BRITISH STANDARD

BS EN
15333-2:2009

Respiratory equipment — Open-circuit umbilical supplied compressed gas diving apparatus

Part 2: Free flow apparatus

ICS 13.340.30

BSI
British Standards

National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Foreword

This document (EN 15333-2:2009) 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of an identical text or by endorsement, at the latest by August 2009, and conflicting national standards shall be withdrawn at the latest by August 2009.

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Introduction

A given open-circuit umbilical supplied compressed gas diving apparatus can only be approved when the apparatus or apparatus sub-assemblies satisfy the requirements of the tests specified in this European Standard, and practical performance tests have been carried out successfully on complete apparatus where specified in this European Standard.

The production of this European Standard has identified varying methods of surface supply and has separated them into two parts; apparatus that supplies demand type facepieces and apparatus that supplies free flow type facepieces.

1 Scope

This European Standard specifies minimum requirements for free flow surface supplied and free flow surface oriented diving apparatus to ensure a minimum level of safe operation of the apparatus. It applies to the following:

— a maximum depth of 50 m for apparatus using:

  a) air or;

  b) oxygen or;

  c) oxygen in nitrogen mixtures (Nitrox) or;

  d) oxygen in helium mixtures (Heliox) or;

  e) oxygen, nitrogen and helium mixtures (Trimix);

— water temperatures between 4 °C and 34 °C or outside these temperatures as specified by the manufacturer;

— environmental temperatures between -20 °C and 50 °C or outside these temperatures as specified by the manufacturer.

The requirements of this European 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.

This European Standard does not cover saturation diving systems, mini bell systems or apparatus used for oxygen decompression only.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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 397, *Industrial safety helmets*

EN 812, *Industrial bump caps*

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

EN 14593-1:2005, *Respiratory protective devices — Compressed air line breathing apparatus with demand valve — Part 1: Apparatus with a full face mask — Requirements, testing, marking*

EN 61508 (parts 1–7), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

EN ISO 12209 (all parts), *Gas cylinders — Outlet connections for gas cylinder valves for compressed breathable air*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 132:1998 and the nomenclature given in EN 134:1998 and the following apply.

3.1
auxiliary gas supply system
bail out
auxiliary and independent gas supply or breathing apparatus for use in case of a failure of the umbilical supply

3.2
body harness
component to attach the breathing apparatus, umbilical and any pressure vessels to the body of the diver

3.3
breathing frequency
number of breathing cycles per minute

3.4
displaced volume
tidal volume
volume of respirable gas displaced by a breathing simulator during one half cycle (inhalation or exhalation)

NOTE Measured in litres.

3.5
exhaust device
device for releasing excess gas from the facepiece

3.6
full face mask
facepiece covering mouth, nose, eyes and chin which may be fitted with either a mouthpiece or an inner mask

3.7
helmet
facepiece covering the whole head, which may be fitted with either a mouthpiece or an inner mask

3.8
high pressure
pressure greater than medium pressure

3.9
hydrostatic imbalance
difference at both end exhalation no flow and end inhalation no flow between the pressure within the facepiece (see Figure 1) and that at the reference point, which could be either the suprasternal notch or the lung centroid of the diver (see Figure 2)

3.10
life line
component of the apparatus which connects the diver to the surface and may be used to help a diver in distress

3.11
lifting harness
component of the apparatus attached to the diver for lifting the diver from the water

3.12
low pressure
pressure within the facepiece, i.e. approximately ambient pressure

3.13
medium pressure
internal pressure between a pressure reducer and a facepiece

NOTE This is sometimes referred to as intermediate pressure.

3.14
neck connector
device that provides a sealed connection between the helmet and a wearers drysuit

NOTE It is normally worn with some form of retaining device that prevents the helmet from floating off the wearers head.

3.15
neckdam
device that connects to the helmet and seals at the wearers neck

NOTE It is normally worn with some form of retaining device that prevents the helmet from floating off the wearers head.

3.16
pressure volume diagram
diagram generated during one breathing cycle by plotting the respiratory pressure against the displaced volume (see Figure 1)

3.17
rated working pressure
maximum allowable pressure for which the apparatus is designed

3.18
respiratory minute volume
RMV
product of the tidal volume and breathing frequency

NOTE Measured in litres per minute.

3.19
respiratory pressure
differential pressure at the mouth relative to the no flow pressures at the mouth at the end of inhalation and exhalation (see Figure 1)

3.20
surface control system
system that controls the supply from (a) gas source(s) to the diver(s) via the umbilical

NOTE It may also have a separate independent controlled supply for a stand by diver.

3.21
free flow surface supplied diving apparatus
diving apparatus that has gas supplied from the surface through a surface control system or system via an umbilical, allowing the diver to breathe under water from a facepiece

NOTE The apparatus is designed and constructed to pass a continuous flow of gas through the facepiece from which the diver inhales. Excess gas passes into the water or to a return hose, if fitted.

3.22
umbilical
connection to the diver from the surface control system

NOTE It may consist of a single hose or multiple lines, comprising life line, gas supply and if fitted voice communication and depth measuring system together with other services such as heating or cooling for suits, power for lighting and camera video signals.

3.23
work of breathing
work expended during one breathing cycle

NOTE 1 Measured in Joule per litre.

NOTE 2 This work is proportional to the area bounded by the pressure volume diagram (see Figure 1).

4 Minimum equipment

The apparatus may consist of subassemblies.

The apparatus shall comprise, at least the following components:

- surface gas supply:
  - gas supply;
  - surface control system;
  - gas monitoring;
- breathing system:
  - facepiece;
  - flow control devices;
  - body harness;
  - umbilical;
  - safety device(s).

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

The apparatus may also include the following components:

- auxiliary gas supply;
- lifting harness;
- depth measuring device;
- voice communication system.

5 Requirements

5.1 Design

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

Testing shall be done in accordance with 6.2.

5.1.2 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 all pre-dive functional checks specified by the manufacturer.

Testing shall be done in accordance with 6.2 and 6.13.

5.1.3 The combination of components and parts shall not adversely affect the safe operation and use of the apparatus.

Testing shall be done in accordance with 6.2 and 6.13.

5.1.4 The apparatus shall not have any sharp edges or protrusions that can injure the diver or surface operator.

Testing shall be done in accordance with 6.2 and 6.13.

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

Testing shall be done in accordance with 6.13.

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

Testing shall be done in accordance with 6.2 and 6.13.

5.1.7 The apparatus may have an auxiliary independent gas supply (bail out) to allow the diver to return safely to the surface or a point of safety. If fitted, the design shall prevent inadvertent use of the auxiliary supply and to prevent the supply from exhausting into the water in the event of a main umbilical failure.

Testing shall be done in accordance with 6.2 and 6.13.

5.1.8 The design shall prevent negative facepiece pressure in the event of any gas supply failure.

Testing shall be done in accordance with 6.2.

5.1.9 The apparatus shall include a means to expel water from the facepiece.

Testing shall be done in accordance with 6.2 and 6.13.

5.1.10 The apparatus shall be designed to prevent any 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 6.13.

5.1.11 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 6.5.2 and 6.5.3.

5.1.12 The apparatus shall allow the use of a suitable auxiliary gas supply.

Testing shall be done in accordance with 6.2 and 6.13.

5.2 Materials

5.2.1 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, 6.3, 6.4, 6.8, 6.9, 6.10, 6.11 and 6.13.

5.2.2 Any materials that may come into contact with pressurized gas above 25 bar, other than air in accordance with EN 12021, and with an oxygen content greater than 21 %, shall be compatible for use with high pressure oxygen. All components and assemblies shall be supplied clean to meet the intended service.

Testing shall be done in accordance with 6.2 and 6.12.

5.2.3 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 6.13.

5.2.4 Any material that may come into contact with sea water shall be sea water resistant. After conditioning in accordance with 6.9 the apparatus shall still be fully functional.

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

5.3 Diver worn pressure vessel(s) (if fitted)

The pressure vessel(s) shall be designed in accordance with appropriate regulations 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 Diver worn pressure vessel valve(s) (if fitted)

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

Testing shall be done in accordance with 6.2 and 6.12 if applicable.

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

— EN ISO 12209 (all parts) 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 shall be used.

Testing shall be done in accordance with 6.2.

5.4.3 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 (e.g. 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.

Testing shall be done in accordance with 6.2 and 6.13.

5.4.4 The function of a pressure vessel valve shall not be impaired by the ingress of water.

Testing shall be done in accordance with 6.2.

5.4.5 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.

5.4.6 The pressure drop measured across the complete pressure vessel valve(s) assembly with a pressure vessel pressure of 50 bar shall not exceed 10 bar.

Testing shall be done in accordance with 6.14.

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 rated working pressure.

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.

It shall not be possible to connect a pressure component to a system with a pressure greater than the rated working pressure of that component.

Testing shall be done in accordance with 6.2, 6.3 and 6.13.

5.5.2 Pressure reducer(s)

Any pre-set pressure reducer 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 6.13.

5.5.3 Pressure relief system(s)

Each section of a given high pressure system shall be either capable of operating up to the maximum rated working pressure of the system or shall be provided with an adequate pressure relief valve.

All medium pressure supplies shall be fitted with a pressure relief system.

In the event of a pressure reducer failure the relief system shall maintain the pressure within the rated working pressure of the system.

The manufacturer shall specify the relief pressure and flow based on the failure mode effect and critically analysis. In any case the maximum relief pressure shall not exceed 50 % of the burst pressure specified by the manufacturer.

Testing shall be done in accordance with 6.2 and 6.6.3.

5.6 Hoses

5.6.1 General

The same high pressure or medium pressure hose assembly shall meet the requirements specified in the following sequence: 5.6.2, 5.6.3, 5.6.4, 5.6.5, 5.6.6 or 5.6.7 and 5.6.8, respectively.

5.6.2 Tensile strength of high and medium pressure hose assemblies

The unpressurised hose assembly shall be subjected to a tensile strength of 1 000 N for a test period of 10 s to 15 s. It shall not burst, leak or have any indication of failure.

Testing shall be done in accordance with 6.4.2.

5.6.3 Flexibility of high and medium pressure hose assemblies

The unpressurised hose assembly shall be capable of being bent to an angle of 180° for 8 h. It shall not burst, leak or have any indication of failure.

Testing shall be done in accordance with 6.4.3.

5.6.4 Kinking of high and medium pressure hoses

Any hose used in the umbilical shall be resistant to kinking in accordance with EN 14593-1.

Testing shall be done in accordance with 6.2 and 6.4.4.

5.6.5 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 6.4.5.

5.6.6 High pressure hose assemblies bursting pressure

Any high pressure hose shall withstand a pressure of 4 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 6.3.

5.6.7 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 6.4.5.

5.6.8 Medium pressure hose assemblies bursting pressure

Any medium pressure hose assembly shall be capable of withstanding 4 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 6.3.

5.6.9 Umbilical

The umbilical shall be attached to the diver so that the strain is not taken by the connections to the facepiece.

The complete umbilical (including all components) as well as complying with the requirements for the relevant pressure hose assemblies in 5.6.2 to 5.6.8, shall have a negative buoyancy between < 20 N per 10 m length or a positive buoyancy < 10 N per 10 m length.

The apparatus shall have a life line that can be used to help recover a diver in distress. It may be a separate line or can be the umbilical. The life line including any connectors shall be capable of withstanding a tensile load of 3 500 N without damage.

The umbilical shall be attached to the diver such that it cannot inadvertently be released underwater by the diver, fouling or other incident. It shall be possible to be cut by hand tools carried by a diver.

Testing shall be done in sequence and in accordance with 6.2, 6.4.4, 6.4.6, 6.4.7 and 6.13.

5.7 Breathing system

5.7.1 Performance requirements

5.7.1.1 Breathing performance at standard RMV

The breathing performance shall be measured using a sinusoidal waveform from a breathing simulator with simulated RMV up to 62,5 l min^{-1} (ATP; Ambient Temperature and Pressure (see Table 6)). The performance of the system shall be determined using air or an oxygen in nitrogen gas mixture at an ambient pressure of 6 bar and where appropriate using an oxygen in helium based mixture at an ambient pressure of 6 bar or a reduced pressure specified by the manufacturer.

The breathing system shall meet the following requirements related to an RMV (BTPS; body temperature at pressure saturated) from 10 l min^{-1} to 70 l min^{-1}:

a) the work of breathing (WOB) shall not exceed a value of:

$$WOB = 0,5 + 0,03 \times RMV \qquad [J \times l^{-1}] \qquad (1)$$

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.

b) inspired and expired respiratory pressures shall be determined as shown in Figure 1. The inspired and expired respiratory pressures shall not exceed 25 mbar each;

c) the positive work of breathing during inhalation shall not exceed 0,3 $J \times l^{-1}$;

d) pressure spikes with no measurable positive work of breathing shall not exceed 25 mbar;

e) pressure peaks with measurable positive work of breathing shall not exceed 5 mbar.

Testing shall be done in accordance with 6.5.1, 6.5.2 and 6.5.3.

5.7.1.2 Breathing performance at high RMV

The breathing performance shall be measured using a sinusoidal waveform from a breathing simulator with simulated RMV at 75 l/min (ATP; Ambient Temperature and Pressure (see Table 6)). The performance of the system shall be determined using air or an oxygen in nitrogen gas mixture at an ambient pressure of 6 bar and where appropriate using an oxygen in helium based mixture at an ambient pressure of 6 bar or a reduced pressure specified by the manufacturer.

The breathing system shall meet the following requirements related to an RMV (BTPS) from 70 l min^{-1} to 85 l min^{-1}:

a) the work of breathing (WOB) shall not exceed a value of:

$$WOB = 0,5 + 0,04 \times RMV \qquad [J \times l^{-1}] \qquad (2)$$

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.

b) inspired and expired respiratory pressures shall be determined as shown in Figure 1. The inspired and expired respiratory pressures shall not exceed 35 mbar each;

c) the positive work of breathing during inhalation shall not exceed 0,5 $J \times l^{-1}$;

d) pressure spikes with no measurable positive work of breathing shall not exceed 25 mbar;

e) pressure peaks with measurable positive work of breathing shall not exceed 12 mbar.

Testing shall be done in accordance with 6.5.1, 6.5.2 and 6.5.3.

5.7.1.3 Cold water performance

The breathing performance shall be measured using a sinusoidal waveform from a breathing simulator with simulated RMV of 62,5 l min^{-1}. The air exhaled by the breathing simulator shall be heated and humidified. The air temperature shall be (28 $\pm$ 2) °C and the relative humidity greater than 90 % when measured at the mouth (see Table 6). The performance of the apparatus shall be determined using air at an ambient pressure of 6 bar.

The breathing system shall meet the following requirements related to an RMV (BTPS; body temperature at pressure saturated) of 62,5 l min^{-1}:

a) the work of breathing (WOB) shall not exceed a value of:

$$WOB = 0,5 + 0,03 \times RMV \qquad [J \times l^{-1}] \qquad (3)$$

b) inspired and expired respiratory pressures shall be determined as shown in Figure 1. The inspired and expired respiratory pressures shall not exceed 25 mbar each;

c) the positive work of breathing during inhalation shall not exceed 0,3 $J \times l^{-1}$;

d) pressure spikes with no measurable positive work of breathing shall not exceed 25 mbar;

e) pressure peaks with measurable positive work of breathing shall not exceed 5 mbar.

Testing shall be done in accordance with 6.10.3.

5.7.2 Facepiece gas supply non-return device

The facepiece shall be designed in such a way that in the event of a diver's umbilical being severed or a failure of the gas supply it shall prevent loss of breathing gas from the facepiece through the gas supply system.

Testing shall be done in accordance with 6.5.5.

5.7.3 Exhaust device

The apparatus shall have an exhaust device, operated automatically by excess gas in the facepiece.

Any bubbles emerging shall not impede the diver's vision when swimming or in vertical position, i.e. with diver pitch from 0° to 90° (diver roll 0°) (see Figures 4 and 5).

Where a neckdam is connected, the exhaust device shall prevent the pressure in the facepiece exceeding 40 mbar.

Where a neckdam is not present, the exhaust device shall prevent the pressure in the facepiece exceeding 80 mbar.

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

The operation of the exhaust device shall not be degraded after being subjected to a constant flow of 300 l min^{-1} (ATP) for a period of 1 min.

Testing shall be done in accordance with 6.2, 6.5.6 and 6.13.

5.7.4 Maximum inspired partial pressure of carbon dioxide

For all ventilation rates as given in Table 6, the volume-weighted average inspired partial pressure of carbon dioxide shall not exceed 20 mbar.

Testing shall be done in accordance with 6.5.4.

5.7.5 Hydrostatic imbalance

The design of the given apparatus will indicate if testing is necessary. It is not automatically mandatory for all designs.

If applicable, 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 pitch and roll angles are defined in Figures 4 and 5, respectively.

Testing shall be done in accordance with 6.5.7.

Table 1 — Hydrostatic imbalance

Pitch degrees (Roll at 0°)	**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°)		
+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

5.8 Surface control system

5.8.1 General

The system, or the components of the system, shall be water resistant.

The system shall have strain relief securing points for hoses and umbilicals. If portable, it shall also have securing points to prevent the assembly being pulled overboard or dropped while in use.

The system shall have venting connector caps for protecting inlets and outlets that are not in use.

All inlets and outlets shall be clearly marked with details of their intended use.

Testing shall be done in accordance with 6.2, 6.5.1 and 6.13.

5.8.2 Gas supply

The gas supply shall be designed in such a way that in the event of a diver's umbilical being cut or severed it does not deprive any other diver or stand by diver of their gas supply.

The control system shall, for each diver, have an independent gas supply system including inlet supply pressure indicator, diver supply pressure indicator and if fitted, a diver depth indicator.

The control system shall have, as a minimum, two supply inlets. In the event of a supply failure a back up supply shall be immediately available for selection. If the control system also supplies gases with an oxygen content greater than air as specified in EN 12021 then to prevent cross contamination these gases shall have separate inlets and reducers and where necessary be fitted with non-return valves.

Inlet connections for a gas with an oxygen content greater than air as specified in EN 12021 shall be different and not interchangeable with those used for air or other gases with an oxygen content equal to or less than air.

Testing shall be done in accordance with 6.2, 6.5.1 and 6.13.

5.8.3 Gas monitoring

Apparatus that supplies breathing mixtures other than air shall have oxygen content monitoring for each diver outlet downstream of any regulator or control system.

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

Table 2 — Limit deviation of oxygen percent display

Oxygen %	Limit deviation %
0 to 40	± 1,0
> 40 to 100	± 2,0

Testing shall be done in accordance with 6.2, 6.6.4 and 6.13.

5.9 Safety devices

5.9.1 General

All safety devices that give a visual indication 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 6.13.

5.9.2 Pressure indicator

Each gas supply shall be fitted with a pressure indicating system. The apparatus shall be designed and fitted so as to enable the diver, or surface control system operator to take readings without difficulty.

Any flexible hose(s) connecting the pressure indicator(s) shall 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 20 % in excess of the rated working pressure of the gas supply system.

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 with an intended maximum indicating pressure of less than 50 bar shall have an accuracy better than ± 2 % of full scale.

Any submersible pressure indicator shall be waterproof to at least twice the intended maximum diving depth specified by the manufacturer for at least 15 min.

The pressure indicator shall be provided with a blow out release which protects the wearer against injuries.

The gauge window shall be made of a material being non-splintering when breaking. 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.

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, 6.6.1 and 6.13.

5.9.3 Depth indicator (if fitted)

The gauge factor for the transformation from pressure to depth shall be such that an increase in pressure of 1 bar would cause an increase in the depth displayed of 10 m.

NOTE This rule assumes a water density of 1,0197 kg l^{-1}.

If fitted each depth monitor shall have a display in increments of 1 m or less with an accuracy of ± 0,5 m at depths from 0 to 50 m and ± 1,0 m at depths greater than 50 m.

Testing shall be done in accordance with 6.2, 6.6.2 and 6.13.

5.10 Facepiece

5.10.1 General

The facepiece shall be either a full face mask or a helmet. An inner mask may be fitted within the facepiece.

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

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

Testing shall be done in accordance with 6.2 and 6.13.

5.10.2 Helmet

A helmet and any associated neck dam system or integral fitting to a dry suit with a neck connector shall have a double locking system so that the diver cannot inadvertently release it underwater by fouling or other incident. It shall be able to be removed by the diver unaided.

Testing shall be done in accordance with 6.2 and 6.13.

5.10.3 Full face mask harness

The full face mask harness shall be designed so that the full face mask 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 6.13.

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

Buckles and attachment lugs (if fitted) shall withstand the same pull.

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

Testing shall be done in accordance with 6.7.2.

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

Testing shall be done in accordance with 6.2 and 6.13.

5.10.4 Breathing system connections

Connections between a full face mask or a helmet and the system may be achieved by permanent or special type connections. If a thread connection is used then it shall not be possible to interchange with threads specified in EN 148 (all parts). All connections between the facepiece and the system shall be sufficiently robust to withstand a tensile force of 300 N in the foreseeable direction of stress.

The connection between the facepiece and the suit, where the facepiece is integrated in the suit, shall be sufficiently robust to withstand a tensile force of 800 N in the foreseeable direction of stress.

Testing shall be done in accordance with 6.2 and 6.7.1.

5.10.5 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, 6.7.3 and 6.13.

Visors shall not distort vision in air and under water.

Testing shall be done in accordance with 6.13.

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 6.7.7.

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

Testing shall be done in accordance with 6.13.

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 and 6.13.

5.10.6 Head protection against impact

The head protection given by the facepiece system shall be classified as either:

— Class A; 'Head protection' or

— Class B; 'Bump protection' or

— Class C; 'No protection'.

Class A facepiece systems shall be of sufficient rigidity to act as a head protector in respect of shock absorption and impact resistance according to EN 397.

Testing shall be done in accordance with 6.2 and 6.7.4.2.

Class B facepiece systems shall be of sufficient rigidity to act as a head protector in respect of shock absorption and impact resistance according to EN 812.

Testing shall be done in accordance with 6.2 and 6.7.4.3.

Class C facepiece systems shall be clearly marked with a warning that no head protection can be assumed when worn.

Testing shall be done in accordance with 6.2.

5.11 Harnesses

5.11.1 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.

The body harness shall provide a method to securely attach the umbilical to the diver. Each securing point on the body harness shall withstand a tensile load of 3 500 N for 5 min.

Testing shall be done in accordance with 6.2, 6.4.7 and 6.13.

5.11.2 Lifting harness

The apparatus may include a lifting harness for lifting an unconscious diver from the water. The lifting harness may be the body harness or a separate system, in any event it shall be possible to easily remove the diving apparatus and auxiliary supply without removal of the lifting harness.

If fitted the lifting harness shall provide lifting points on both the front and the back of the diver. Each lifting harness as a whole including adjustment systems, buckles, etc. shall withstand a tensile force of 9 000 N.

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

5.12 Auxiliary gas supply system (bail out)

The apparatus shall allow an auxiliary gas supply system (bail out) to be used. The diver shall be able to switch to and breathe from the auxiliary gas supply system (bail out) within 10 s.

Testing shall be done in accordance with all relevant tests in Clause 6, and at least 6.2 and 6.13.

If an auxiliary gas supply system (bail out) system is used with the apparatus it shall fulfil the requirements of the appropriate standard.

Testing shall be done in accordance with the relevant standard.

5.13 Resistance of the apparatus to temperature

5.13.1 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 6.10.2.

5.13.2 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 6.10.1.

5.14 Connectors

Components of the whole system shall be easily disassembled for cleaning, testing and examining after conditioning in accordance with 6.9. 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, 6.9 and 6.13.

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.

NOTE It is recommended to ensure the complete removal of all traces of the detergents which are used during cleaning and disinfecting from respiratory apparatus intended for oxygen/nitrox use (see EN ISO 15001).

Testing shall be done in accordance with 6.2, 6.11 and 6.13.

5.16 Pressure resistance of casings and monitors

If casings and monitors are sealed against ambient pressure they shall be waterproof.

Testing shall be done in accordance with 6.16 after the temperature resistance test in accordance with 6.10.

5.17 Oxygen compatibility

Sub-assemblies that operate at a total pressure above 25 bar and come into 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 6.12.

5.18 Functional safety of electrical systems

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

Testing shall be done in accordance with 6.2.

5.19 Voice communications

5.19.1 General

If fitted, the apparatus shall include surface to diver and diver to surface two way communications. It may also allow diver to diver communications.

The diver communications microphone shall be active and the surface microphone ‘Push to talk’.

NOTE Although the voice communication is not covered by the PPE Directive, it is regarded to be a serious safety issue and therefore, if fitted, requirements for it are included in this European Standard.

Communications shall achieve a Modified Rhyme Test score greater than 75 %.

Testing shall be done in accordance with 6.7.6 and 6.13.

5.19.2 Communication recording

The apparatus may have the facility for all voice communications to be recorded. The system may either be integral to the surface control system or have an ‘audio out’ for an external recording device. If fitted an integral device shall be able to record for a minimum of 4 h.

Testing shall be done in accordance with 6.2.

5.20 Noise

The measured noise levels at the maximum flow rate and a ventilation of 40 l min^{-1} shall be compared to the exposure limit value noise dose of $L_{(ep,d)}$80 dB(A) re 20 μPa or a modified weighting of the sound spectrum taking into consideration the effects of different ambient conditions (gas composition, pressure, water). Using current occupational health time weighted exposures and the principle of 3 dB halving of noise dose the manufacturer shall state the maximum permissible noise exposure time taking into consideration the time the diver will spend at each RMV and flow rate. In stating the maximum permissible noise exposure time, the manufacturer shall give information about appropriate hearing protection for the diver.

All recorded noise levels shall be less than the peak sound pressure level (135 dB(C) re 20 μPa).

Testing shall be done in accordance with 6.7.5.

5.21 Practical performance

The apparatus shall undergo practical performance tests under realistic conditions. These general tests serve the purpose of checking the apparatus for imperfections that cannot be determined by the tests described elsewhere in this European Standard.

If during any activity, by any test subject the test subject fails to finalise the selected activity due to the apparatus being not fit for the purpose for which it has been designed, the apparatus shall be deemed to have failed.

The test house shall provide full details of those parts of the practical performance tests which revealed these imperfections.

Testing shall be done 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, complementary components, as specified by the manufacturer, that comply with this and other relevant standards shall be used.

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

The tests shall be carried out in the sequence according to Table 3.

Table 3 — Testing schedule and sequence

Test sequence	Test clause	Condition
1	6.2	A.R.
2	6.10	From test sequence 1
2	6.12	From test sequence 1
2	6.7.7	From test sequence 1
2	6.14	From test sequence 1
2	6.3	From test sequence 1
3	6.9	From test sequence 2
4	6.11	From test sequence 3
5	6.7.1	From test sequence 4
5	6.4.2	From test sequence 4
5	6.8	From test sequence 4
6	6.7.2	From test sequence 5
6	6.4.3	From test sequence 5
7	6.7.3	From test sequence 4
7	6.4.4	From test sequence 6
8	6.4.7	From test sequence 7
9	6.4.5	From test sequence 8
10	6.5.3, 6.5.4, 6.5.5., 6.5.6, 6.5.7, 6.7.5 6.5.3, 6.5.4 or 6.5.5, resp., 6.5.6, 6.5.7, 6.7.5	From test sequence 9 and 4
10	6.10.3	From test sequence 9 and 4
11	6.6.1	From test sequence 4
11	6.6.2	From test sequence 4
11	6.6.3	From test sequence 4
11	6.6.4	From test sequence 4
11	6.7.4	From test sequence 4
11	6.4.6	From test sequence 10
11	6.15	From test sequence 4
12	6.13	From test sequence 11
13	6.7.6	From test sequence 11
14	6.2	From test sequence 12 and 13

6.1.2 Nominal values and tolerances

Unless otherwise specified, the values shall be subjected to a limit deviation of ± 5 %. Unless otherwise specified, the room temperature for testing shall be (22 ± 5) °C and at a relative humidity of at least 50 %. The temperature limits shall be subject to a limit deviation of ± 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 3. The test orifice shall be inserted into the test rig in place of the breathing system and tested with air at 62,5 l min^{-1} (25 cycles min^{-1}, 2,5 l tidal volume) at 6,0 bar absolute. The values for work of breathing (WOB) and inhalation/exhalation pressures shall be 3,3 J×l^{-1} and ± 25 mbar respectively using air.

The performance of the volume weighted inspired carbon dioxide test equipment shall be defined by the use of a calibration tube. The calibration tube shall be attached to the 'mouth' of the breathing simulator, have an internal diameter of (30,0 ± 0,2 mm) and a length of (150 ± 1 mm). It shall be tested at ambient pressure with air and the breathing simulator at 62,5 l min^{-1} (25 cycles min^{-1}, 2,5 l tidal volume) with a carbon dioxide injection of 2,5 l min^{-1} STPD. A 0,2 m s^{-1} forced ventilation should be provided across the open end of the tube to remove the exhaled carbon dioxide. The value for the volume weighted inspired carbon dioxide shall be (4,2 ± 0,2 mbar).

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.

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

Unless otherwise specified testing shall be carried out with the compressed air which complies with EN 12021.

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 and information supplied by the manufacturer and any safety data sheets (if applicable) or declarations relevant to the materials used in its construction.

6.3 Pressure test 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. The test pressure shall be reached between 5 s and 10 s. There shall be no observed leakage of water.

6.4 Hoses and umbilical assemblies

6.4.1 General

Any high and medium pressure hose or umbilical assemblies shall be subjected to the following tests:

6.4.2 Tensile force of high and medium pressure hose assemblies

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

6.4.3 Flexibility of high and medium pressure hoses

Bend the hose around a cylinder ((65 ± 2,5) mm radius).

6.4.4 Kinking of high and medium pressure hoses

Testing shall be done in accordance with EN 14593-1:2005, 6.11.

6.4.5 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. No bubbles shall be observed.

6.4.6 Umbilical buoyancy

The complete umbilical assembly shall be tested. Seal the ends of the gas supply lines on the umbilical and suspend the whole assembly in water. If negatively buoyant suspend the umbilical from a weighting device and record the force. If positively buoyant the umbilical shall be suspended by being pulled sub-surface and the upthrust recorded.

6.4.7 Umbilical life line

If the life line is part of the umbilical, this assembly shall be submitted to this test. From the securing point at the diver's end to the securing point on the surface the umbilical life line shall be submitted to a tensile load of 3 500 N for 5 min. There shall be no indication of failure, e.g. leakage, hose burst, tearing.

6.5 Breathing system

6.5.1 Configuration

The breathing system for testing purposes shall include all of the following sub assemblies:

— facepiece with exhaust device and the gas supply non-return device;

— if fitted, auxiliary supply (bail out) assemblies;

— umbilical;

— surface control system with regulators, gauges, valves and gas supply;

— voice communication (if fitted);

— if the apparatus is provided with hot or cold water shrouds then they should also be tested.

6.5.2 General test conditions

The system shall be rigged on a vertical mannequin (diver pitch 90°) according to the information supplied by the manufacturer.

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

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

Stabilize the temperature of the water in the test chamber at (4^{0}_{-2}) °C, or lower if specified by the manufacturer.

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

Tests shall be conducted at the minimum and maximum supply pressures stated by the manufacturer, where not stated a supply pressure of 50 bar shall be used for the test up to 62,5 l min^{-1} RMV and at 100 bar, for the peak performance test at 75 l min^{-1} RMV.

Any inlet flow device that incorporates adjustable controls shall be tested with the settings at both minimum and maximum.

Terminating connectors such as quick fit connections can significantly alter the performance of an umbilical supply; the system shall be tested with gas supplied through all appropriate connectors.

Record the performance of the system at test pressures of 6 bar with air or oxygen in nitrogen gas mixture and if required at 6 bar with oxygen in helium based mixtures or a reduced pressure specified by the manufacturer.

6.5.3 Breathing performance

Set the breathing simulator at the ventilation rates in Table 6.

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.

6.5.4 Volume weighted average inspired carbon dioxide

The breathing simulator shall be set to provide an end tidal CO_2 level of (50 ± 2) mbar. A tolerance of ± 10 mbar is permitted, if corrected by calculation. Determine the volume weighted average inspired carbon dioxide under the conditions in accordance with 6.1.3.

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.

6.5.5 Gas supply non-return device

The device shall be subjected to a differential pressure of 10 bar for 10 min. During this period no more than 0,5 l of gas shall emerge.

Thereafter, the device shall be subjected to a differential pressure of 0,01 bar for 10 min. During this period no more than 0,5 l of gas shall emerge.

The apparatus shall still be fully functional after this test.

6.5.6 Exhaust device

The exhaust device shall not leak after being subjected to:

a) a constant flow of 300 l min^{-1} STPD 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 device (when in the wetted condition) shall not exceed 0,25 ml min^{-1} (STP) when tested with a negative pressure of 7 mbar (equivalent to 0,5 mbar pressure loss with a proof volume of 500 ml during 1 min).

6.5.7 Hydrostatic imbalance

Fully rig the breathing system on a rotating manikin as specified in 6.5.2 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^{-1} and the mouth pressure recorded at the end of exhalation (see Figure 1).

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

6.6 Safety devices

6.6.1 Pressure indicator

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

6.6.2 Depth indicator(s)

If fitted any depth indicator shall be subjected to pressures from 1,0 bar to its maximum depth. The depth indicated shall be recorded at 0,3 bar intervals to 1,5 bar and at 0,5 bar intervals thereafter.

6.6.3 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.

6.6.4 Oxygen monitor

Calibrate the monitor in accordance with manufacturer's instructions.

Test the monitor by exposing it to oxygen percentages of 10, 20, 40, 60 and 100 %. The monitor shall read within the limits given in Table 2.

6.7 Facepiece

6.7.1 Mechanical strength of the connections between the facepiece and the connector

Support the facepiece on a dummy head which can be adjusted so that the strength can be applied 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). In case the facepiece is a helmet the test shall be conducted in a similar, appropriate way.

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

Record the force.

6.7.2 Full face mask 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.

6.7.3 Impact resistance of the 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 a full face mask before and after the test, the test shall be carried out on a dummy head with a pressure of -10 mbar created in the cavity of the facepiece. When conducting this test the inhalation port shall be sealed and the exhalation valve disc shall be moistened.

Five visors shall be tested.

The pressure shall be measured by usual test methods using a scale, divided in maximal 0,1 mbar steps.

6.7.4 Head protection

6.7.4.1 Classification

The helmet shall be tested in accordance with its classification.

6.7.4.2 Class A

The following tests within EN 397 shall be successfully completed in accordance with the requirements of the standard:

— shock absorption test following water immersion;

— resistance to penetration test following water immersion.

6.7.4.3 Class B

The following tests within EN 812 shall be successfully completed in accordance with the requirements of the standard:

— shock absorption test following water immersion;

— resistance to penetration test following water immersion.

6.7.5 Noise assessment

The internal noise in the facepiece at the diver's ears shall be measured. The noise shall be measured immersed at the surface and the maximum depth of the apparatus at the maximum and minimum flow rates with simulated RMV up to 75 l min^{-1}.

Measurement of sound exposure level shall be undertaken using a mannequin with a sound-measuring instrument positioned at each of the diver’s ears. Measurements shall be made using a traceable, calibrated sound-measuring instrument such as a hydrophone; the characteristics of the instrument shall not vary with temperature, ambient pressure or humidity (see Figure 11). Measurements shall take account of background laboratory noise levels.

6.7.6 Communications modified rhyme test

The test shall be conducted at a depth greater than 2 m.

The Modified Rhyme Test consists of a set of spoken monosyllabic words of which there are six alternative word ensembles. In the first 25 ensembles, the final consonantal element is varied, and the initial element is constant; in the second 25 ensembles, the reverse is true.

The test lists (25 + 25) shall be generated by random selected from the word ensemble list in Table 5, and spoken in the form of “Word number “x” is .....”. There is a 5 s pause between phrases to allow the listener to make and indicate his response to the phrase on the modified rhyme test response sheet. Phrases should not be repeated.

The test shall be scored by a listener who marks which of the six words in each line was spoken.

A sample test list is shown in informative Annex B.

NOTE Table 5 and the list in Annex B show examples only which fit the English language and cannot be translated directly to other languages without losing the sense. Other countries may use wordings taken from their language, as long as the principle of this test is followed.

The test list is then compared to the scored list and the % intelligibility is calculated:

Intelligibility (%) = 2 · (Number of correct responses - ((Number of attempted responses – number of correct responses) / 5)

Only test subjects who can achieve a score of 95 % or greater without breathing apparatus, when sitting facing each other (2 m separation) in a quiet surface environment shall be used.

Six divers shall complete the test in water both reading and listening to the modified rhyme test. The test may be conducted with one or more surface operators for the surface reading and listening, the surface operator(s) may be selected from the divers. Where appropriate the test should also include a test of diver to diver communication.

Each of the following means should exceed 75 %:

— Mean of the six surface to diver listening scores;

— Mean of the six diver to surface listening scores;

— If applicable the mean of the six diver to diver listening scores.

6.7.7 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).

6.8 Lifting harness

Test three samples; fix the harness to a dummy according to the information supplied by the manufacturer; each securing point on the safety harness shall be submitted to a tensile force of 9 000 N for 5 min in the direction of lift. There shall be no tearing or indication of failure.

6.9 Sea water resistance

The complete apparatus with the gas supply in the 'on' position shall be submerged for 8 h ± 5 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 h ± 30 min at 15 °C to 25 °C and a relative humidity of not more than 75 %. Apply four complete cycles.

6.10 Resistance to temperature

6.10.1 Testing at – 20 °C and 50 °C

Place the fully assembled apparatus, with pressure vessel valves closed and pressure vessels (if fitted) charged to 50 % of the rated working pressure in an environmental chamber and cool to –20 °C for a period not less than 3 h.

Open and set the gas supply system, ensuring the apparatus is still at –20 °C.

Let the system stabilize for 10 min and shut off the gas supply. There shall be no observed pressure drop during 1 min.

Repeat the same test at 50 °C.

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

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

Switch on the gas supply system.

The performance of the apparatus shall remain within the limits specified in 5.7.1.1 and 5.7.1.2.

6.10.3 Cold water testing

The breathing performance shall be measured using a sinusoidal waveform from a breathing simulator with simulated RMV of 62,5 l min^{-1}. The air exhaled by the breathing simulator shall be heated and humidified. The air temperature shall be (28 ± 2) °C and the relative humidity greater than 90 % when measured in the mouth opening (see Table 6). The performance of the apparatus shall be determined using air at the maximum flow rate and at an ambient pressure of 6 bar.

The apparatus shall be tested for a period of not less than 5 min at maximum supply pressure during which time the breathing performance shall remain within the limits specified in 5.7.1.3.

The apparatus shall be immersed in the cold water for a period of 10 min prior to starting the test. The surface unit and the necessary amount of gas as well as the umbilical shall be kept at a temperature of -20 °C for at least 3 h.

6.11 Cleaning and disinfection

Use the disinfectant and procedure recommended by the manufacturer. Perform the test 30 times. If no other temperatures are indicated, the temperature of the disinfectant solution shall be 40 °C.

6.12 Oxygen pressure surge test

For all types of sub-assemblies the pressure surge test shall be carried out with pure oxygen at 1,2 times the rated working pressure of the device.

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 tube, is replaced by a reliable pressure monitor.

The maximum pressure at the dead end of the copper (or any other compatible material, e.g. stainless steel, monel) tube (measured by pressure monitor and recorded on an oscilloscope) shall be achieved between 15 ms and 20 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 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 9, 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 ≤ 10 ml 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 tube having an internal diameter of 5 mm and a length of 1 m.

— Two test sequences shall be carried out in accordance with Table 4.

Table 4 — 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 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.

NOTE Test personnel should be aware of the combustion and explosion hazards in conducting this test.

6.13 Practical performance

6.13.1 General

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

The test shall be conducted in front of a test panel of not less than two people competent in the use and assessment of the surface supplied diving apparatus.

6.13.2 Test subjects

The apparatus shall be tested by six 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 requirement for a medical examination immediately before tests and medical supervision during the tests shall be decided by the testing authority.

6.13.3 Basic testing

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

During the test the apparatus shall be subjectively assessed by the surface system operator and the wearer.

The surface system operator’s comments for the following points shall be recorded after the test:

a) security of fastenings and couplings;

b) accessibility and where applicable visibility of controls, pressure indicators and oxygen monitors;

c) where there is an adjustable valve the operator shall assess the performance of the valve over the full range of adjustment;

d) any other comments reported by the operator on request.

The wearer's comments for the following points shall be recorded after the test:

e) harness comfort;

f) security of fastenings and couplings, including the harness;

g) accessibility and where applicable visibility of controls and pressure indicators;

h) clarity and field of vision of the visor of the facepiece;

i) where there is an adjustable valve the diver shall assess the performance of the apparatus over the full range of adjustment;

j) facepiece comfort and security of gas supply (where applicable, this to include simulated failure of a facepiece retaining strap);

k) any other comments reported by the wearer on request;

l) evidence that the apparatus has not any sharp edges or protrusions that can injure the diver;

m) function of the apparatus out of water.

6.13.4 Functional testing when diving

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

During the test the apparatus shall be subjectively assessed by the surface system operator and the wearer.

The wearer's comments for the following points shall be recorded after the test:

a) donning and doffing of the apparatus as well as adjustment of all straps of the apparatus without help on land;

b) set up and use of all the surface control systems;

c) two dives to be conducted by each diver of which at least one dive to be completed at the maximum depth for each relevant gas mixture under controlled conditions;

d) checking of oxygen monitors and pressure indicators;

e) modified rhyme test;

f) where there is an adjustable valve, the apparatus performance over the full range of adjustment shall be verified;

g) changing to and from bail out (if fitted);

h) checking the means to expel water from the facepiece;

i) checking that pre-set indicators cannot be accidentally altered or reset;

j) checking that bubbles emerging do not impede the diver's vision;

k) checking that helmet cannot be released inadvertently.

6.13.5 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.

6.14 Pressure vessel valve

At an ambient pressure of 6 bar a sinusoidal minute volume of 62,5 l min^{-1} (25 cycles min^{-1}, 2,5 l $stroke^{-1}$) is extracted whilst the cylinder pressure is maintained at 50 bar. Pressure vessel valves fitted with reserve valves should be tested with the reserve valve in the fully open position. The test shall be conducted using air or nitrox.

6.15 Casings and monitors

The casings and monitors shall be immersed in water and pressurized to 1,3 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.

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 shall be marked on all components listed under minimum equipment (Clause 4), including optional items.

7.4 Where the reliable performance of components may be affected by ageing 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 (e.g. fittings, threads) 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 Helmets and – if applicable – full face masks shall be marked with Class of head protection (see 5.10.6).

7.8 If a facepiece is approved for use with hearing protection, this fact shall be marked on the apparatus.

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 equipment certification;
- gas mixtures to be employed and maximum depth for each mixture;
- limitations on use;
- assembly:
  - subassemblies;
  - components;
  - connections;
  - safety devices;
  - interface requirements;
- assessment of risk:
  - water temperature conditions;
  - environmental temperature conditions;
  - mass of apparatus;
  - work rates;
  - visibility;
  - use of high oxygen content gases (regarding e.g. compressed gases, suit inflation systems, buoyancy compensator devices, any kind of ignition source);

- noise exposure and appropriate hearing protection for the diver, if applicable;
- classification of head protection;

— apparatus checks:

- prior to use, including the verification of the correct working of the facepiece non-return device;
- post dive;

— donning and fitting of the apparatus on the diver;

— use;

— maintenance (preferably separately printed instructions);

- cleaning and disinfection;
- use of oxygen cleaning procedures;

— storage:

- conditions;
- shelf lives (where applicable);
- precautions;

— inspection intervals.

8.4 The instructions shall include information on:

— purity and tolerances of gases to be used;

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

— the fact, that suit inflation systems shall only use air or oxygen in nitrogen gas mixtures where the oxygen content is less than or equal to that in air as specified in EN 12021;

— the integration and performance of voice communication, if fitted;

— the apparatus configuration(s) that have been tested (e.g. number of users at the same time, length of umbilical(s), accessories, etc.).

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

8.6 Any other information the supplier may wish to provide.

Table 5 — Modified Rhyme Test sheet illustrating word ensembles

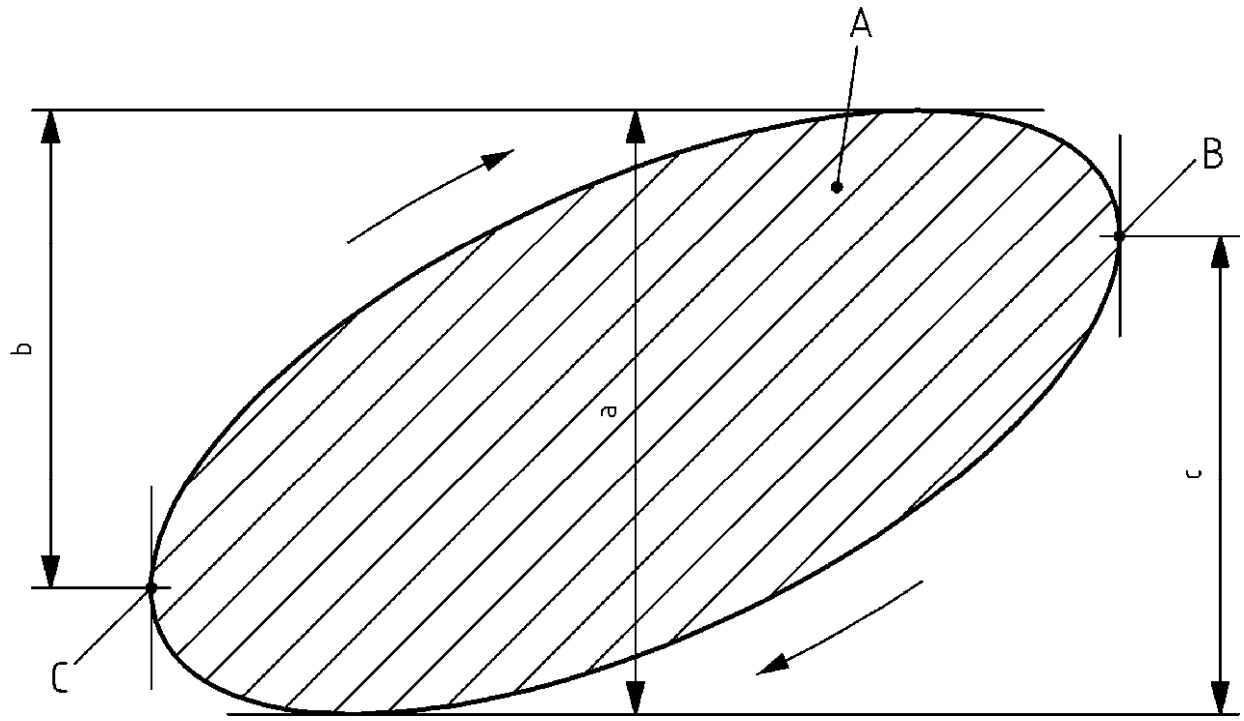
	1	2	3	4	5	6
1	BAT	BAD	BACK	BASS	BAN	BATH
2	BEAN	BEACH	BEAT	BEAM	BEAD	BEAK
3	BUN	BUS	BUT	BUFF	BUCK	BUG
4	CAME	CAPE	CANE	CAKE	CAVE	CASE
5	CUT	CUB	CUFF	CUP	CUD	CUSS
6	DIG	DIP	DID	DIM	DILL	DIN
7	DUCK	DUD	DUNG	DUB	DUG	DUN
8	FILL	FIG	FIN	FIZZ	FIB	FIT
9	HEAR	HEATH	HEAL	HEAVE	HEAT	HEAP
10	KICK	KING	KID	KIT	KIN	KILL
11	LATE	LAKE	LAY	LACE	LANE	LAME
12	MAP	MAT	MATH	MAN	MASS	MAD
13	PAGE	PANE	PACE	PAY	PALE	PAVE
14	PASS	PAT	PACK	PAD	PATH	PAN
15	PEACE	PEAS	PEAK	PEAL	PEAT	PEACH
16	PILL	PICK	PIP	PIG	PIN	PIT
17	PUN	PUFF	PUP	PUCK	PUS	PUB
18	RAVE	RAKE	RACE	RATE	RAZE	RAY
19	SAKE	SALE	SAVE	SANE	SAFE	SAME
20	SAD	SASS	SAG	SACK	SAP	SAT
21	SEEP	SEEN	SEETHE	SEED	SEEM	SEEK
22	SING	SIT	SIN	SIP	SICK	SILL
23	SUD	SUM	SUB	SUN	SUP	SUNG
24	TAB	TAN	TAM	TANG	TACK	TAP
25	TEACH	TEAR	TEASE	TEAL	TEAM	TEAK

Table 5 (*concluded*)

	1	2	3	4	5	6
26	LED	SHED	RED	BED	FED	WED
27	SOLD	TOLD	HOLD	FOLD	GOLD	COLD
28	DIG	WIG	BIG	RIG	PIG	FIG
29	KICK	LICK	SICK	PICK	WICK	TICK
30	BOOK	TOOK	SHOOK	COOK	HOOK	LOOK
31	HARK	DARK	MARK	LARK	PARK	BARK
32	GALE	MALE	TALE	BALE	SALE	PALE
33	PEEL	REEL	FEEL	HEEL	KEEL	EEL
34	WILL	HILL	KILL	TILL	FILL	BILL
35	FOIL	COIL	BOIL	OIL	TOIL	SOIL
36	FAME	SAME	CAME	NAME	TAME	GAME
37	TEN	PEN	DEN	HEN	THEN	MEN
38	PIN	SIN	TIN	WIN	DIN	FIN
39	SUN	NUN	GUN	FUN	BUN	RUN
40	RANG	FANG	GANG	BANG	SANG	HANG
41	TENT	BENT	WENT	DENT	RENT	SENT
42	SIP	RIP	TIP	DIP	HIP	LIP
43	TOP	HOP	POP	COP	MOP	SHOP
44	MEAT	FEAT	HEAT	SEAT	BEAT	NEAT
45	KIT	BIT	FIT	SIT	WIT	HIT
46	HOT	GOT	NOT	POT	LOT	TOT
47	NEST	VEST	WEST	TEST	BEST	REST
48	BUST	JUST	RUST	MUST	GUST	DUST
49	RAW	PAW	LAW	JAW	THAW	SAW
50	WAY	MAY	SAY	GAY	DAY	PAY

Table 6 — Breathing simulator settings

Tidal volume **at ATP** l	**Breathing frequency** min^{-1}	**Ventilation rate** **at ATP** l min^{-1}	**Approximate carbon dioxide injection rate** **at STPD** l min^{-1}
1,0	10	10,0	0,40
1,5	15	22,5	0,90
2,0	20	40,0	1,60
2,5	25	62,5	2,50
3,0	25	75,0	3,00



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)

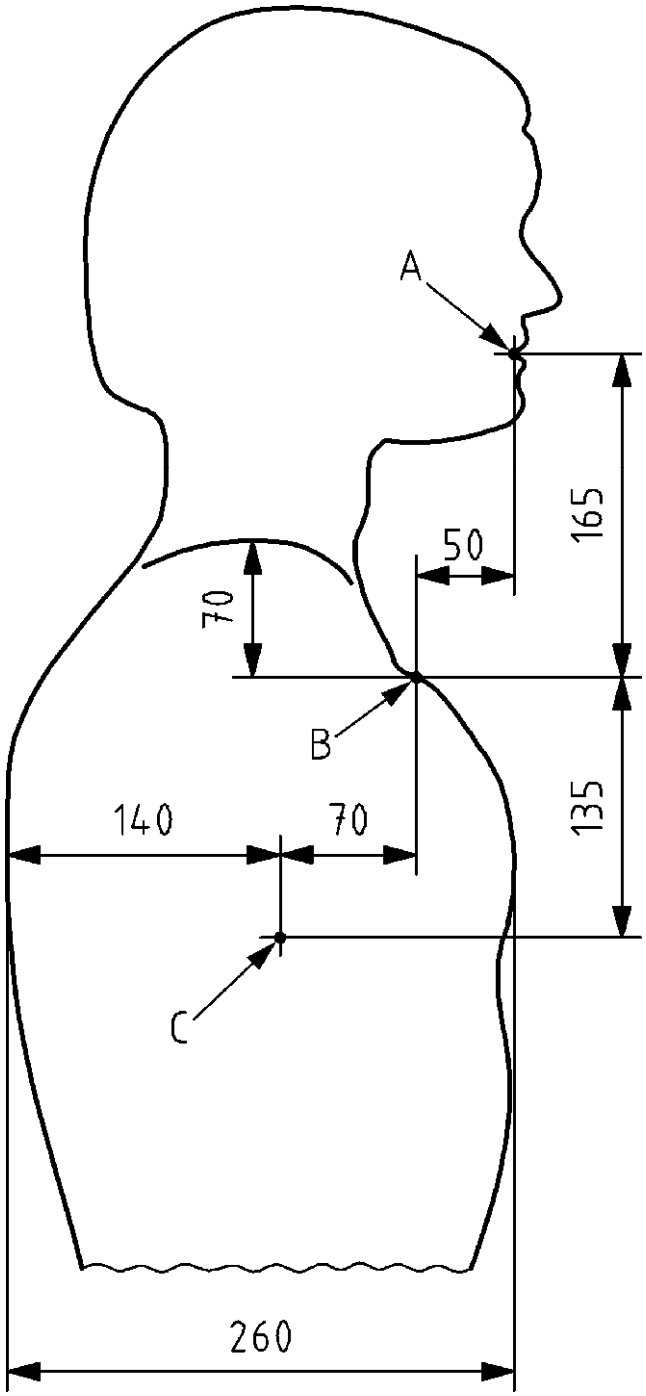
A work Of Breathing (WOB)

B end exhalation no flow point

C end inhalation no flow point

Figure 1 — Analysis of pressure volume loops

Dimensions in millimetres



Key

A) mouth

B) suprasternal notch

C) lung centroid

Figure 2 — Reference points

Dimensions in millimetres

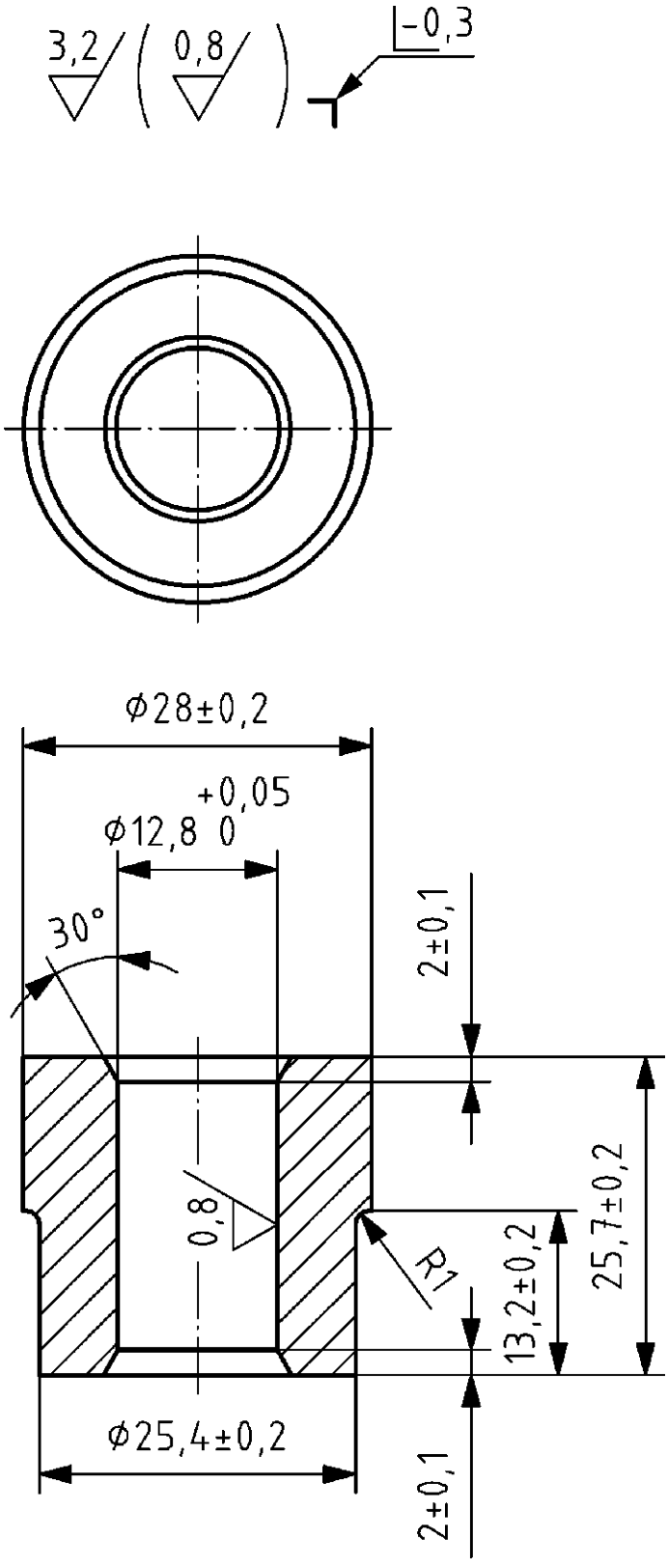
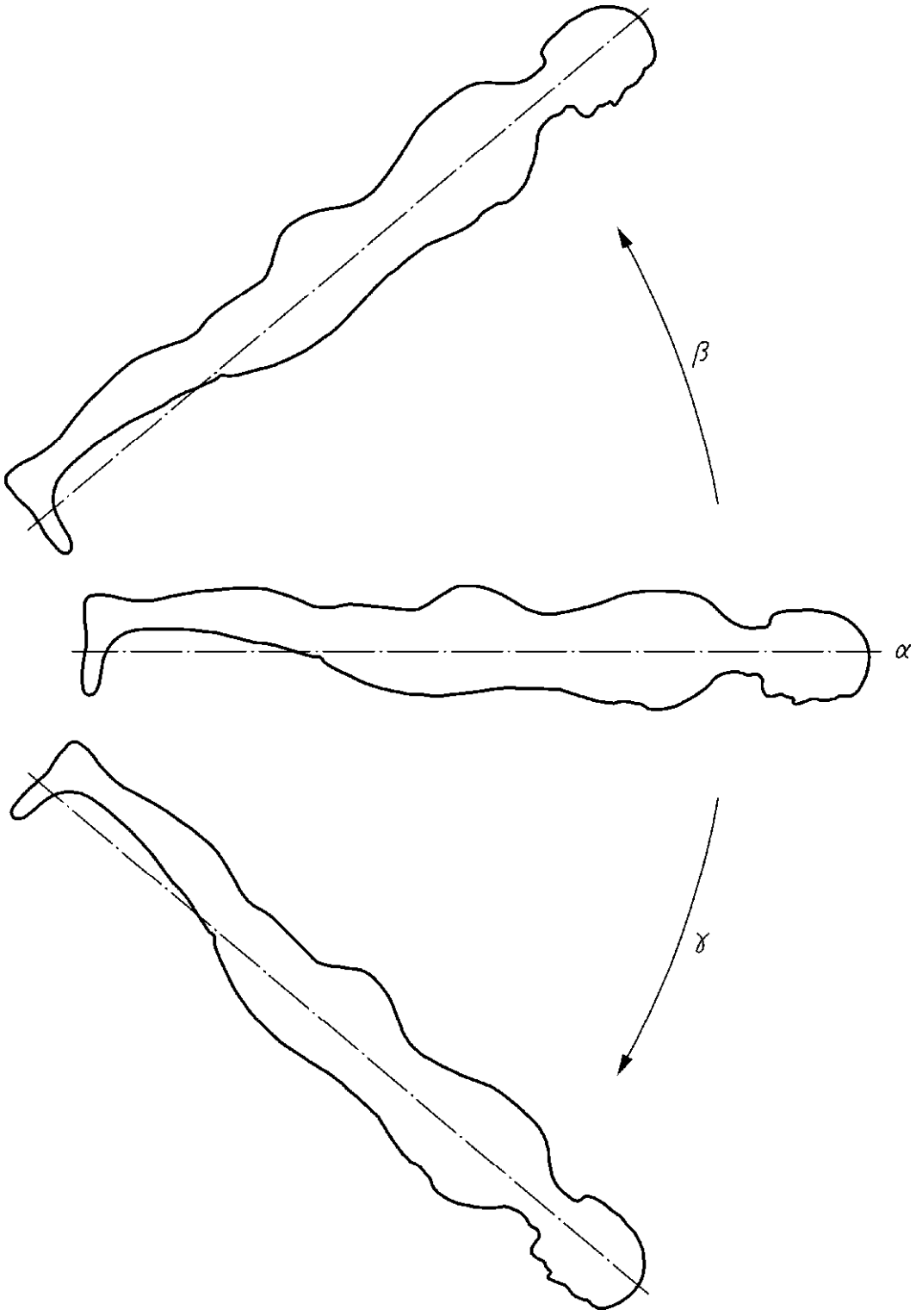


Figure 3 — Calibration orifice



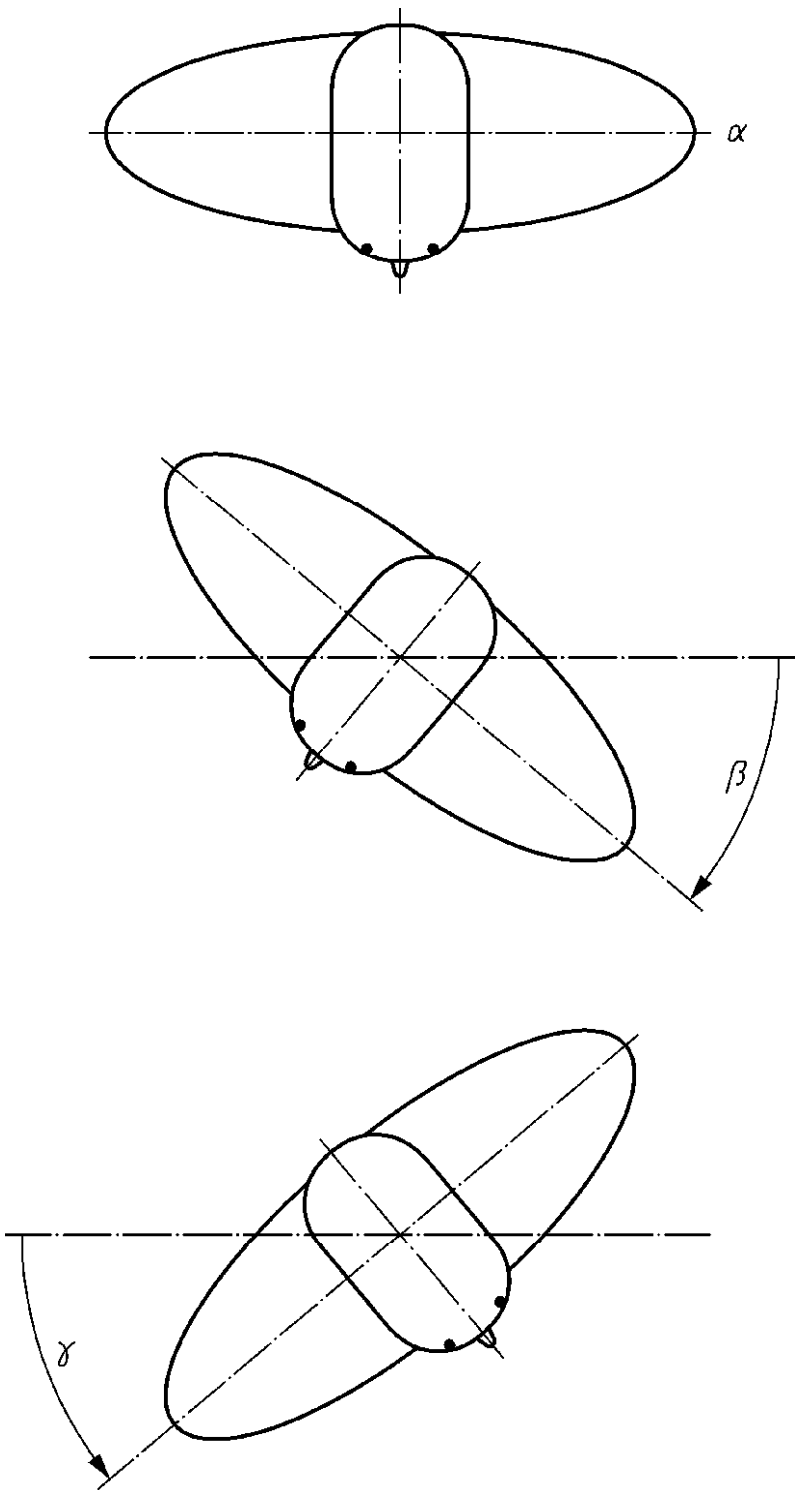
Key

α) horizontal face down – roll 0°

β) positive pitch (+ degrees)

γ) negative pitch (- degrees)

Figure 4 — Diver pitch



Key

α) horizontal face down – roll 0°

β) positive pitch (+ degrees)

γ) negative pitch (- degrees)

Figure 5 — Diver roll

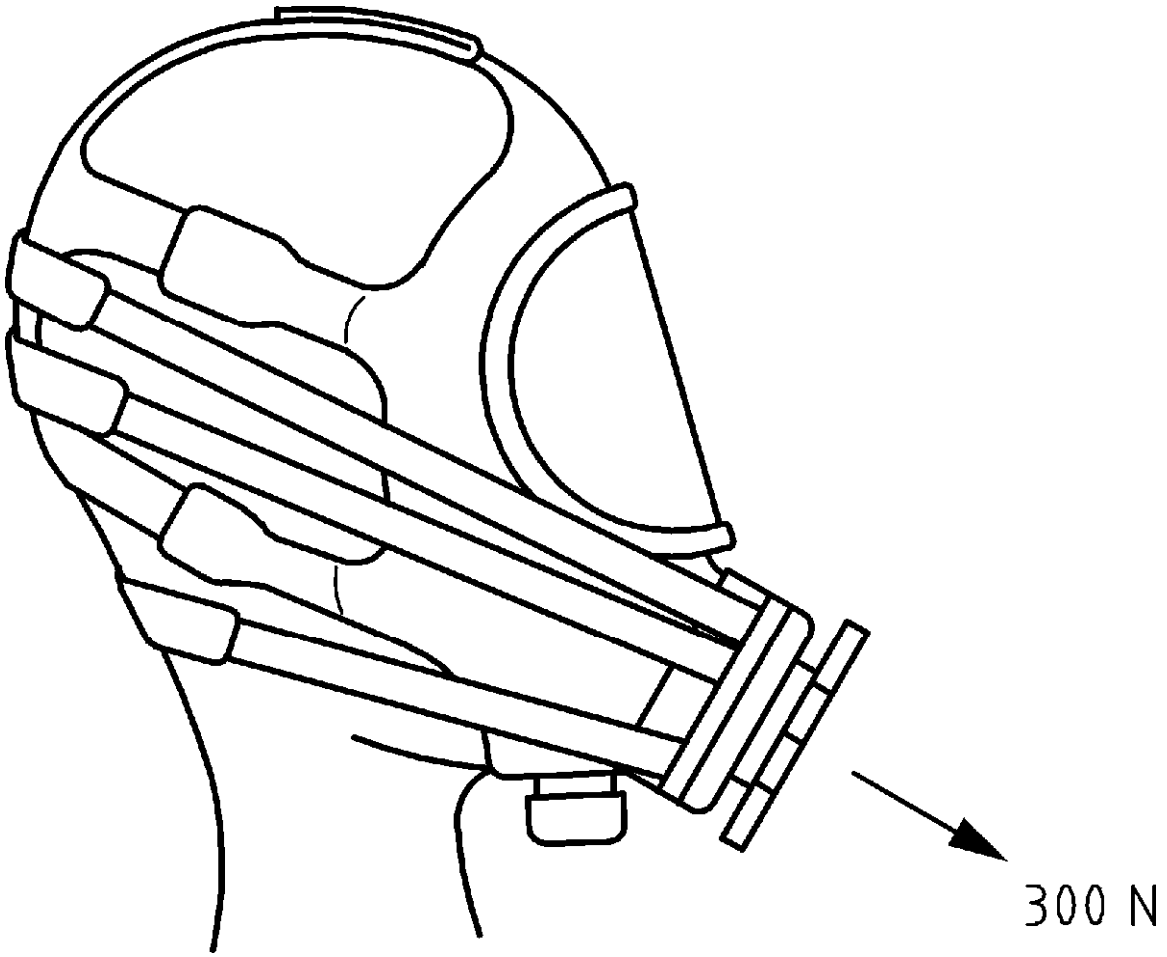
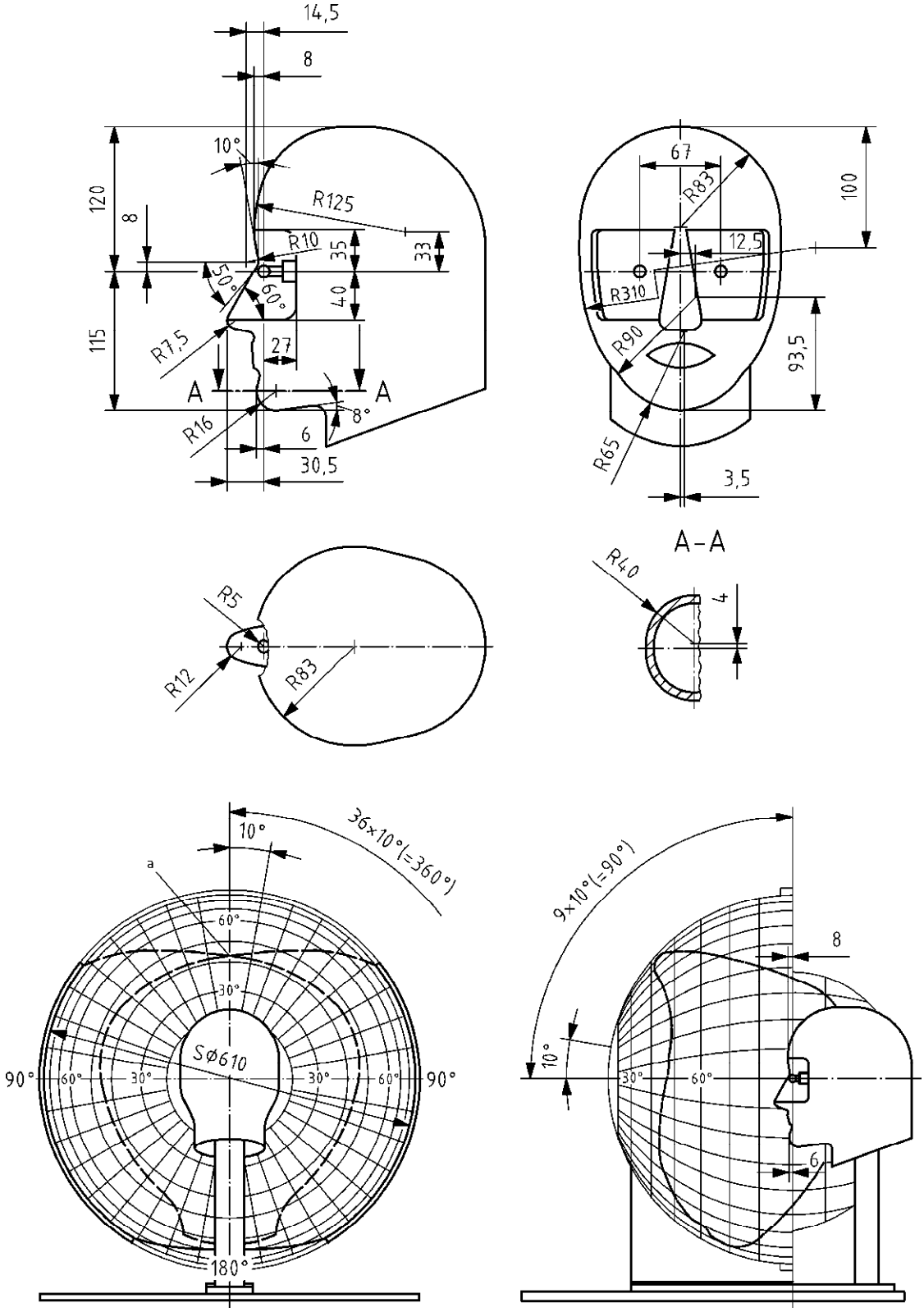


Figure 6 — Typical test arrangement for tensile force

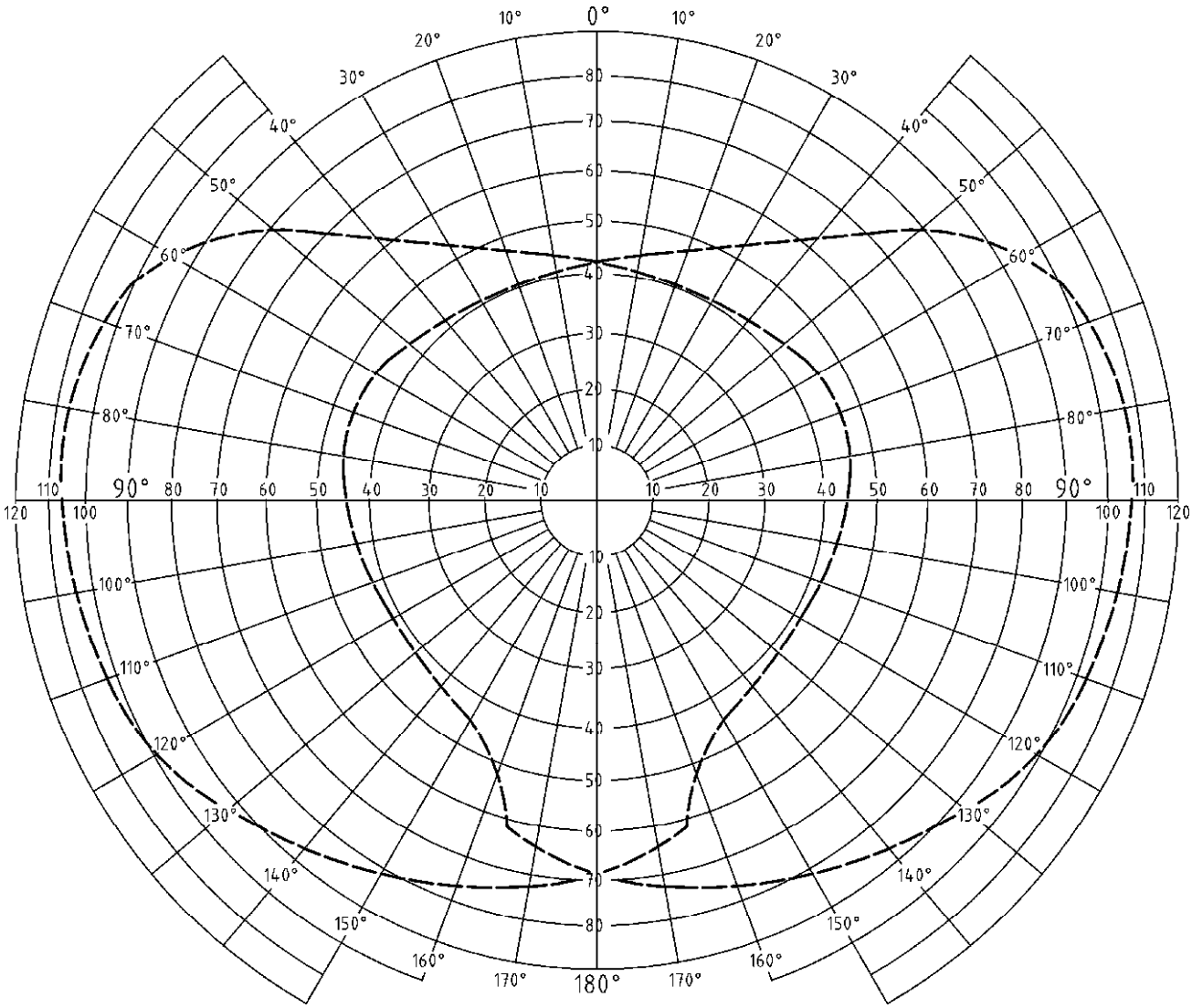
Dimensions in millimetres



Key

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

Figure 7 — Stoll Apertometer



Key

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

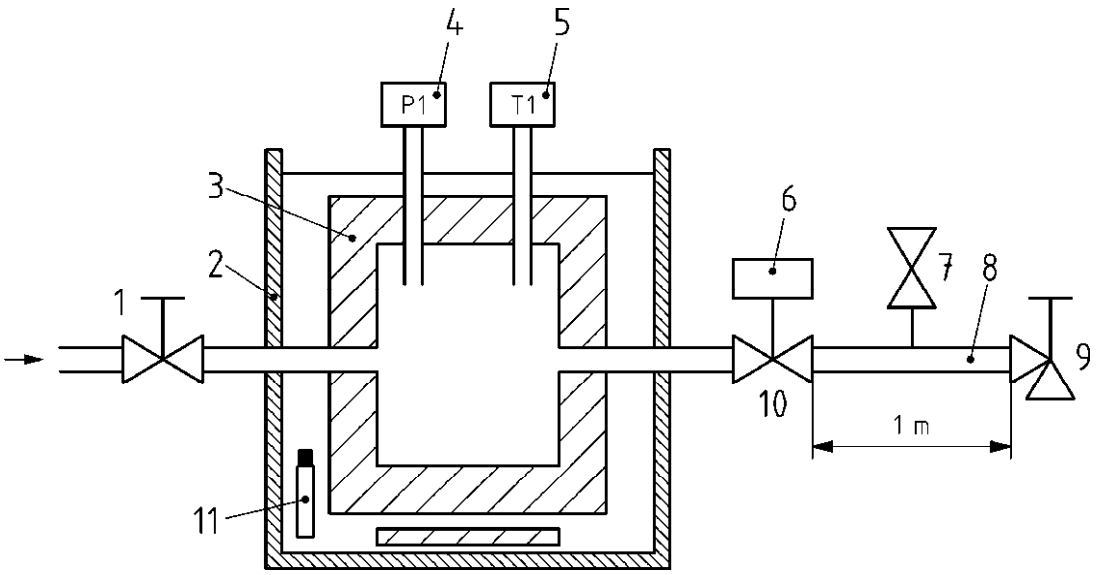
The area enclosed by circular lines of the diagram are proportional to the corresponding areas marked on the spherical shell of the apertometer.

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.....%

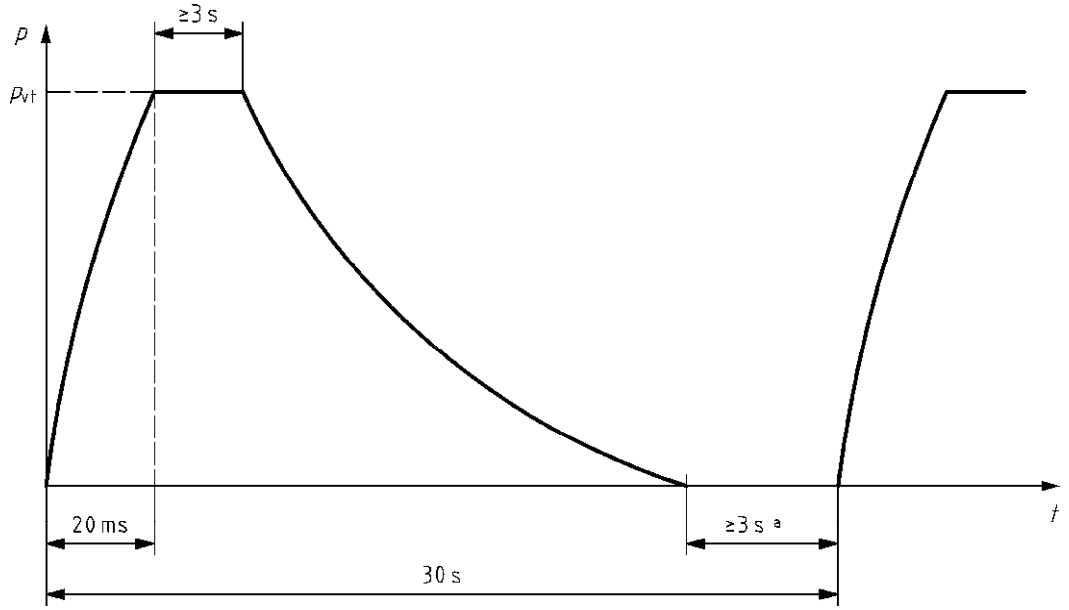
Figure 8 — Apertometer diagram (not to scale)



Key

1 inlet valve
2 pre-heating device (e.g. water bath with electric heating)
3 oxygen vessel
4 pressure monitor
5 temperature monitor
6 actuator
7 depressurisation valve
8 tube
9 sample device
10 quick opening valve
11 thermostat

Figure 9 — Example of an ignition test installation



Key

a) pause

Figure 10 — Pressure cycle specification

Dimensions in millimetres

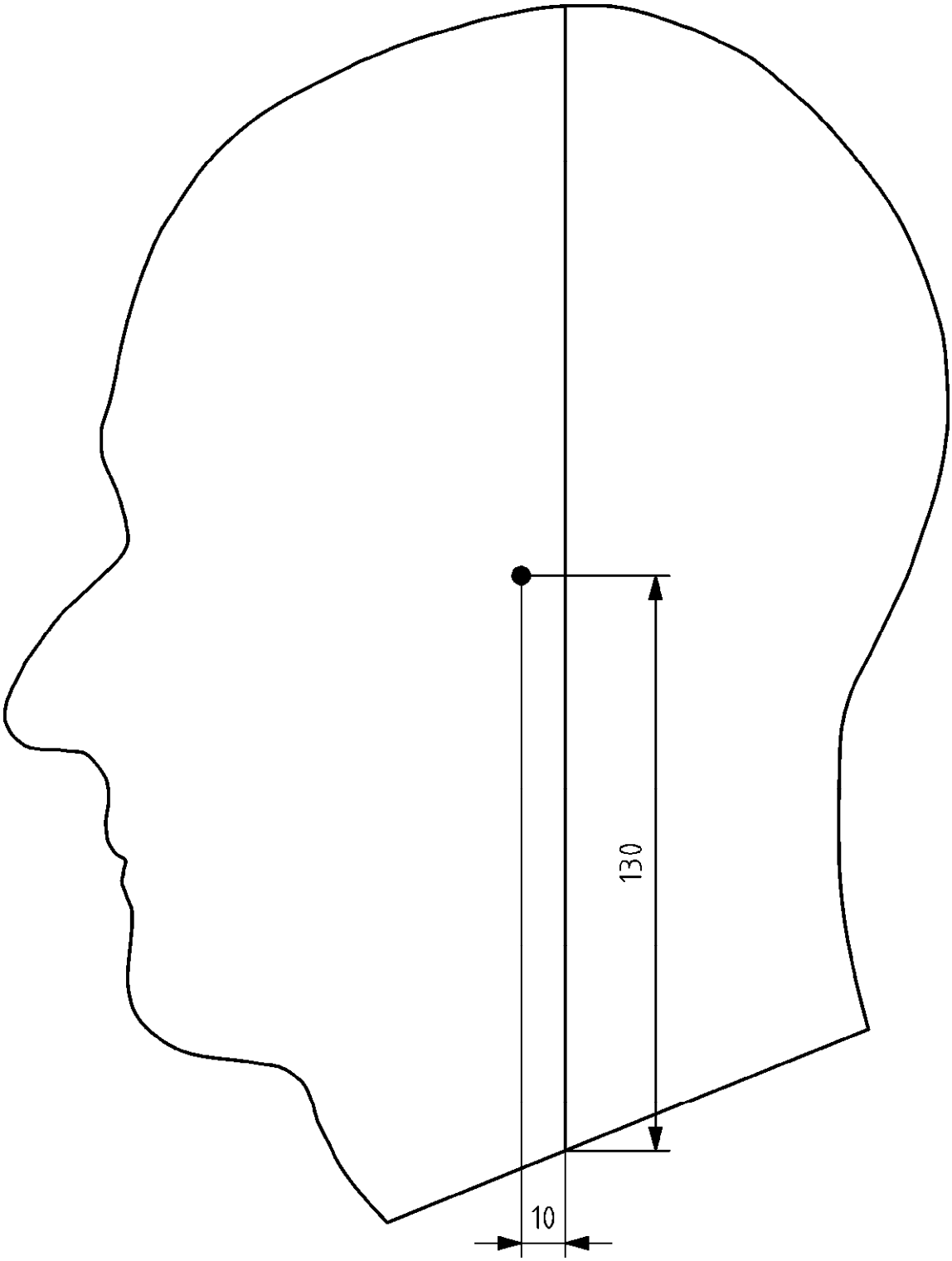


Figure 11 — Microphone positions

Annex A
(informative)

Artificial sea water

28,0 g NaCl

5,0 g $MgCl_2 \times 6\ H_2O$

2,4 g $CaCl_2 \times 6\ H_2O$

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

7,0 g $MgSO_4$ and 0,2 g $NaHCO_3$

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 $7 \leq pH \leq 8$ by adding NaOH-solution.

Annex B
(informative)

A typical Modified Rhyme Test word list

The word	1	is	BATH		The word	26	is	BED
The word	2	is	BEACH		The word	27	is	SOLD
The word	3	is	BUT		The word	28	is	WIG
The word	4	is	CANE		The word	29	is	KICK
The word	5	is	CUP		The word	30	is	TOOK
The word	6	is	DIG		The word	31	is	PARK
The word	7	is	DUCK		The word	32	is	GALE
The word	8	is	FIZZ		The word	33	is	EEL
The word	9	is	HEAT		The word	34	is	BILL
The word	10	is	KILL		The word	35	is	COIL
The word	11	is	LAME		The word	36	is	SAME
The word	12	is	MAT		The word	37	is	MEN
The word	13	is	PACE		The word	38	is	PIN
The word	14	is	PAD		The word	39	is	RUN
The word	15	is	PEAS		The word	40	is	RANG
The word	16	is	PIP		The word	41	is	TENT
The word	17	is	PUCK		The word	42	is	RIP
The word	18	is	RACE		The word	43	is	POP
The word	19	is	SALE		The word	44	is	FEAT
The word	20	is	SASS		The word	45	is	BIT
The word	21	is	SEEM		The word	46	is	LOT
The word	22	is	SIN		The word	47	is	REST
The word	23	is	SUNG		The word	48	is	GUST
The word	24	is	TAB		The word	49	is	THAW
The word	25	is	TEAM		The word	50	is	SAY

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 89/686/EEC (PPE)

This European Standard has been prepared under a mandate given to CEN/CENELEC by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 89/686/EEC on the Approximation of the laws of the Member States relating to Personal Protective Equipment.

Once this European Standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this European Standard given in Table ZA confers, within the limits of the scope of this European Standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA — Correspondence between this European Standard and Directive 89/686/EEC

Clauses of this standard	EU Directive 89/686/EEC, Annex II:
5.11.1, 5.21	1.1.1
5.21	1.1.2.1
5.1.1, 5.1.3, 5.1.5, 5.1.6, 5.1.8, 5.1.9, 5.1.10, 5.2.2, 5.4.2, 5.4.3, 5.4.4, 5.4.5, 5.5.1, 5.5.3, 5.6.4, 5.6.5, 5.6.7, 5.6.9, 5.7.2, 5.7.3, 5.10.1, 5.10.2, 5.10.4, 5.11.1, 5.11.2, 5.12, 5.13.2, 5.16, 5.17, 5.18, 5.20	1.2.1
5.2.3	1.2.1.1
5.1.4, 5.21	1.2.1.2
5.21	1.2.1.3
5.10.3, 5.11.1, 5.21	1.3.1.
5.1.2, 5.1.11, 5.2.1, 5.2.4, 5.5.1, 5.5.3, 5.6.2, 5.6.3, 5.6.6, 5.6.7, 5.6.8, 5.6.9, 5.10.3, 5.10.4, 5.10.5, 5.11.1, 5.11.2, 5.13.1	1.3.2
5.15, 8	1.4
5.5.2, 5.11.1, 5.21	2.1
5.7.3, 5.10.5	2.3
7	2.4
5.1.2, 8	2.8
5.14	2.9
5.5.1, 5.10.4	2.10
7	2.12
5.10.6	3.1.1
5.7.1.1, 5.7.1.2, 5.7.1.3, 5.7.4, 5.7.5	3.11, 1)

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

Bibliography

The following documents and publications are of relevance in the context of this European Standard:

[1] EN 148 (all parts), *Respiratory protective devices — Threads for facepieces*

[2] EN 250, *Respiratory equipment — Open-circuit self-contained compressed air diving apparatus — Requirements, testing, marking*

[3] EN ISO 15001, *Anaesthetic and respiratory equipment — Compatibility with oxygen (ISO 15001:2003)*

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