

ICS 13.340.30

English version

## Respiratory equipment - Self-contained re-breathing diving apparatus

Apareils respiratoires - Appareils de plongée autonomes à circuit fermé

Atemgeräte - Autonome Regenerationstauchgeräte

This European Standard was approved by CEN on 7 August 2003.

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## Foreword

This document (EN 14143:2003) has been prepared by Technical Committee CEN/TC 79 "Respiratory protective devices", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2004, and conflicting national standards shall be withdrawn at the latest by March 2004.

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.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

## **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 complete apparatus where specified in the standard.

The production of the standard has raised new questions regarding the interpretation of the physiological and equipment acceptance limits for the diving application which have not been fully answered. However, this standard has been published to provide a level of safety for re-breathing diving apparatus.

## 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 between 4 °C and 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

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 132:1998, *Respiratory protective devices - Definitions of terms and pictograms*

EN 134:1998, *Respiratory protective devices - Nomenclature of components*

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 250, *Respiratory equipment - Open circuit self contained compressed air diving apparatus - Requirements, testing and marking*

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

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

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

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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

### 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 pressure vessel(s) and between the pressure vessel(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 in the facepiece relative to the no flow pressures in the facepiece 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 within the facepiece (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 l

#### 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 litres 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. It may be a mouthpiece assembly, a diving half mask or a full face mask

## 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 pressure vessel(s);
- safety device(s);
- body harness.

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

## 5 Requirements

### 5.1 Design

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

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.

The combination of components and parts shall not adversely 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.

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.

The apparatus shall function satisfactorily out of the water and in all orientations in the water.

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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.

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.

If the apparatus is intended for use in water temperatures less than 4 °C the manufacturer shall state the minimum temperature and its performance shall be tested at that temperature.

Testing shall be done in accordance with 6.2, 6.15 and 6.16.

### 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.

Any materials that may come into contact with a high pressure gas with an oxygen content greater than air as specified in EN 12021 shall be compatible for use with high pressure oxygen.

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.

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

After testing in accordance with 6.17 the apparatus shall still be fully functional.

Testing shall be done in accordance with 6.2, 6.8, 6.9, 6.13, 6.14, 6.15, 6.16 and 6.17.

### 5.3 Pressure vessel(s)

The pressure vessel(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 pressure vessel(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.

Testing shall be done in accordance with 6.2.

### 5.4 Pressure vessel valve(s)

Pressure vessel valve(s) shall comply with appropriate national or European specifications and shall be approved and tested for use at the rated working pressure and gas.

The threads for connecting the pressure vessel(s) and the valve(s) shall be as described in EN 144-1 where the preferred versions are M 18 x 1,5 or M 25 x 2.

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

- EN 250 for pressure vessels intended for compressed air;
- EN 144-3 for pressure vessels intended for compressed Nitrox and compressed oxygen.

If no specific standards for other respirable gases are available connections according to EN 144-3 are recommended.

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 pressure vessel valve shall not be impaired by the ingress of water.

The pressure vessel valve(s) shall be protected against the entrainment of dirt, solid particles and water from inside the pressure vessel 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, 6.15 and 6.16.

## **5.5 High and medium pressure parts and connections**

### **5.5.1 General**

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

Non-metallic high and medium pressure tubes, valves and couplings shall be tested to prove that they are capable of withstanding a pressure of twice the rated working pressure of the pressure vessel.

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

Testing shall be done in accordance with 6.2 and 6.9.

### **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.

If fitted, any pressure reducer which 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, 6.15 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**

The breathing performance shall be measured using a sinusoidal waveform from a breathing machine with simulated RMVs up to  $75 \text{ l min}^{-1}$  (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.

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 and y from a reference point on the apparatus to the supra-sternal notch. For details see Figure 2.

#### **5.6.1.2 Work of breathing (WOB)**

Work of breathing shall not exceed a value of:

$$\text{WOB} = 0,5 + 0,03 \cdot \text{RMV} \quad [\text{J l}^{-1}] \text{ related to an RMV from } 10 \text{ l min}^{-1} \text{ to } 75 \text{ l min}^{-1}$$

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 and inspired and expired respiratory pressures shall be determined as shown in Figure 1. The peak to peak respiratory pressure shall not exceed 50 mbar. The inspired and expired respiratory pressures shall not exceed 25 mbar each.

Testing shall be done in accordance with 6.3.2.

#### **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)	Suprasternal notch	
	+ mbar	- mbar
+180	+20,0	-20,0
+90	+20,0	-20,0
+45	+20,0	-20,0
0	+20,0	-25,0
-45	+20,0	-20,0
-90	+20,0	-20,0
Roll degrees (Pitch at 0 degrees)		
+90	+20,0	-20,0
+45	+23,0	-23,0
0	+20,0	-25,0
-45	+23,0	-23,0
-90	+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.

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.

Means 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 so designed as to provide sufficient breathable volume for the diver whilst in any attitude. It shall allow a tidal volume of at least 4,5 l.

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Testing shall be done in accordance with 6.5.1 and 6.15.

### 5.6.4 Breathing circuit burst pressure

The breathing circuit shall be capable of withstanding a pressure of 300 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.

The design and configuration of the exhaust valve shall prevent the ingress of water in all positions.

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

- a) a constant flow of  $300 \text{ l min}^{-1}$  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.

Testing shall be done in accordance with 6.5.3 and 6.15.

### 5.6.6 Carbon dioxide absorbent canister

The endurance of the charged carbon dioxide absorbent canister in water at  $(4 \pm 1) \text{ }^\circ\text{C}$  shall be stated by the manufacturer for each specified absorbent material. It shall maintain an end of inspiration partial pressure of carbon dioxide of less than 5 mbar for the stated endurance.

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  $40 \text{ }^\circ\text{C}$ .

Testing shall be done in accordance with 6.6.1 and 6.6.2.

## 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 automatically 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) 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 the 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.

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  $40 \text{ l min}^{-1}$  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 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 6.8.1.

### 5.8.3 Flexibility of high and medium pressure hoses

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

Testing shall be done in accordance with 6.8.2.

**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 6.8.3.

**5.8.5 High pressure hose assemblies bursting pressure**

Any high pressure hose 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 6.8.4.

**5.8.6 Medium pressure hose assemblies leak test**

Any medium pressure hose 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 6.8.3.

**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 6.8.4.

**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 under chin or arm pressure during practical performance tests.

Testing shall be done in accordance with 6.15.

The hose shall not collapse and the elongation shall be at least 10 % and not greater than 30 %.

Testing shall be done in accordance with 6.8.5.

The permanent deformation of the hose shall not be more than 10 %.

Testing shall be done in accordance with 6.8.6.

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

Testing shall be done in accordance of 6.8.1.

**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 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 pressure vessel shall be fitted with a pressure indicating system; this may be either an analogue pressure gauge or pressure transducer. The apparatus shall be designed and fitted so as to enable the diver to take readings 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  $100 \text{ l min}^{-1}$  of gas measured at STPD.

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

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  $\pm 5$  bar;
- at 100 bar  $\pm 10$  bar;
- at 200 bar  $\pm 10$  bar;
- at 300 bar  $\pm 15$  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  $300 \text{ l min}^{-1}$ .

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  $\pm 3$  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 monitor shall have a limit deviation under all conditions within  $\pm 3$  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 include a system to 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 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.

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

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.

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

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, 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.

### 5.10.4 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**

Any electrical, electronic or programmable electronic part of the apparatus shall satisfy the requirements of IEC 61508, Part 1 to Part 7.

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 and during calibration of any electrical system the performance or calibration of the apparatus shall not be affected when exposed to electromagnetic fields and shall satisfy the requirements of EN 61000-6-1.

Testing shall be done in accordance with 6.12.

### **5.14 Resistance to temperature**

#### **5.14.1 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.

#### **5.14.2 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.

### **5.15 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 6.17.

## 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

High 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 6.16.

## 5.19 Pressure resistance of casings and monitors

If casings and monitors are sealed against ambient pressure they shall be waterproof to 1,3 times the intended maximum diving depth specified by the manufacturer for at least 15 min.

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

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

NOTE 2 As a diver can encounter variable water temperatures and can not have a means of identifying an increase in inspired carbon dioxide level to increase safety, tests will be conducted at a temperature of  $(4 \pm 1)$  °C.

### 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  $(22 \pm 5)$  °C and at a relative humidity of at least 50 %. The temperature limits shall be subject to a limit deviation of  $\pm 1$  °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  $\text{min}^{-1}$ , 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.

### **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 verify that the apparatus has been produced in accordance with the manufacturer's technical file and include marking and information supplied by the manufacturer.

### **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.

The breathing 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.

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

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

For apparatus that do not add gas during tests the breathable volume shall be optimised 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  $(4 \pm 1) \text{ }^\circ\text{C}$ , or lower if specified by the manufacturer.

#### **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  $0^\circ$  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 rates 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.

### 6.4 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 l min<sup>-1</sup> and the mouth pressure recorded at the end of exhalation (see figure 1).

After breathable volume optimisation as defined in 6.3.1 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° (see figure 4).

Fill the apparatus with gas until an internal pressure at the mouthpiece of + 25 mbar is achieved or the exhaust valve starts to release gas.

Withdraw 4,5 l of gas from the apparatus recording the internal pressure. Then inject 4,5 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 mbar.

#### 6.5.2 Breathing circuit burst pressure test

To perform this test the exhaust valve shall be sealed off.

#### 6.5.3 Exhaust valve

##### 6.5.3.1 Maximum pressure within the breathing circuit

This test shall be performed in dry conditions.

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<sup>-1</sup> 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 Ingress of water**

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 in all 5 roll positions mentioned in Table 1 each for a time of 3 min at an RMV of 62,5 l min<sup>-1</sup>.

For closed-circuit breathing apparatus inject gas at a rate of 5 l min<sup>-1</sup> throughout the test.

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

The pH value shall not exceed 9.

The ingress of water shall not exceed 50 ml.

### **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.

## **6.6 Apparatus endurance**

### **6.6.1 General**

Conduct all relevant 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 °C ± 4 °C and a relative humidity greater than 80 %.

Test the apparatus with the breathing simulator ventilating at 40 l min<sup>-1</sup> and carbon dioxide injected into the exhale gas from the breathing simulator at a rate of 1,6 l min<sup>-1</sup>.

Record the time taken for the end inspired partial pressure of carbon dioxide to reach 5 mbar and 10 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. The pH value shall not exceed 9.

### **6.6.3 Gas endurance**

Test the apparatus with the breathing simulator ventilating at 40 l min<sup>-1</sup> and oxygen being removed from the exhaled gas from the breathing simulator at a rate of 1,78 l min<sup>-1</sup>.

Determine the time taken for any gas supply pressure vessel 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  $30 \text{ m min}^{-1}$  and an ascent rate of  $20 \text{ m min}^{-1}$ .

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. The tests at each work rate shall be continued until a steady state inspired oxygen is achieved. The inspired oxygen levels shall remain within acceptable limits.

## 6.8 Hoses assemblies

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

### 6.8.1 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.

### 6.8.2 Flexibility of high and medium pressure hoses

Bend the hose around a proof pressure vessel ( $65 \text{ mm} \pm 2,5 \text{ mm}$  radius).

### 6.8.3 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.

### 6.8.4 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.

### 6.8.5 Flexibility of breathing hoses

Suspend the breathing hose assembly for testing elongation. Measure the hose length (without couplings).

Afterwards apply a force of 10 N to the hose assembly for a period of 5 min and measure and record the length of the hose.

Calculate the elongation (%).

### 6.8.6 Permanent axial deformation of breathing hoses

Immediately, after the test of 6.8.5 submit the corrugated hose to a force of 10 N for 48 h after which the force is removed. After a recovery period of 6 h, measure and record the length of the hose.

Calculate the permanent axial deformation (%).

## **6.9 Burst 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 partial pressure oxygen 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 partial pressure of oxygen 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<sup>-1</sup>. 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 partial pressure of oxygen monitor shall be decompressed using the stop depth specified by the manufacturer. The rate of ascent shall be 20 m min<sup>-1</sup> and the partial pressure of oxygen monitor held at each stop for a period of 2 min.

### **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  $\pm 3$  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  $\pm 3$  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 strength 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 strength 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 strength in accordance with figure 6 for a period of 10 s.

Record the force.

### 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 m 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.

## 6.12 Electrical systems, Electromagnetic compatibility (EMC)

Test the apparatus in accordance with EN 61000-6-1 with imposed electromagnetic field frequencies in the range 80 MHz to 1 000 MHz.

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 and then during 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 pressure vessel valves closed and pressure vessels 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 pressure vessel 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<sup>-1</sup> with an oxygen consumption of 1,78 l min<sup>-1</sup> 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.

During the test the apparatus 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) Where there is an adjustable valve the diver shall assess the performance of the apparatus over the full range of adjustment;
- f) Facepiece comfort and security of gas supply;
- g) Any other comments reported by the wearer on request.

### 6.15.4 Functional testing when diving

- a) Donning and doffing of the apparatus as well as adjustment of all straps of the apparatus without help on land;
- b) Two dives to be conducted by each diver of which at least one dive to be completed deeper than 3 m;
- c) No continuous leakage while swimming in all orientations (front and back);
- d) Checking of partial pressure oxygen and pressure indicators;
- e) Swimming at maximum speed;
- f) Where there is an adjustable valve, the apparatus performance over the full range of adjustment shall be verified;
- g) Changing to and from independent breathing apparatus.

### 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  $(20 \pm 5)$  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  $(60 \pm 3)$  °C shall be used.

The quality of oxygen shall be:

- minimum purity 99,5 % by volume;
- hydrocarbon content  $\leq 10 \times 10^{-6}$ .

Each test shall be carried out as follows:

- Supply oxygen at a temperature of  $(60 \pm 3)$  °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  $(60 \pm 3)$  °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 50 pressure cycles from atmospheric pressure to the device test 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 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.

## 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 application.

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;

- 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.

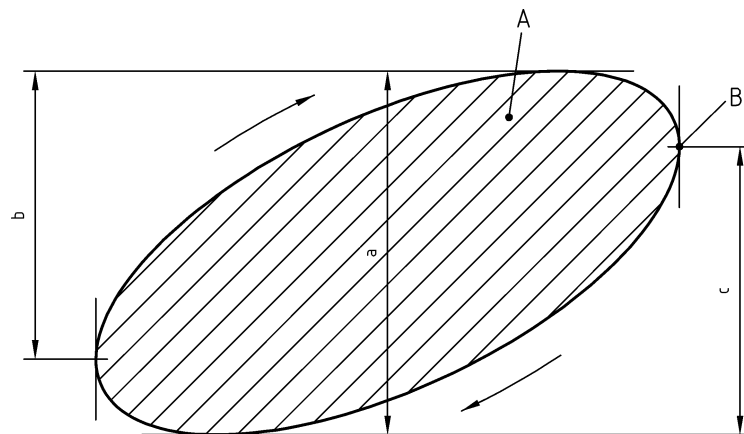
**Table 4 — Breathing simulator settings**

<b>Tidal volume</b> at BTPS l	<b>Breathing frequency</b> min <sup>-1</sup>	<b>Ventilation rate</b> at BTPS l min <sup>-1</sup>	<b>Carbon dioxide injection rate</b> at STPD l min <sup>-1</sup>	<b>Oxygen consumption rate</b> at STPD l min <sup>-1</sup>	<b>Maximum WOB</b> J l <sup>-1</sup>
1,0	10	10,0	0,40	0,44	0,80
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 $\text{min}^{-1}$	Ventilation rate at BTPS $\text{l min}^{-1}$
4,5	5	22,5

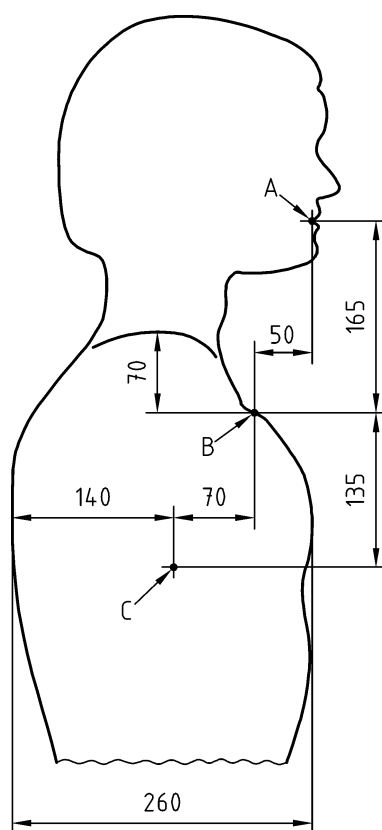


**Key**

- a) peak to peak respiratory pressure
- b) peak expired respiratory pressure (end inhalation to peak exhalation)
- c) peak inspired respiratory pressure (end exhalation to peak inhalation)
- A WOB
- B Reference point of hydrostatic imbalance; end of exhalation ("no flow")

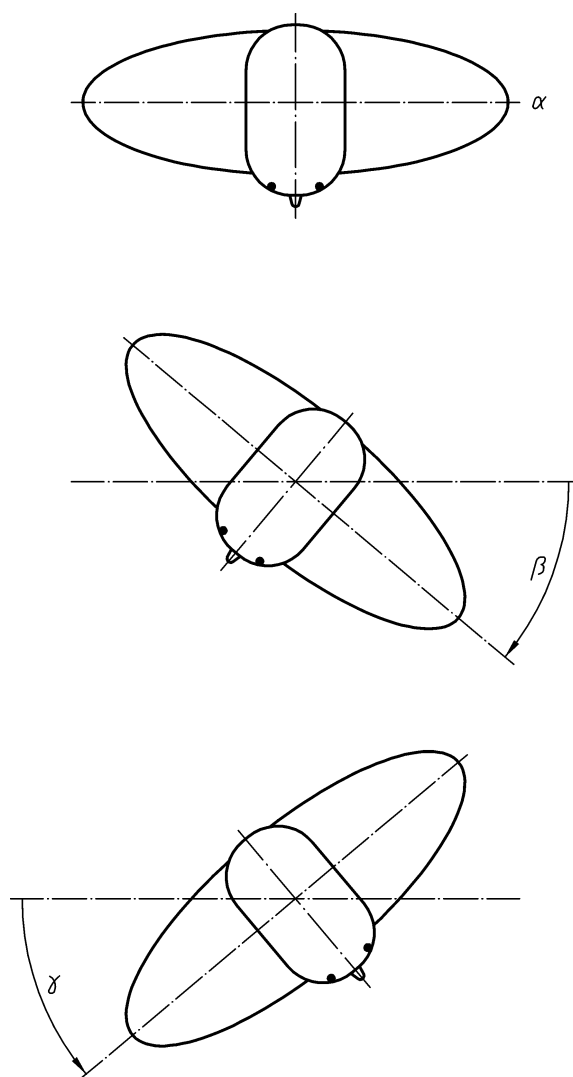
**Figure 1 — Analysis of pressure volume loop**

Dimensions in millimetres

**Key**

- A) mouth
- B) suprasternal notch
- C) lung centroid

**Figure 2 — Reference points**



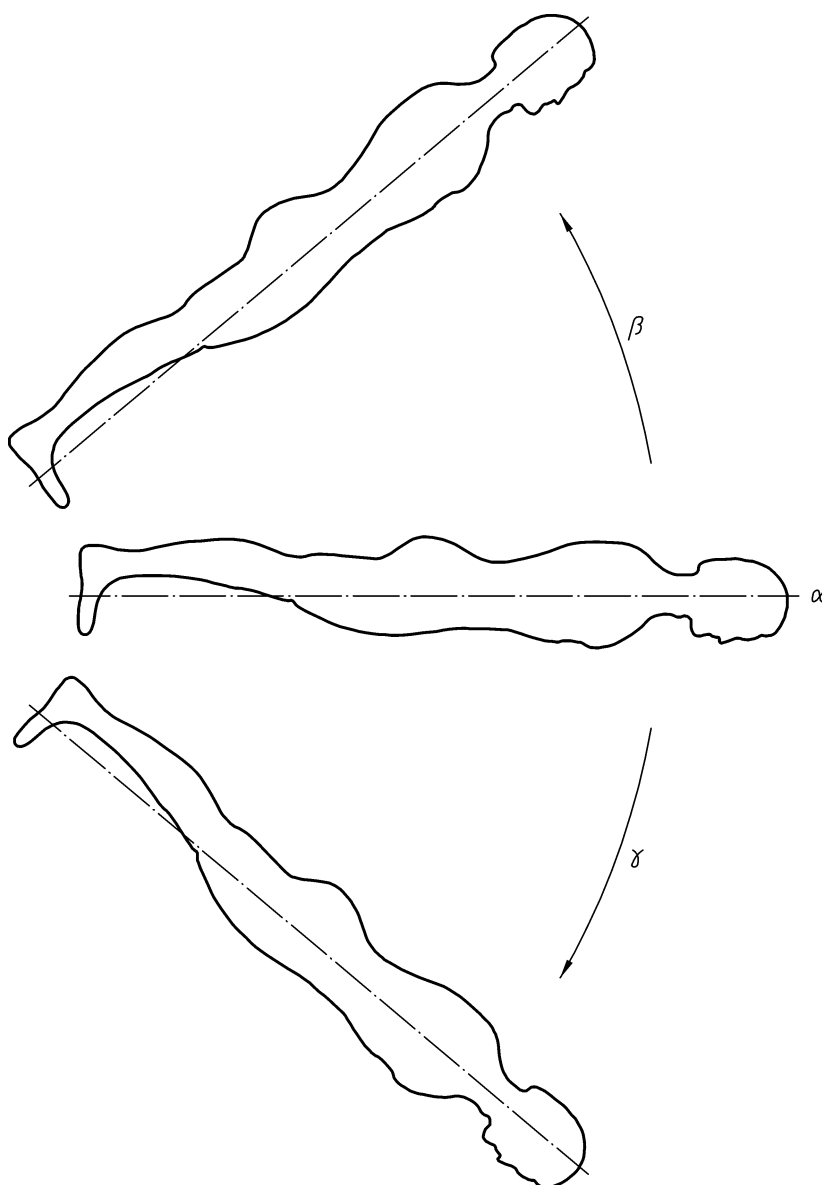
**Key**

$\alpha$ ) horizontal face down - roll  $0^\circ$

$\beta$ ) positive roll ( + degrees)

$\gamma$ ) negative roll ( - degrees)

**Figure 3 — Diver roll**

**Key**

$\alpha$ ) horizontal face down – roll  $0^\circ$

$\beta$ ) positive pitch (+ degrees)

$\gamma$ ) negative pitch (- degrees)

**Figure 4 — Diver pitch**

Dimensions in millimetres

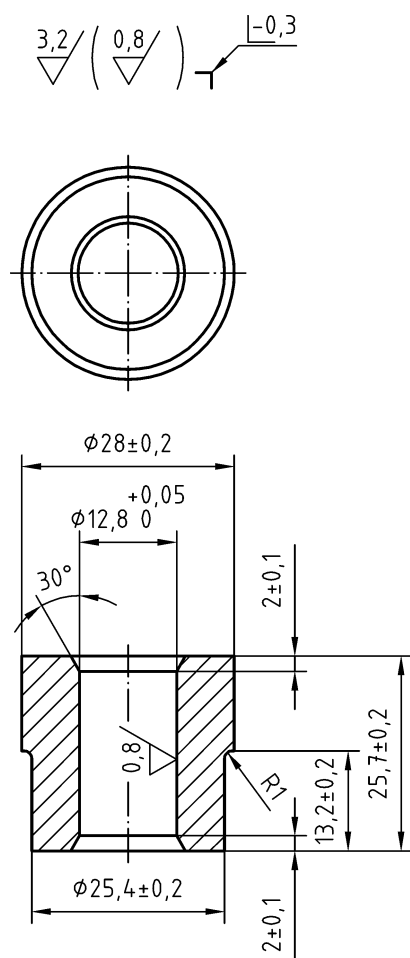


Figure 5 — Calibration orifice

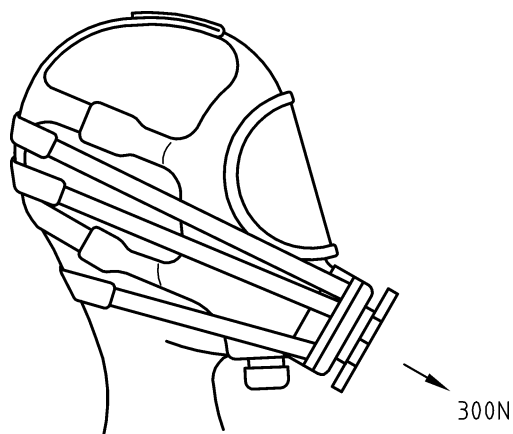
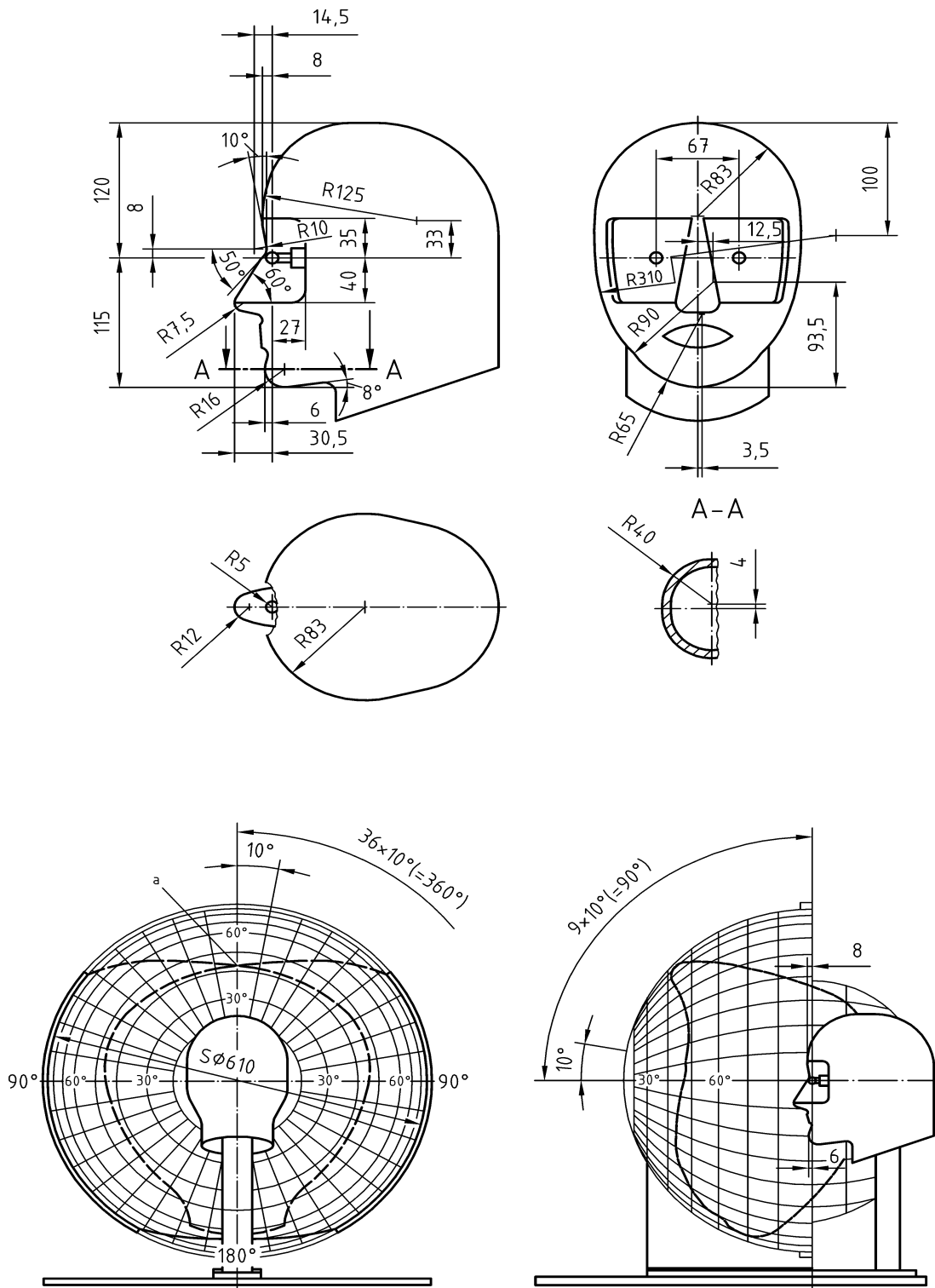


Figure 6 — Test arrangement for tensile force



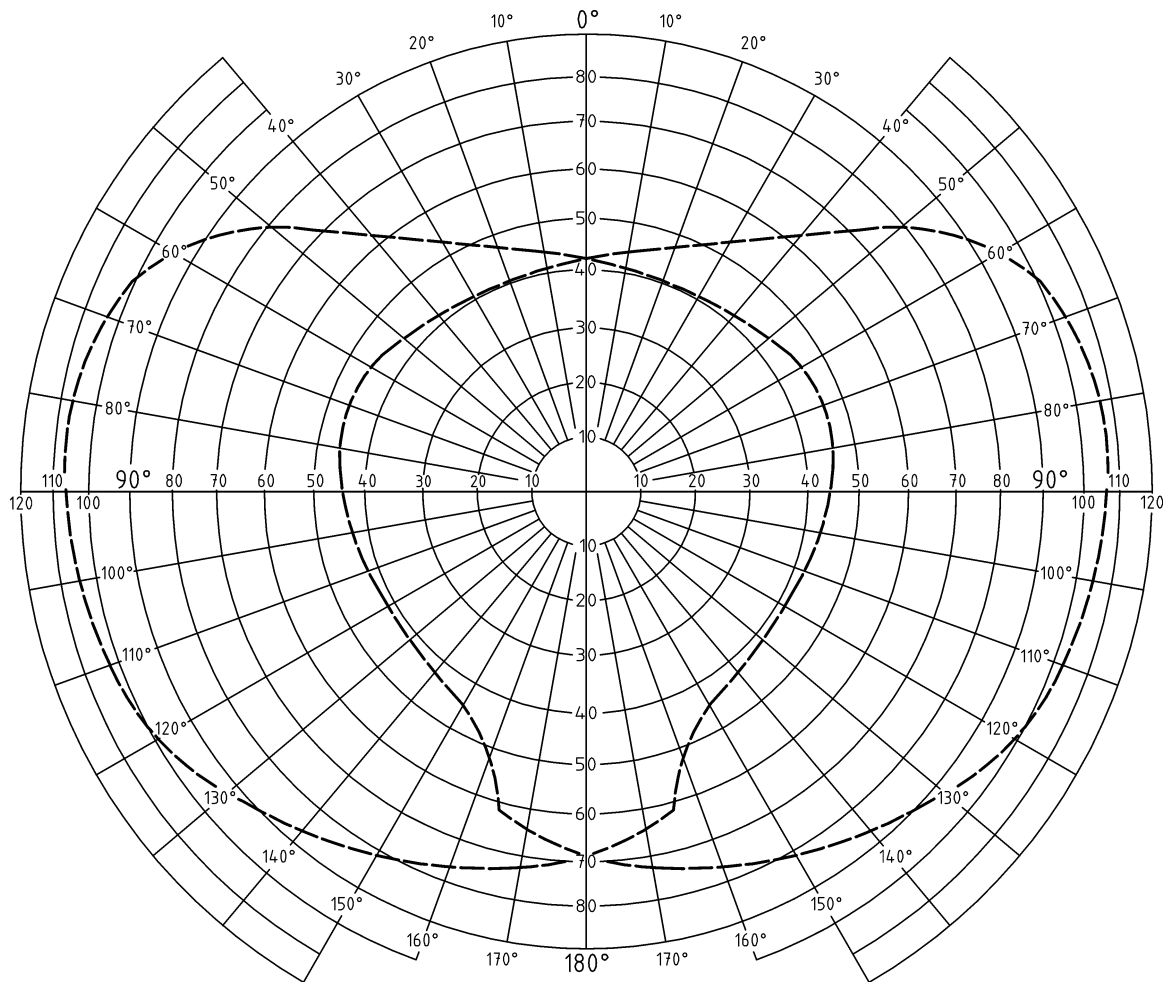
**Key**

- 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 cm<sup>2</sup>

Natural field of vision inside of the 90° circle (78,8 %).....= 100,0 cm<sup>2</sup>

Natural field of vision outside of the 90° circle.....= 12,0 cm<sup>2</sup>

Natural field of vision totally.....= 112,0 cm<sup>2</sup> = 100 %

Natural overlapped field of vision.....= 39,0 cm<sup>2</sup> = 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 planimeted and noted in cm<sup>2</sup>.

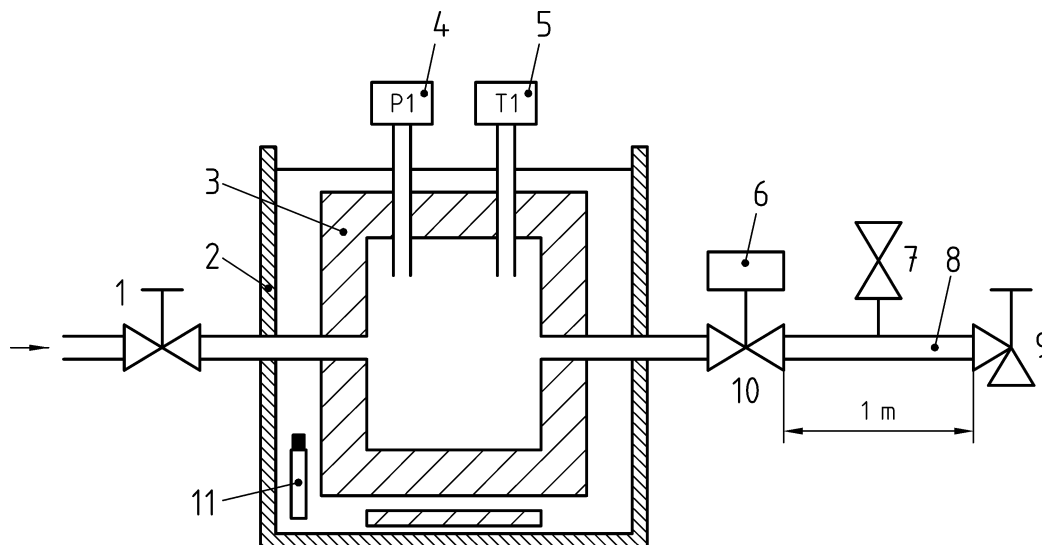
Planimetered area of effective field of vision (totally).....cm<sup>2</sup>

Planimetered area of effective overlapped field of vision.....cm<sup>2</sup>

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

Effective overlapped field of vision.....%

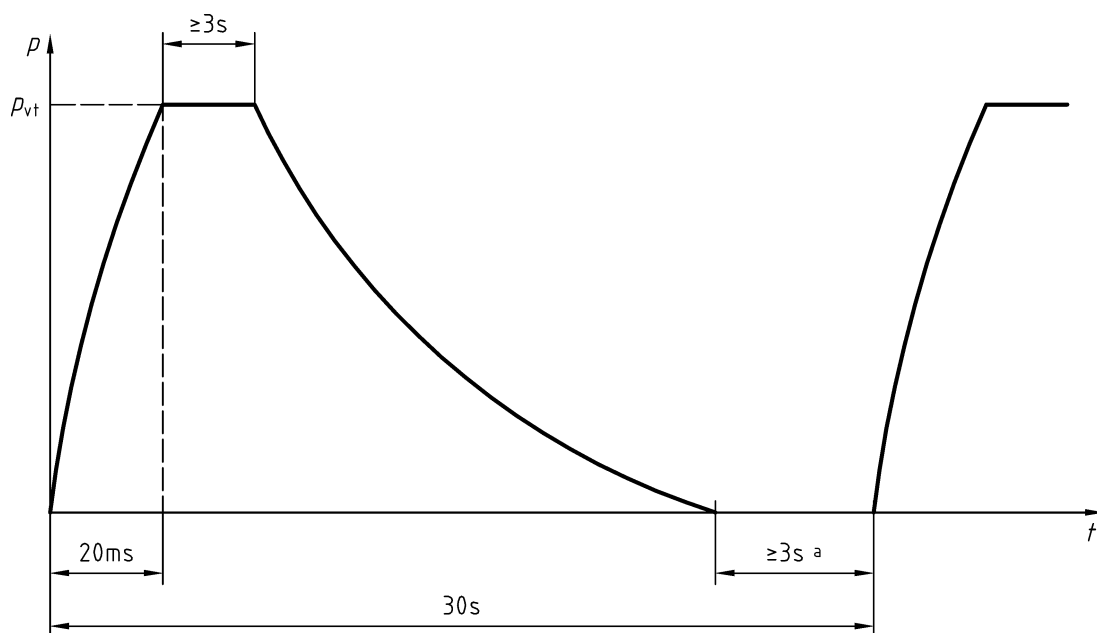
**Figure 8 — Apertometer diagram (not to scale)**



**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**

**Annex A**  
(informative)

**Artificial sea water**

28,0 g NaCl

5,0 g  $\text{MgCl}_2 \cdot 6 \text{H}_2\text{O}$

2,4 g  $\text{CaCl}_2 \cdot 6 \text{H}_2\text{O}$

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

7,0 g  $\text{MgSO}_4$  and 0,2 g  $\text{NaHCO}_3$

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 Commission 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

EN 144-2:2000, *Respiratory protective devices - Gas cylinder valves – Part 2: Outlet connections*