

- purity and tolerances of gases to be used;
- absorbent material(s) to be used and specification for each material;

— compatibility of accessories and/or other personal protective equipment which may be added to the apparatus.

8.5 The manufacturer shall provide sufficient information to allow the user to form a risk assessment in order to estimate the gas endurance of the apparatus.

8.6 The instructions shall be unambiguous. If helpful, illustrations, part numbers, marking etc. shall be added.

8.7 Any other information the supplier may wish to provide.

Table 4 — Breathing simulator settings

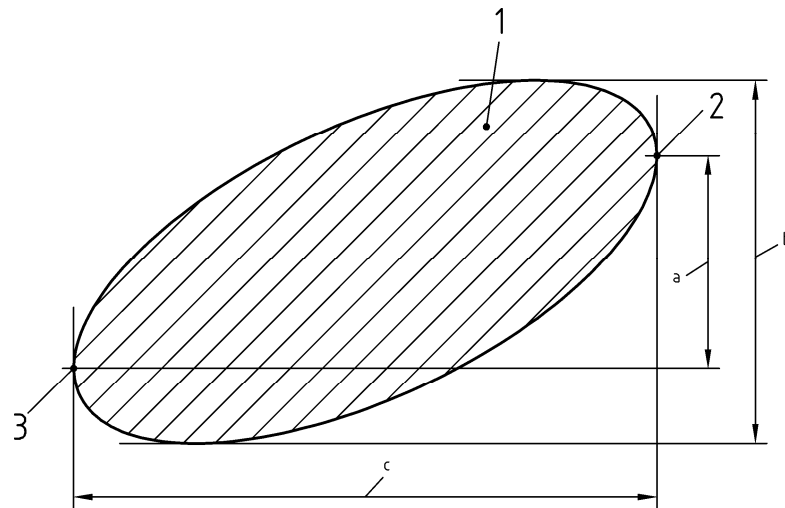
| Tidal volume at BTPS l | Breathing frequency min ⁻¹ | Ventilation rate at BTPS l min ⁻¹ | Carbon dioxide injection rate at STPD l min ⁻¹ | Oxygen consumption rate at STPD l min ⁻¹ | Maximum WOB J l ⁻¹ |
|------------------------------|--|--|---|---|----------------------------------|
| 1,5 | 10 | 15,0 | 0,60 | 0,67 | 0,95 |
| 1,5 | 15 | 22,5 | 0,90 | 1,00 | 1,18 |
| 2,0 | 20 | 40,0 | 1,60 | 1,78 | 1,70 |
| 2,5 | 25 | 62,5 | 2,50 | 2,78 | 2,38 |
| 3,0 | 25 | 75,0 | 3,00 | 3,33 | 2,75 |

Table 5 — Respiratory volume

| Tidal volume at BTPS l | Breathing frequency min ⁻¹ | Ventilation rate at BTPS l min ⁻¹ |
|------------------------------|--|--|
| 4,5 | 5 | 22,5 |

Table 6 — Breathing simulator respiratory exchange settings

| Tidal volume at BTPS l | Breathing frequency min ⁻¹ | Ventilation rate at BTPS l min ⁻¹ | Oxygen consumption rate at STPD l min ⁻¹ | Carbon dioxide injection rate at STPD l min ⁻¹ |
|------------------------------|--|--|---|---|
| 1,5 | 15 | 22,5 | 0,75 | 0,68 |
| 2,5 | 25 | 62,5 | 3,47 | 3,12 |



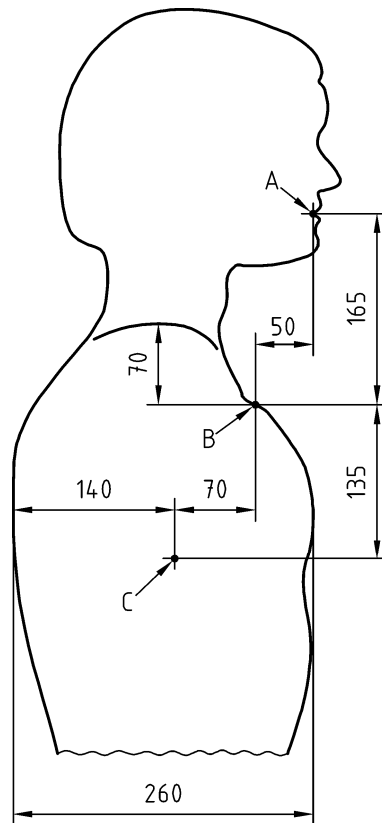
Dimensions in millimetres

Key

- 1 Work of breathing WOB
- 2 Reference point of hydrostatic imbalance; end of exhalation ("no flow")
- 3 Peak to peak respiratory pressure

$$\text{Compliance} = \frac{a}{c}$$

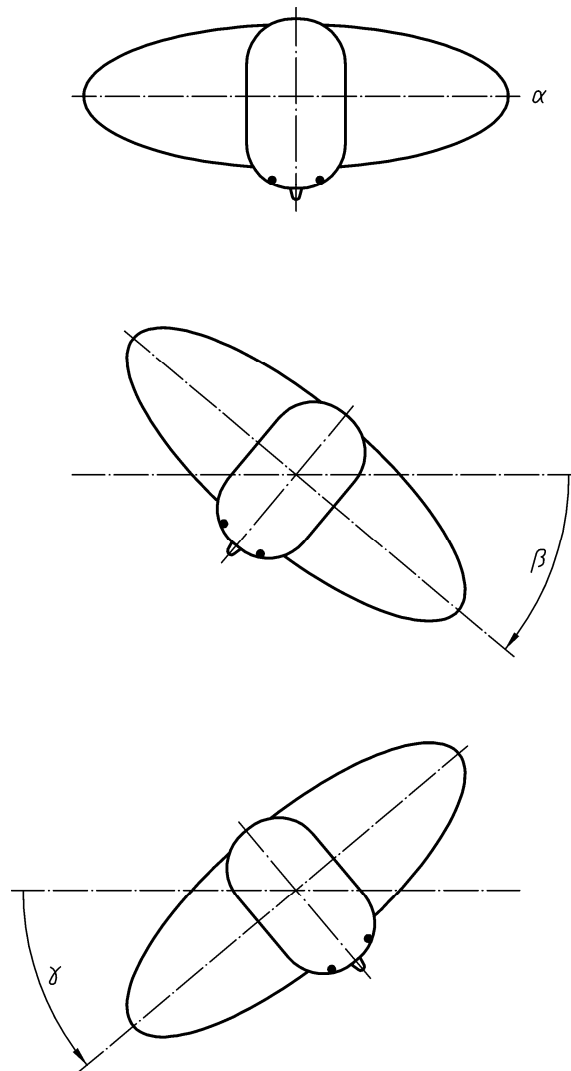
Figure 1 — Analysis of pressure volume loop



Key

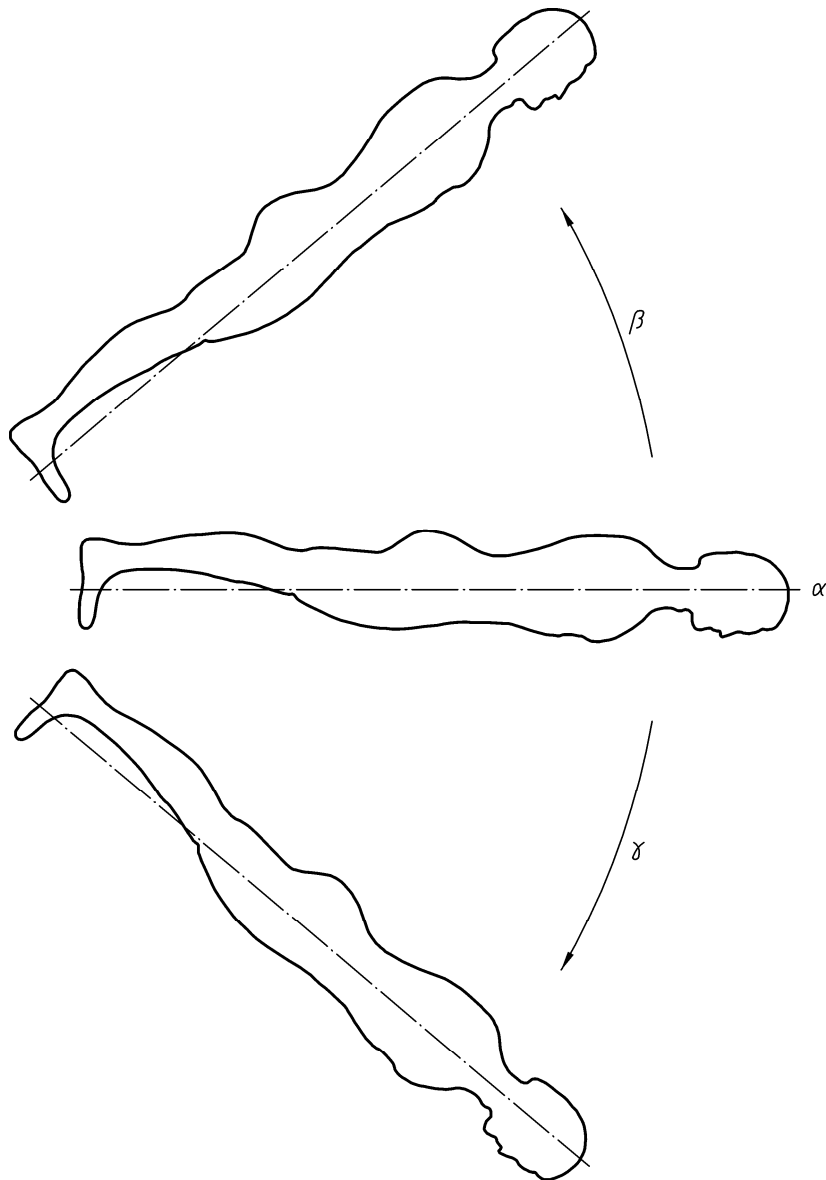
- A mouth
- B suprasternal notch
- C lung centroid

Figure 2 — Reference points

**Key**

- α horizontal face down - pitch 0°
- β positive roll (+ degrees)
- γ negative roll (- degrees)

Figure 3 — Diver roll



Key

- α horizontal face down – roll 0°
- β positive pitch (+ degrees)
- γ negative pitch (- degrees)

Figure 4 — Diver pitch

Dimensions in millimetres

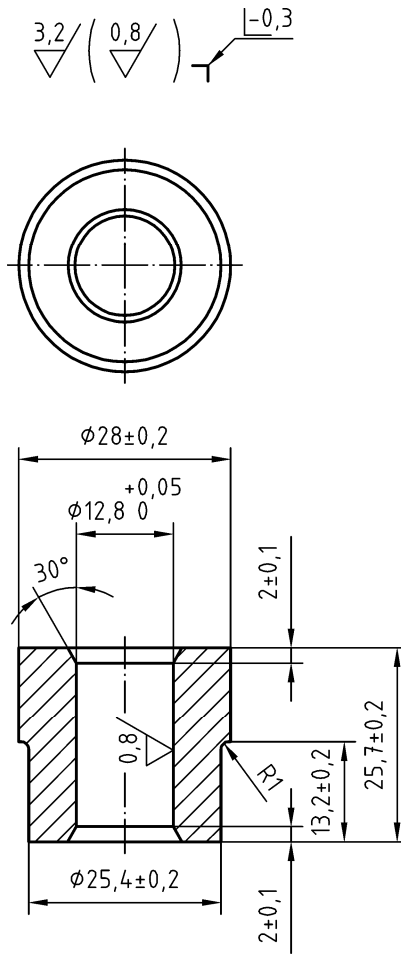


Figure 5 — Calibration orifice

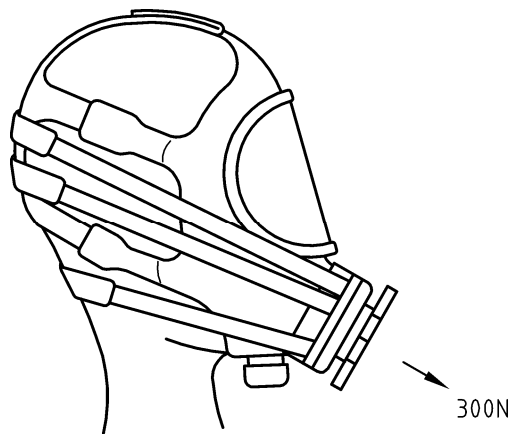
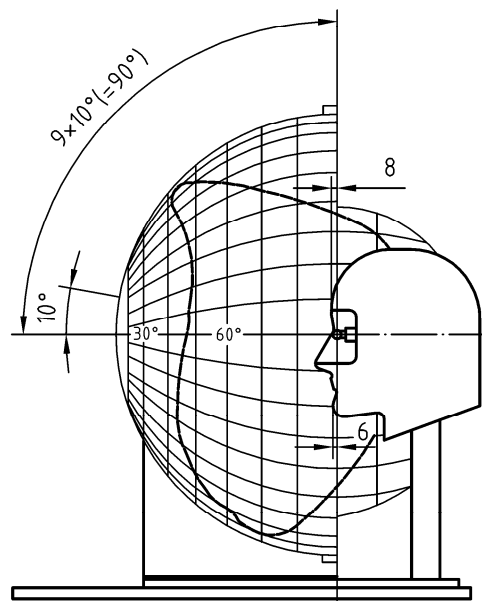
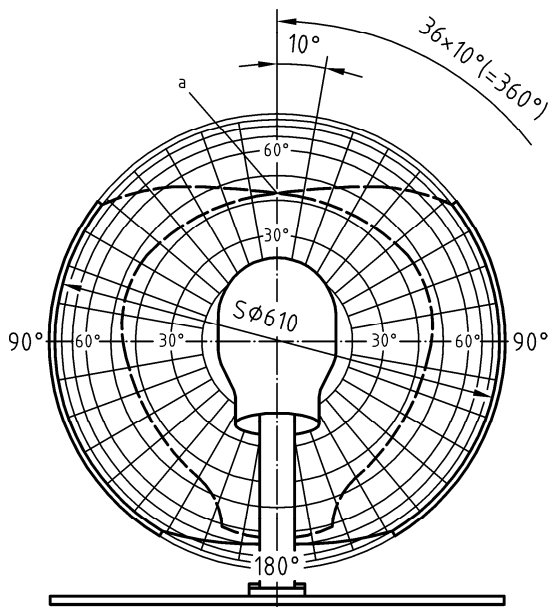
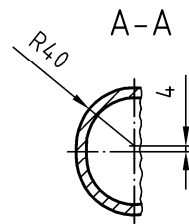
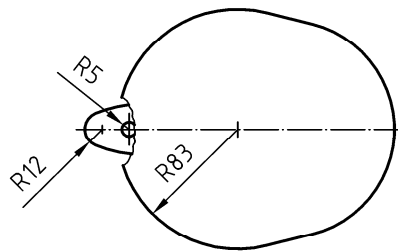
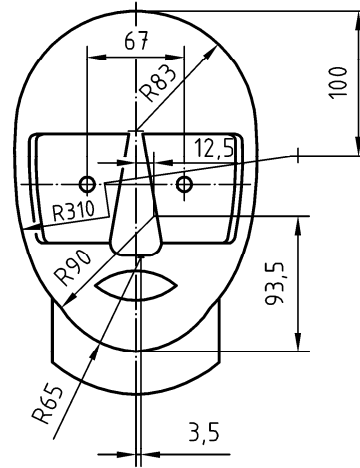
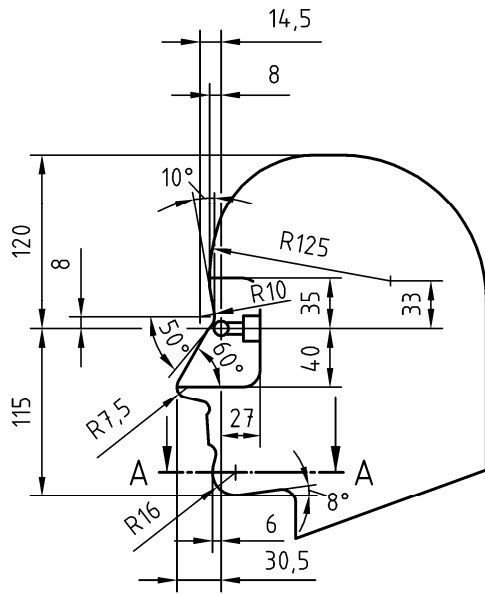


Figure 6 — Test arrangement for tensile force

Dimensions in millimetres

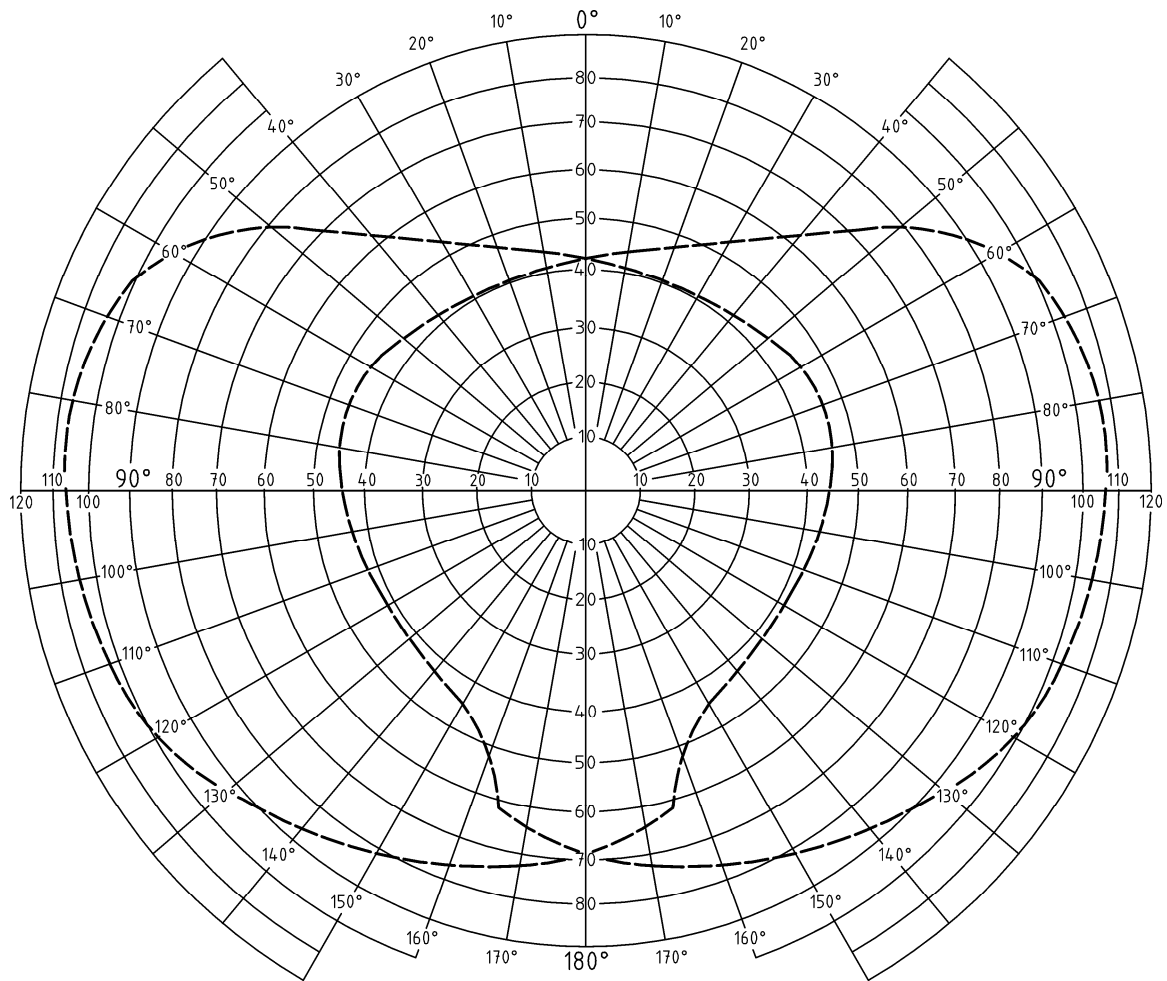


Key

- a Transfer the natural field of vision with the natural overlapped field of visions to the diagram

Figure 7 — Stoll Apertometer

Dimensions in millimetres



Key

..... natural field of vision with natural overlapped field of vision

The area enclosed by circular lines of the diagram are proportional to the corresponding areas marked on the spherical shell of the apertometer.

Semi-circular surface represented inside of the 90° circle..... = 126,9 cm²

Natural field of vision inside of the 90° circle (78,8 %)..... = 100,0 cm²

Natural field of vision outside of the 90° circle..... = 12,0 cm²

Natural field of vision totally..... = 112,0 cm² = 100 %

Natural overlapped field of vision..... = 39,0 cm² = 100 %

Shape of lenses: _____ Facepiece model: _____
(dimensions)

Where measurements of the field of vision are taken, the effective field of vision as observed by the apertometer shall be transferred to the diagram. Only the effective field of vision within the natural field of vision respectively the effective overlapped field of vision shall be planimetered and noted in cm².

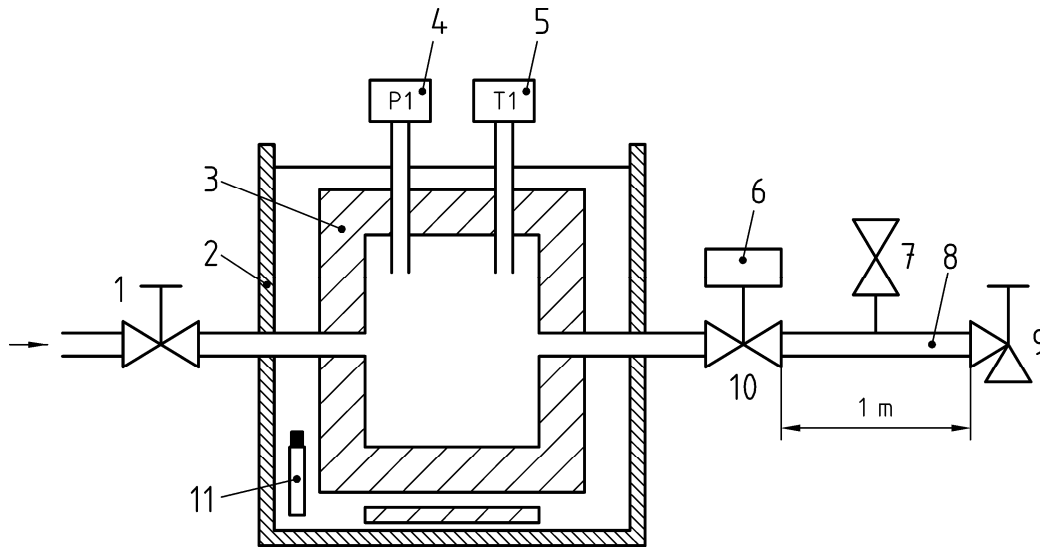
Planimetered area of effective field of vision (totally).....cm²

Planimetered area of effective overlapped field of vision.....cm²

Effective field of vision (totally).....%

Effective overlapped field of vision.....%

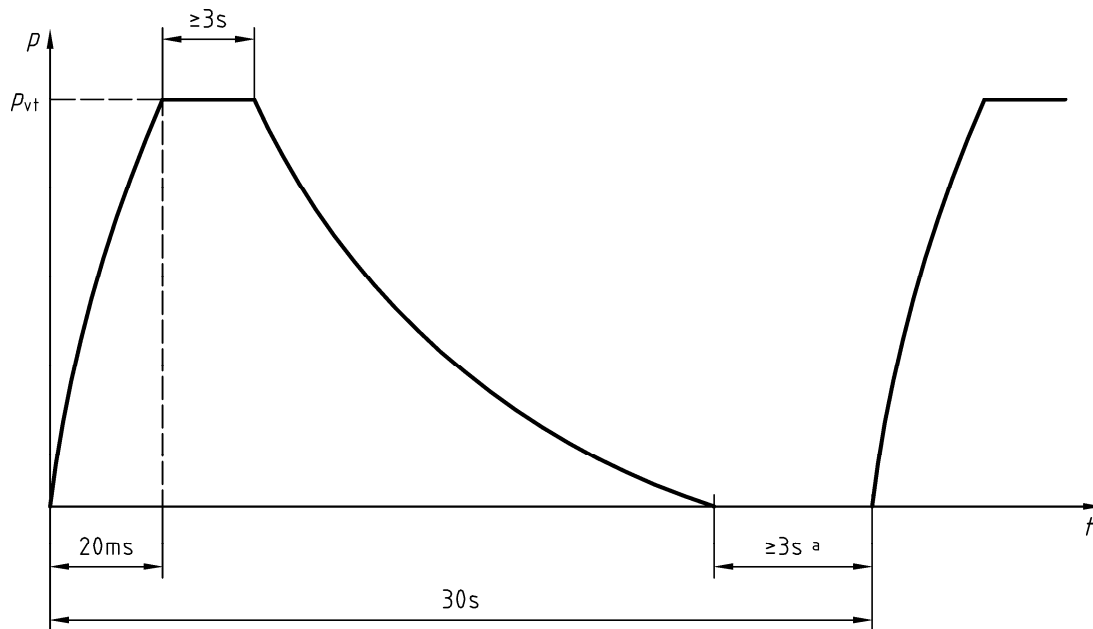
Figure 8 — Apertometer diagram (not to scale)



Key

- | | | | |
|---|--|----|------------------------|
| 1 | Inlet valve | 7 | Depressurisation valve |
| 2 | Pre-heating device (e.g. water bath with electric heating) | 8 | Copper tube |
| 3 | Oxygen vessel | 9 | Sample device |
| 4 | Pressure monitor | 10 | Quick opening valve |
| 5 | Temperature monitor | 11 | Thermostat |
| 6 | Actuator | | |

Figure 9 — Example of an ignition test installation



Key

- a pause

Figure 10 — Pressure cycle specification for oxygen pressure surge test

Annex A
(informative)

Artificial sea water

28,0 g NaCl

5,0 g MgCl₂ · 6 H₂O

2,4 g CaCl₂ · 6 H₂O

are completely dissolved in 885 ml of desalinated water (solution A).

7,0 g MgSO₄ and 0,2 g NaHCO₃

are completely dissolved in 100 ml of desalinated water (solution B).

Solution B is poured into solution A as a thin jet.

After 24 h, the mixture is filtered and adjusted to $7 \leq \text{pH} \leq 8$ by adding NaOH-solution.

Annex ZA (informative)

Clauses of this European Standard addressing essential requirements or other provisions of EU Directives

This European Standard has been prepared under a mandate given to CEN by the European Union and the European Free Trade Association and supports essential requirements of EU Directive 89/686/EEC.

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

The clauses of this standard are likely to support requirements of Directive 89/686/EEC, Annex II:

| EU Directive 89/686/EEC, Annex II: | Clauses of this standard: |
|------------------------------------|--|
| 1.1.1 | 5.1; 5.2; 5.6.1; 5.6.1.3; 5.7.1; 5.8.8; 5.10; 5.11 |
| 1.1.2.1 | 5.6.1; 5.7.1; 5.7.4; 5.13.1; 5.13.3,5.14.2 |
| 1.1.2.2 | 5.6.1; 5.14.2 |
| 1.2.1 | 5.1; 5.6; 5.17 |
| 1.2.1.1 | 5.2; 5.6.6; 5.15; 5.18 |
| 1.2.1.2 | 5.1; 5.10.2;5.10.4; 5.11; 5.17 |
| 1.2.1.3 | 5.1; 5.6.1.4; 5.6.6; 5.10.4; 5.17 |
| 1.3.1 | 5.1; 5.8.8; 5.10.2; 5.11; 5.17 |
| 1.3.2 | 5.1; 5.2; 5.5.3; 5.8.2; 5.8.5; 5.8.7; 5.18 |
| 1.3.3 | 5.12 |
| 1.4 | 8 |
| 2.1 | 5.10.2; 5.11 |
| 2.3 | 5.10 |
| 2.4 | 5.2; 8 |
| 2.8 | 5.14; 8 |
| 2.9 | 5.1; 5.3; 5.4; 5.5; 5.10; 5.16 |
| 2.12 | 7 |
| 3.10.1 | 5.1; 5.2; 5.6.6; 5.10.1; 7; 8 |

Compliance with this standard provides one means of conforming with the specific essential requirements of the Directive concerned and associated EFTA regulations.

Bibliography

- [1] EN 144-2:2000, *Respiratory protective devices – Gas cylinder valves – Part 2: Outlet connections*
- [2] EN 13949:2003, *Respiratory equipment – Open-circuit self-contained diving apparatus for use with compressed Nitrox and oxygen – Requirements, testing, marking*