BS EN 14143:2013

BSI Standards Publication

Respiratory equipment — Self-contained re-breathing diving apparatus

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National foreword

This British Standard is the UK implementation of EN 14143:2013. It supersedes BS EN 14143:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/4/7, Underwater breathing apparatus.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Respiratory equipment - Self-contained re-breathing diving apparatus

Appareils respiratoire - Appareils de plongée autonome à recyclage de gaz

Atemgeräte - Autonome Regenerationstauchgeräte

This European Standard was approved by CEN on 1 May 2013.

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Foreword

This document (EN 14143:2013) 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of an identical text or by endorsement, at the latest by January 2014, and conflicting national standards shall be withdrawn at the latest by January 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 14143:2003.

Annex D provides details of significant technical changes between this European Standard and the previous edition.

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.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

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

— a maximum depth of 6 m for apparatus using pure oxygen;

— a maximum depth of 40 m for apparatus using oxygen in nitrogen gas mixtures;

— a maximum depth of 100 m for apparatus using oxygen and helium or oxygen, nitrogen and helium gas mixtures;

— water temperatures from 4 °C to 34 °C or outside these temperatures as specified by the manufacturer.

2 Normative references

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

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

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

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

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

EN 15333-1:2008*, Respiratory equipment — Open-circuit umbilical supplied compressed gas diving apparatus — Part 1: Demand apparatus*

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

EN ISO 10297, *Transportable gas cylinders — Cylinder valves — Specification and type testing (ISO 10297)*

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

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

EN ISO 12209-3, *Gas cylinders — Outlet connections for gas cylinder valves for compressed breathable air — Part 3: Adapter for 230 bar valves (ISO12209-3)*

3 Terms and definitions

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

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 which enables 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 and inspired partial pressure of the gases within the apparatus remain within acceptable physiological limits so that gas is thus re-circulated within the apparatus

Note 1 to entry: A self-contained re-breathing diving apparatus may also be called a diving re-breather.

3.2
high pressure
pressure inside the gas cylinder(s) and between the gas cylinder(s) and any pressure reducer

3.3
medium pressure
pressure between the pressure reducer and a gas control system

Note 1 to entry: This is sometimes referred to as intermediate pressure.

3.4
low pressure
pressure within the facepiece, breathing hoses, counterlung and absorbent canister, i.e. approximately ambient pressure

3.5
respiratory pressure
differential pressure at the mouth relative to the no flow pressures at the end of inhalation and exhalation

Note 1 to entry: See Figure 2.

3.6
rated working pressure
maximum working pressure of the respective components

3.7
hydrostatic imbalance
difference at end exhalation “no flow” between the pressure at the mouth and that at the reference point which could either be the suprasternal notch or the lung centroid of the diver

Note 1 to entry: See Figure 1 for the suprasternal notch or the lung centroid of the diver and Figure 2 for the difference at end exhalation.

3.8
displaced (tidal) volume
volume of respirable gas displaced by the breathing simulator during one half cycle (inhalation or exhalation) measured in litre

3.9
breathing frequency
setting of the breathing simulator measured in cycles per minute

3.10
respiratory minute volume
RMV
product of the tidal volume and breathing frequency measured in litre per minute

3.11
pressure volume diagram
diagram generated during one breathing cycle by plotting the respiratory pressure against the displaced volume

Note 1 to entry: See Figure 2

3.12
work of breathing
WOB
work expended during one breathing cycle measured in Joule per litre which is proportional to the area bounded by the pressure volume diagram divided by the tidal volume

Note 1 to entry: See Figure 2

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 filled with absorbent materials which will remove as a minimum at least carbon dioxide from the gas passing through them

3.16
dead space
the volume of the cavity formed between the mouth and the inhalation and exhalation parts

3.17
body harness
component of the re-breather to attach the apparatus to the body of the diver

3.18
facepiece
device for connecting the apparatus to the wearer's respiratory tract and isolating the respiratory tract from the environment

Note 1 to entry: It may be a mouthpiece assembly, a half mask, a full face mask or a helmet.

3.19
oxygen and nitrogen gas mixture
gas comprising a specified mixture of oxygen and nitrogen, capable of supporting human life under appropriate diving or hyperbaric conditions

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

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

3.20
trimix
gas comprising a specified mixture of oxygen, helium and nitrogen, capable of supporting human life under appropriate diving or hyperbaric conditions

Note 1 to entry: This includes manufactured gas mixtures made up from combinations of pure oxygen, pure helium and pure nitrogen, with or without compressed air.

3.21
heliox
gas comprising a specified mixture of oxygen and helium, capable of supporting human life under appropriate diving or hyperbaric conditions

3.22
active warning device
device that informs the diver of an adverse event without the diver having to take any action to receive the warning

Note 1 to entry: This information may be audible, visual or tactile.

3.23
emergency breathing system
system that allows the diver to breathe in the event of an apparatus failure

4 Minimum equipment

The apparatus shall comprise at least the following components:

a) breathing circuit;

NOTE The breathing circuit can comprise a facepiece, breathing hose(s), counterlung(s), exhaust valve or absorbent canister.

b) gas control or supply system;

c) gas supply cylinder(s);

d) safety device(s);

e) body harness.

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

The apparatus may also include an emergency breathing system.

5 Requirements[1)]

5.1 Design

The apparatus design shall be supported by the manufacturer through the provision of a failure mode effect and criticality analysis (FMECA) and following the methodology of EN 60812. The safety of the apparatus design shall be such that it has an acceptable risk as defined in Table 3.

In order to quantify the acceptable risk of the use of a re-breather a risk analysis shall be conducted using the risk criteria defined in Table 1 to Table 3.

1) For a comparison between clauses of this European Standard concerning requirements and clauses concerning the respective tests, see Annex A.

Table 1 — Qualitative likelihood categories

Likelihood category	Qualitative Definition
Frequent	Likely to occur repeatedly during one year of use of one re-breather
Probable	Likely to occur from time to time during one year of use of one re-breather
Occasional	Likely to occur once or more during one year of use of one re-breather
Remote	Unlikely, but can exceptionally occur during one year of use of one re-breather
Improbable	Very unlikely to occur during one year of use of one re-breather
Incredible	Extremely unlikely that the event will occur at all, given the assumptions recorded about the domain and the re-breather

Table 2 — Consequence categories

Severity category	Definition
Catastrophic	Multiple deaths
Critical	Up to a single death; and/or multiple severe injuries or severe occupational illnesses
Major	A single severe injury or occupational illness (requiring more than 3 days off work); and/or multiple minor/marginal injuries or minor/marginal occupational illnesses
Marginal	A single injury (requiring more than 3 days off diving)
Negligible	At most a single minor injury or minor occupational illness not requiring time off work or diving

Table 3 — Risk criteria

Severity	**Likelihood (per year)**					
	Frequent[a]	Probable	Occasional	Remote	Improbable	Incredible
	>0,1[b]	>0,01 and ≤0,1	>0,001 and ≤0,01	>0,000 1 and ≤0,001	>0,000 01 and ≤0,000 1	≤0,000 001
Catastrophic	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Acceptable risk
Critical	Unacceptable risk	Unacceptable risk	Unacceptable risk	Unacceptable risk	Acceptable risk	Acceptable risk
Major	Unacceptable risk	Unacceptable risk	Unacceptable risk	Acceptable risk	Acceptable risk	Acceptable risk
Marginal	Unacceptable risk	Unacceptable risk	Acceptable risk	Acceptable risk	Acceptable risk	Acceptable risk
Negligible	Unacceptable risk	Acceptable risk	Acceptable risk	Acceptable risk	Acceptable risk	Acceptable risk

[a] Quantitative likelihood category.

[b] Likelihood of dangerous failure of any safety critical function (in a single re-breather per year) .

Check by assessment of FMECA report(s) (see 6.2).

The apparatus shall be designed and its components and parts located to provide protection against mechanical damage caused by external influence and to ensure that it is possible to perform the required pre-dive functional checks. It shall not be possible to assemble or combine the components or parts in such a way that it can affect the safe operation and safe 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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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.

Test in accordance with 6.18.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.15.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.3, 6.7 and 6.8.

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

Check compliance by visual inspection (see 6.2).

5.2 Materials

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.8, 6.9, 6.13 and 6.18.

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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.3 Gas cylinder(s)

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

The gas cylinder(s) shall be marked with the appropriate neck thread designation in accordance with EN 144-1 where the preferred threads are M 18 x 1,5 or M 25 x 2.

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

Check compliance by visual inspection (see 6.2).

5.4 Cylinder valve(s)

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.15, if applicable.

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

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

a) EN ISO 12209-1, EN ISO 12209-2 or EN ISO 12209-3 for gas cylinders intended for compressed air; or

b) EN 144-3 for gas cylinders intended for use with gases with an oxygen content greater than air as specified in EN 12021.

Check compliance by visual inspection (see 6.2).

The opening of the valve orifice shall be progressive. Complete opening shall require more than one rotation of the operating mechanism. For valves in which it is technically difficult to limit opening in this way (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 (they) cannot be closed inadvertently, e.g. by requiring at least two full turns from fully open to fully closed position.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

The cylinder valve(s) shall be protected against the entrainment of dirt, solid particles and water from inside the gas cylinder.

EXAMPLE By means of a protective tube with a length of at least 30 mm and an inside diameter of at least 2,5 mm.

Check compliance by visual inspection (see 6.2).

5.5 High and medium pressure parts and connections

5.5.1 General

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

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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

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

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

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

There shall be no leakage or burst.

Check compliance by visual inspection (see 6.2) and test in accordance with 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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

If fitted, any pressure reducer which is pressurised above 25 bar absolute and can 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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.15.

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 their failure mode effect and criticality analysis. In any case, the maximum relief pressure shall not exceed 50 % of the burst pressure of the relevant components specified by the manufacturer.

Test in accordance with 6.10.5.

5.6 Breathing circuit

5.6.1 Performance requirements

5.6.1.1 General

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

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

When the apparatus is intended to be used with Trimix, the breathing performance test shall be carried out at the maximum intended diving depth specified by the manufacturer with the highest intended gas density at that depth.

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

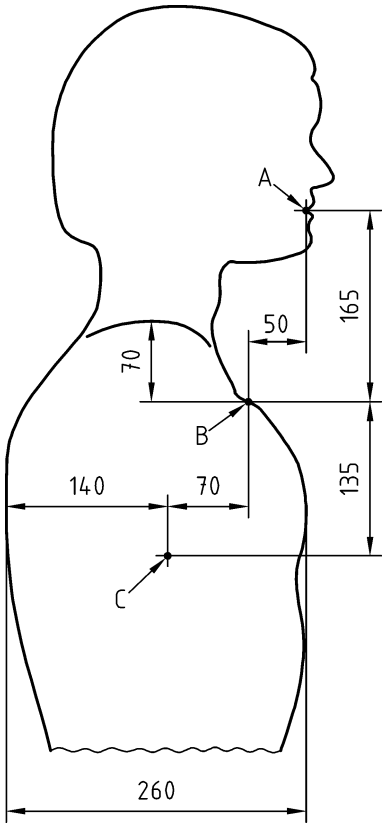
The manufacturer shall supply to the test house values in x, y and z from a reference point on the apparatus related to the suprasternal notch. For details, see Figure 1.

Apparatus only used with pure oxygen shall be tested at an ambient pressure of 1,6 bar.

Table 4 — Breathing simulator settings

Tidal volume at BTPS l	**Breathing frequency** min^{-1}	**RMV** at BTPS l/min	**Carbon dioxide injection rate** at STPD[a] l/min	**Oxygen consumption rate** at STPD[a] l/min	**Maximum WOB** J l^{-1}
1,5	10	15,0	0,60	0,67	0,95
1,5	15	22,5	0,90	1,00	1,18
2,0	20	40,0	1,60	1,78	1,70
2,5	25	62,5	2,50	2,78	2,38
3,0	25	75,0	3,00	3,33	2,75
[a] Standard Temperature and Pressure, Dry.					

Dimensions in millimetres



Key
A mouth
B suprasternal notch
C lung centroid

Figure 1 — Reference points

5.6.1.2 Work of breathing (WOB)

Work of breathing shall not exceed a value of:

WOB = 0,5 + 0,03 • RMV [J l^{-1}] related to an RMV from 15 l/min to 75 l/min

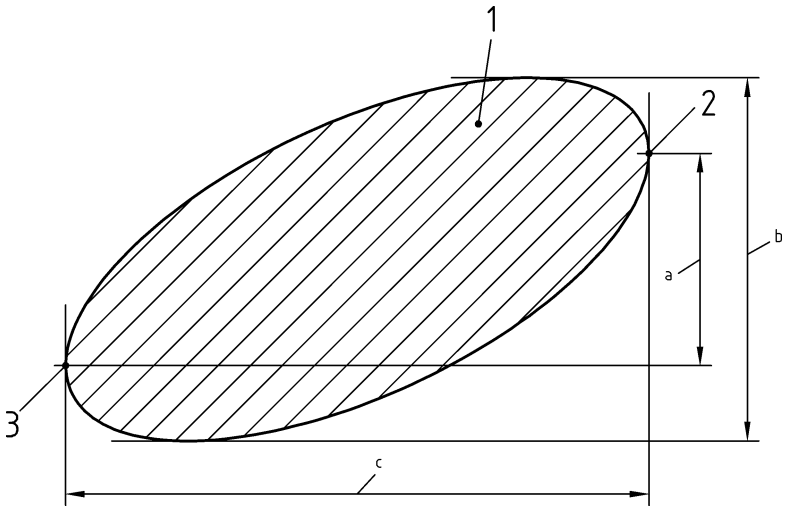
The WOB specified is considered to be a physiological maximum level and the manufacturers should endeavour to keep the WOB as low as possible.

Test in accordance with 6.3.2.

5.6.1.3 Respiratory pressures

Peak-to-peak respiratory pressure shall be determined as shown in Figure 2 (expressed by *b*) and shall not exceed 50 mbar. The elastance of the system, determined in Figure 2 and expressed by *a/c*, shall not exceed 10 mbar l^{-1} tidal volume.

Test in accordance with 6.3.2.



Key
1 work of breathing WOB
2 reference point of hydrostatic imbalance; end of exhalation (“no flow”)
3 reference point of hydrostatic imbalance; end of inhalation (“no flow”)
a pressure difference between reference point 2 and 3
b peak-to-peak respiratory pressure
c tidal volume

Figure 2 — Analysis of pressure volume loop

The peak-to-peak respiratory pressure for the activation of an automatic volume addition system shall not exceed 60 mbar (measure as on Figure 2).

Test in accordance with 6.3.5.

5.6.1.4 Hydrostatic imbalance

The hydrostatic imbalance shall not exceed the values specified in Table 5 under the following conditions:

— with 0° diver roll and diver pitch from +180° to −90°;

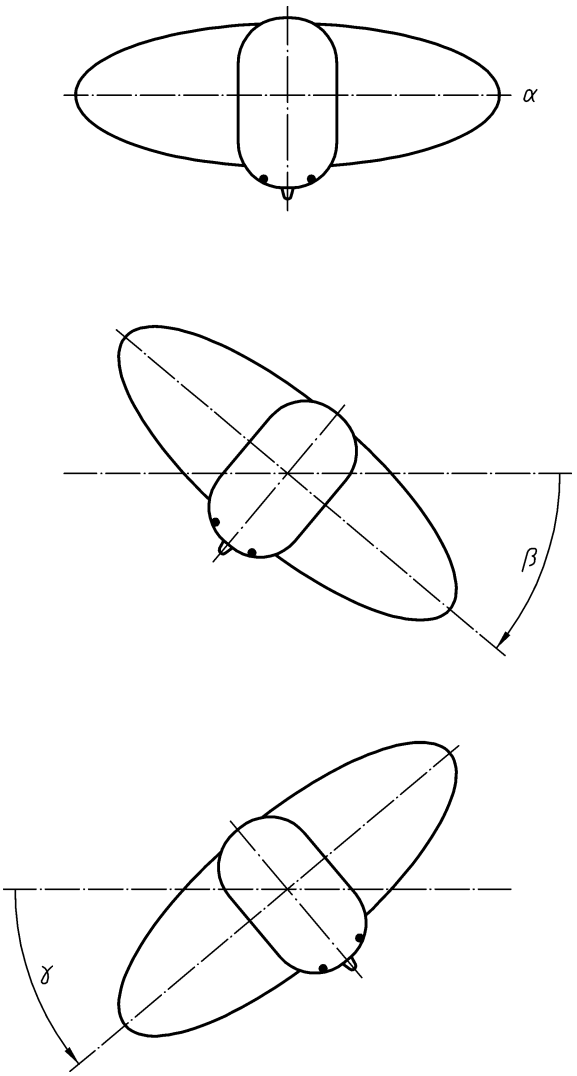
— with 0° diver pitch and diver roll from +90° to −90°.

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

Test in accordance with 6.4.

Table 5 — Hydrostatic imbalance

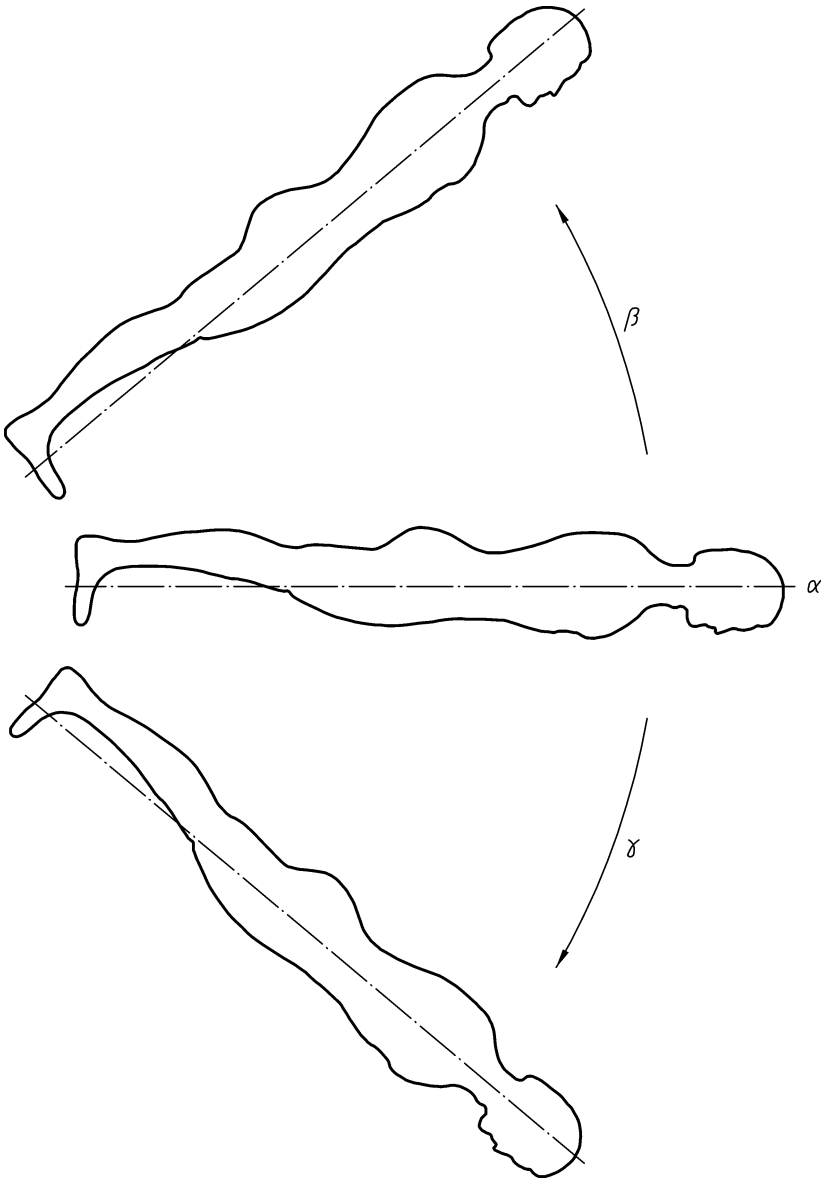
Pitch degrees	**Roll degrees**	**Lung centroid** mbar		**Suprasternal notch** mbar	
180	0	+20,0	−20,0	+27,0	−13,0
90	0	+20,0	−20,0	+33,5	−6,5
45	0	+20,0	−20,0	+24,6	−15,4
0	0	+20,0	−20,0	+13,0	−27,0
−45	0	+20,0	−20,0	+5,5	−34,5
−90	0	+20,0	−20,0	+6,5	−33,5
0	90	+20,0	−20,0	+20,0	−20,0
0	45	+20,0	−20,0	+15,1	−24,9
0	0	+20,0	−20,0	+13,0	−27,0
0	−45	+20,0	−20,0	+15,1	−24,9
0	−90	+20,0	−20,0	+20,0	−20,0



Key

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

Figure 3 — Diver roll



Key

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

Figure 4 — Diver pitch

5.6.1.5 Maximum inspired partial pressure of carbon dioxide

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

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

Test in accordance with 6.3.3.

5.6.1.6 Automatic volume addition system

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

Test in accordance with 6.3.5.

5.6.2 Breathable volume

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

Test in accordance with 6.18.

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

Test in accordance with 6.5.1.

5.6.3 Breathing circuit test pressure

The breathing circuit shall be capable to withstand a pressure of 200 mbar.

There shall be no leakage or burst.

Test in accordance with 6.5.2.

5.6.4 Exhaust valve

5.6.4.1 Maximum pressure within the breathing circuit

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.

Test in accordance with 6.5.3.1 after testing in accordance with 6.5.3.2.

5.6.4.2 Leakage

After stress testing in accordance with 6.5.3.2, the operation of the exhaust valve shall not be adversely affected or leak.

The leakage of the exhaust valve (when in the wetted condition) shall not exceed 0,5 ml (STP) min^{-1}.

Test in accordance with 6.5.3.2.

5.6.5 Inhalation and exhalation valves

The facepiece shall include inhalation and exhalation valves to minimise dead space and ensure gas circulation through the apparatus.

Valve assemblies shall be designed so as to be easily assembled and maintained.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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 in accordance with 6.3.2, 6.3.4, 6.3.5, 6.6.1 and 6.6.2.

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

5.6.6 Carbon dioxide absorbent canister

The manufacturer shall specify the absorbent materials that may be used with the apparatus. For each absorbent material specified, the endurance of the charged carbon dioxide absorbent canister in water at (4 ± 1) °C shall be stated by the manufacturer. It shall maintain an end of inspiration partial pressure of carbon dioxide of less than 5 mbar for the stated endurance.

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

Test in accordance with 6.6.1 and 6.6.2.

5.6.7 Inhalation temperature

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

Test in accordance with 6.3.4.

5.6.8 Ingress of water

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

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

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

Test in accordance with 6.5.5.

5.7 Gas control or supply system

5.7.1 Inspired partial pressure of oxygen

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

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

For apparatus where the inspired partial pressure of oxygen is not maintained automatically, all the following additional requirements shall be fulfilled:

— The system shall have a minimum continuous flow of oxygen into the breathing circuit of 0,5 l/min STPD.

— The system shall have at least one inspired partial pressure of oxygen monitor with an alphanumeric display.

— The system shall have at least one active warning device for minimum and maximum permitted oxygen partial pressures. The minimum warning level shall be 0,4 bar or greater. The maximum warning level shall be less than or equal to 1,6 bar.

— Provision shall be made for the addition of gas by the diver at all times during the dive to both increase and decrease the partial pressure of oxygen in the apparatus.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.7 and 6.18.

5.7.2 Oxygen partial pressure set point maintenance

In apparatus with a fixed oxygen partial pressure set point the inspired partial pressure of oxygen shall be maintained within ± 0,10 bar during constant depth phases of the dive at a ventilation of 40 l/min and associated oxygen consumption of 1,78 l/min 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).

Test in accordance with 6.7.

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

Any apparatus, where the breathing gas is made up by mixing gases from different gas sources during the dive, shall have an alphanumeric display for inspired partial pressure of oxygen.

The display shall enable the diver to read the information without difficulty during all phases of the dive.

Check in accordance with 6.18.

The accuracy of the displayed partial pressure of oxygen shall be as defined in Table 6.

Table 6 — Accuracy of the displayed partial pressure of oxygen

Oxygen partial pressure bar	**Accuracy** bar
0,1 to 0,4	± 0,03
> 0,4 to 2,0	± 0,06

Check compliance by visual inspection (see 6.2) and test in accordance with 6.10.2.

5.7.4 Gas endurance

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

Additional gas consumption due to the conduct of the dive shall be considered.

Test in accordance with 6.6.1 and 6.6.3.

5.8 Hose assemblies

5.8.1 Tensile strength of high and medium pressure hose assemblies subjected to external tensile force

The unpressurised hose assembly shall withstand a tensile strength of 1 000 N.

There shall be no separation of parts.

Test in accordance with 6.8.2.

5.8.2 Flexibility of high and medium pressure hoses

The unpressurised hose shall be capable of being bent around a cylinder with a diameter of (130 ± 5) mm.

There shall be no permanent deformation.

Test in accordance with 6.8.3.

5.8.3 Leakage of high pressure hose assembly

Any high pressure hose assembly shall withstand the rated working pressure.

There shall be no leakage.

Test in accordance with 6.8.4.

5.8.4 Leakage of medium pressure hose assembly

Any medium pressure hose assembly shall withstand twice the operating pressure of a safety valve or at least 30 bar, whichever is the higher.

There shall be no leakage.

Test in accordance with 6.8.5.

5.8.5 Burst pressure of high pressure hose assembly

Any high pressure hose assembly shall withstand a pressure of four times the rated working pressure.

There shall be no leakage or burst.

Test in accordance with 6.8.6.

5.8.6 Burst pressure of medium pressure hose assembly

Any medium pressure hose assembly shall withstand four times the rated working pressure or at least 100 bar, whichever is the higher.

There shall be no burst.

Test in accordance with 6.8.7.

5.8.7 Breathing hose

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

Test in accordance with 6.18.

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

There shall be no burst or significant deformation.

Test in accordance with 6.8.8.

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 through the visor or eyepiece by a person with normal (or appropriately corrected) visual acuity at all pressures and temperature conditions and under the visibility conditions specified in the information supplied by the manufacturer. Safety devices shall provide an appropriate indication for colour blind people.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.9.2 Pressure indicator

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

Pre-dive, any pressure indicator shall be able to be activated.

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 flexible hose connection has a cover, which is not permeable to gases, the space enclosed by this cover shall be vented.

The pressure indicator shall be automatically activated and remain active during dive. If a flexible link is required for this purpose it shall be protected 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 to the ambient atmosphere.

Check compliance by visual inspection (see 6.2).

The pressure indicator hose connector at the pressure supply point, or if no hose fitted the pressure indicator connector, shall, with an upstream pressure of 100 bar and no indicator fitted, have a flow rate ≤ 100 l/min of gas measured at STPD.

Test in accordance with 6.10.1.1.

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

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

a) ± 15 bar at 300 bar;

b) ± 10 bar at 200 bar;

c) ± 10 bar at 100 bar;

d) ± 5 bar at 50 bar.

Check compliance by visual inspection (see 6.2).

Any pressure indicator shall be waterproof to at least 1,3 times the intended maximum diving depth specified by the manufacturer or at least 20 m, whichever is greater.

Test in accordance with 6.10.1.3.

Any transparent window(s) shall be splinter-proof. Any installed pressure indicator (if mechanical) shall feature a pressure relief facility that in the event of a high pressure gas leak protects the diver against injury.

Check compliance by visual inspection (see 6.2).

The pressure relief facility of a mechanical pressure indicator shall relieve safely at a pressure not higher than 50 % of the burst pressure of the case. The safety device shall also relieve a minimum flow rate of 300 l/min.

Test in accordance with 6.10.1.2.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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 accuracy of the partial pressure of oxygen displayed shall be as specified in Table 6. 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).

Check compliance by visual inspection (see 6.2) and test in accordance with 6.7, 6.10.2 and 6.18.

5.9.3.2 Monitor for inspired partial pressure of carbon dioxide (if fitted)

An inspired carbon dioxide monitor shall have a minimum range from 0,0 mbar up to 25,0 mbar.

An inspired carbon dioxide monitor shall have under all conditions an accuracy of 3 mbar.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.10.3 and 6.18.

5.9.4 Active warning devices

In the event of a failure of any active warning device, it shall fail so as to warn the diver.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.10.4.1 and 6.18.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.10.4.2 and 6.18.

5.10 Facepiece

5.10.1 General

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

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

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

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

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.10.2 Facepiece harness (if fitted)

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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

Each strap of the facepiece (excluding mouthpiece) shall be capable to withstand a pull (force) of 150 N.

The permanent linear deformation of each strap shall not be greater than 5 %

Test in accordance with 6.11.4.2.

Where the facepiece is a mouthpiece, each strap of the mouthpiece, if fitted, shall be capable to withstand a pull (force) of 50 N.

The permanent linear deformation of each strap shall not be greater than 5 %.

Test in accordance with 6.11.4.3.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.10.3 Connection

5.10.3.1 Half mask, full face mask and helmet

The connection between the facepiece and the apparatus may be achieved by a permanent or special type of connection. If a thread connection is used then it shall not be possible to interchange with threads specified in EN 148-1, EN 148-2 and EN 148-3.

Check compliance by visual inspection (see 6.2).

The connection between the faceblank and the connector shall be sufficiently robust to withstand axially a tensile force of 300 N (see Figure 6).

Check compliance by visual inspection (see 6.2) and test in accordance with 6.11.1.

5.10.3.2 Mouthpiece

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

Test in accordance with 6.11.5.

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.11.3.

Visors shall not distort vision.

Test in accordance with 6.18.

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.

Test 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.

Test in accordance with 6.18.

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.

Check compliance by visual inspection (see 6.2).

5.10.5 Head protection against impact (if fitted)

The head protection given by the facepiece system shall meet 5.10.7 and Clause 7 of EN 15333-1:2008.

Check compliance by visual inspection (see 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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.12 Emergency breathing system

The apparatus shall allow the use of a suitable emergency breathing system. This may either be carried by the diver or externally supplied.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.13 Electrical systems

5.13.1 Safety of electrical systems

The manufacturer shall support the safety of electrical systems by the provision of a failure mode effect and criticality analysis (FMECA). The safety of the electrical system shall be such that it has an acceptable risk as defined in Table 3.

Check compliance by visual inspection (see 6.2).

5.13.2 Programmable systems

Any safety-critical software or firmware used on the apparatus shall satisfy the requirements specified in Annex B.

Check compliance by visual inspection (see 6.2).

5.13.3 Electromagnetic compatibility (EMC)

The performance or calibration of the apparatus shall not be affected when exposed to electromagnetic disturbance.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.12.

5.13.4 Power source

No power source shall have direct contact with the breathing gas. For the purposes of this standard, electrochemical gas sensors are not defined as a power source.

Check compliance by visual inspection (see 6.2).

5.14 Resistance to temperature

5.14.1 Storage

Trouble free operation shall be ensured after storage at temperatures of +70 °C and −30 °C.

Test in accordance with 6.13.1 and 6.13.2.

5.14.2 Pre-dive operation

The apparatus shall not leak or release gas at temperatures of +55 °C and −20 °C.

Test in accordance with 6.13.1 and 6.13.3.

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/or disinfectants recommended by the manufacturer.

Check compliance by visual inspection (see 6.2) and test in accordance with 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.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.18.

5.17 Oxygen compatibility and cleanliness

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

Check compliance by visual inspection (see 6.2).

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

Check compliance by visual inspection (see 6.2) and test in accordance with 6.15.

5.18 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 or at least 20 m, whichever is greater.

Test in accordance with 6.16 and after testing in accordance with 6.13.

5.19 Sea water resistance

The apparatus shall be sea water resistant.

Check compliance by visual inspection (see 6.2) and test in accordance with 6.17.

5.20 Practical performance

In addition to the unmanned tests specified in Clause 6, the apparatus shall also undergo practical performance tests. These practical performance tests are to check the ergonomics of the apparatus its compatibility with other PPE, ease of use and the application of the information supplied by the manufacturer.

Where, in the opinion of the testing authority, approval is not granted because practical performance tests show the apparatus has imperfections related to test subject's acceptance, the testing authority shall describe the tests that revealed these imperfections.

Test in accordance with 6.18.

6 Testing

6.1 General

6.1.1 Introduction

The apparatus shall only be approved when the apparatus or all apparatus sub-assemblies satisfy the requirements of the tests specified in this standard, and practical performance tests have been carried out successfully on the complete apparatus where specified in the standard.

6.1.2 Procedure

The apparatus shall be tested and qualified as a complete unit.

When required to test components or assemblies of the apparatus separately, complimentary components that comply with the relevant standards shall be used.

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

Prior to conducting any other test, the following tests shall be performed in the order below:

— cleaning and disinfection (6.14);

— temperature resistance (6.13);

— sea water resistance (6.17).

6.1.3 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.

6.1.4 Test equipment

The performance characteristics of the breathing simulator test equipment shall be verified by the use of a 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 l/min (25 cycles min^{-1}, 2,5 l tidal volume) at 6,0 bar absolute. The values for WOB and inhalation/exhalation pressures shall be 3,3 J l^{-1} and ± 25 mbar respectively using air.

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

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

Dimensions in millimetres

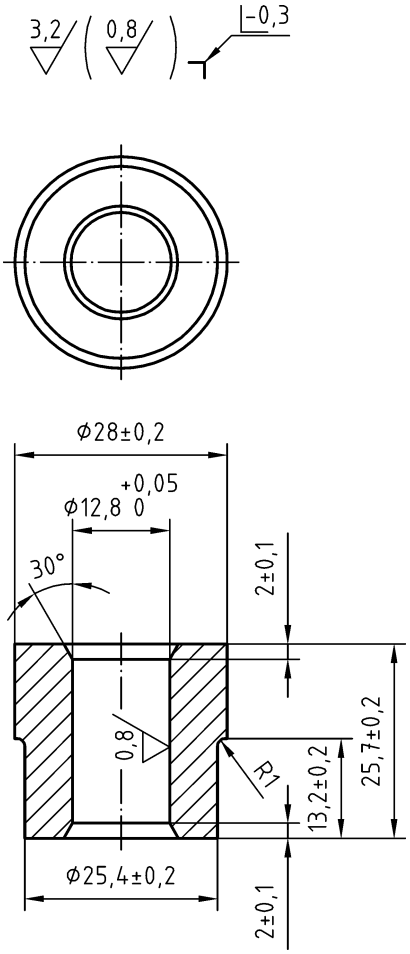


Figure 5 — Test orifice

6.2 Visual Inspection

Visual inspection shall be conducted at normal visual acuity by the responsible expert(s).

Assessment of safety critical software in accordance with Annex B shall be conducted by a responsible expert in safety critical software systems.

The visual inspection shall include the assessment of the device marking, information supplied by the manufacturer, any safety data sheets related to materials (if applicable), the FMECA reports and if applicable the documents demonstrating compliance to Annex B and relevant declarations applicable to its construction.

6.3 Breathing circuit

6.3.1 General test conditions

The apparatus shall be fully rigged on a rotatable mannequin with the dimensions shown in Figure 1, according to the x, y and z coordinates and other information supplied by the manufacturer.

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

The breathing performance of the apparatus 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 gas supply shall be switched on and any adjustable relief valve set to a mechanical midpoint or the manufacturer's recommended setting.

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

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

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

Stabilise the temperature of the water in the test chamber at (4 ± 1) °C, or lower if specified by the manufacturer.

For specific tests other temperatures may apply.

6.3.2 Breathing performance

Set the breathing simulator in turn to all RMVs specified 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 diagrams in accordance with Figure 2.

Simulate the diver in both the vertical and horizontal orientation (+90° and 0° pitch – see Figure 4).

6.3.3 Volume weighted average inspired carbon dioxide

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

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

6.3.4 Inspired gas temperature

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

Completely immerse the apparatus in water at a depth sufficiently deep to preclude surface effects, but not more than 2 m.

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

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

6.3.5 Breathing performance with automatic volume addition system

Set the breathing simulator at a ventilation rate of 40 l/min.

Remove a constant flow from the breathing circuit of 1,78 l/min STP.

Measure the respiratory pressure at the mouth and determine performance from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced volume. Analyse the pressure-volume diagram in accordance with Figure 2.

Simulate the diver in both the vertical and horizontal orientation (+90° and 0° pitch – see Figure 4).

6.4 Hydrostatic imbalance

Fully rig the apparatus on a rotating mannequin as specified in 6.3.1 and completely immerse in water at a depth sufficiently deep to preclude surface effects, but not deeper than 2 m.

Perform the test at a RMV of 62,5 l/min and record the mouth pressure at the end of exhalation (see Figure 2).

After breathable volume optimisation by setting the lowest hydrostatic imbalance at a diver position (roll 0° and pitch +45°) no further adjustment is allowed for roll and pitch variation measurements.

During this test, the mannequin 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 at less than +25 mbar.

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 7.

Table 7 — Respiratory volume

Tidal volume at BTPS l	**Breathing frequency** min^{-1}	**RMV** at BTPS l/min
4,5	5	22,5

The internal pressure when withdrawing the gas shall not exceed –25 mbar and when injecting gas +25 mbar.

6.5.2 Breathing circuit pressure test

The exhaust valve shall be sealed off and the internal pressure shall be increased to 200 mbar. After 60 s the change in pressure shall be less than 10 mbar.

6.5.3 Exhaust valve

6.5.3.1 Maximum pressure within the breathing circuit

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

Exhaust valves that are manually adjustable shall be tested at the maximum relief pressure setting. Exhaust valves which incorporate pre-dive and dive controls shall be tested with the controls set to dive position. Inject gas into the breathing circuit at 150 l/min 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 required by the design of the apparatus.

Record the pressure within the counterlung.

6.5.3.2 Leak test

The test shall be carried out with wetted exhaust valve in air. The exhaust valve shall be subjected to:

a) a constant flow of 300 l/min for a period of 1 min;

b) a static negative pressure of 80 mbar for a period of 10 s.

The leakage of the exhaust valve shall be tested with a negative pressure of 7 mbar for at least one minute.

6.5.4 Inhalation and exhalation valves

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

6.5.5 Ingress of water

Fully rig the apparatus on a rotatable mannequin as specified in 6.3.1 and completely immerse in water at a depth sufficiently deep to preclude surface effects, but not deeper than 2 m. Perform the test in all five roll positions mentioned in Table 5 each for a time of 3 min at an RMV of 62,5 l/min.

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

On completion of the test remove the apparatus from the water, invert the apparatus to the −90° position for 1 min and measure the volume and the pH of any water present in the facepiece.

The apparatus shall then be disassembled and any water present within the breathing loop shall be determined by a combination of volumetric and gravimetric analyses.

6.6 Apparatus endurance

6.6.1 General

Conduct the test in 6.6.2 and 6.6.3 three times at one or more of 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

For each test, the absorbent canister shall be prepared in accordance with the information supplied by the manufacturer.

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

Test the apparatus with the breathing simulator ventilating at 40 l/min and carbon dioxide injected into the exhaled gas from the breathing simulator at a rate of 1,60 l/min.

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

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

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

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

6.6.3 Gas endurance

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

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

6.7 Inspired partial pressure of oxygen

Prior to testing the test house shall decide with the manufacturer the relevant sampling 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 sampling point(s).

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

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

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

Where the oxygen control of the apparatus is dependent on a diver’s ventilation pattern rather than his oxygen consumption, then the apparatus shall be tested at the rates as given in Table 4 and in Table 8.

Table 8 — Breathing simulator respiratory exchange settings

Tidal volume at BTPS l	Breathing frequency min^{-1}	RMV at BTPS l/min	Carbon dioxide injection rate at STPD l/min	Oxygen consumption rate at STPD l/min
1,5	15	22,5	0,68	0,75
2,5	25	62,5	3,12	3,47

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

6.8 Hoses assemblies

6.8.1 General

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

6.8.2 Tensile strength of high and medium pressure hose assemblies subjected to external tensile force

Attach the end fittings to an appropriate anchorage point and apply the tensile load of 1 000 N to the hose assembly for a test period of 10 s to 15 s.

6.8.3 Flexibility of high and medium pressure hoses

Bend the hose through an angle of 180° for 8 h around a cylinder with a diameter of (130 ± 5) mm.

6.8.4 Leakage of high pressure hose assembly

Submerge the high pressure hose assembly in water and apply the rated working pressure for at least 5 min with the gas for intended use as test medium.

6.8.5 Leakage of medium pressure hose assembly

Submerge the medium pressure hose assembly in freshwater and apply twice the operating pressure of a safety valve or at least 30 bar, whichever is the greater, with the gas for intended use as test medium.

6.8.6 Burst pressure of high pressure hose assembly

Apply four times the rated working pressure for at least 20 s with water as test medium.

6.8.7 Burst pressure of medium pressure hose assembly

Apply four times the rated working pressure or at least 100 bar, whichever is greater, for at least 20 s with water as test medium.

6.8.8 Tensile load of breathing hose connections

Apply a tensile load of 250 N for 10 s to the hose assembly by attaching the end fittings into an appropriate anchorage point.

6.9 Test pressure of high and medium pressure parts

The high and medium pressure parts and connections shall be subjected internally to the required hydrostatic pressure for a period of at least 20 s.

6.10 Safety devices

6.10.1 Pressure devices

6.10.1.1 Pressure indicator connector

Connect a 100 bar gas supply to the connector. Connect a suitable flow device to the outlet of the connector. Check that the flow is less than 100 l/min STPD.

6.10.1.2 Pressure relief facility

A pressure flow test shall be carried out to demonstrate that when the case is subjected to the opening pressure of the pressure relief facility there is no damage to the case or the front glass.

The pressure relief facility shall allow a flow of at least 300 l/min.

The manufacturer shall provide documented evidence that the window material does not splinter when broken.

Any mechanical pressure indicator shall be subjected to an internal hydraulic test pressure to determine the burst pressure of the case.

6.10.1.3 Water leak test

The pressure indicator shall be immersed in water and pressurised at a rate of 3 bar/min. After 15 min no ingress of water shall be observed.

6.10.2 Monitor for inspired partial pressure of oxygen

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

Test the oxygen partial pressure monitor by exposure to partial pressures of oxygen in the range 0,1 bar to 2,0 bar in increments of 0,2 bar. Note if the reading stabilises within the response time requirements. Note the readings of the monitor and compare with the limits given in Table 6.

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

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

The oxygen partial pressure monitor shall be decompressed using the stop depth specified by the manufacturer. The rate of ascent shall be 20 m min^{-1} and the partial pressure oxygen monitor held at each

stop for a period of 2 min. After a period of 1 min the indicated value shall be compared with the partial pressure of oxygen in the inhalation hose.

6.10.3 Monitor for inspired partial pressure of carbon dioxide

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

6.10.4 Active warning devices

6.10.4.1 Inspired partial pressure of oxygen

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

6.10.4.2 Inspired partial pressure of carbon dioxide

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

6.10.5 Pressure relief system(s)

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

6.11 Facepiece

6.11.1 Mechanical strength of the facepiece (excluding mouthpiece)

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

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

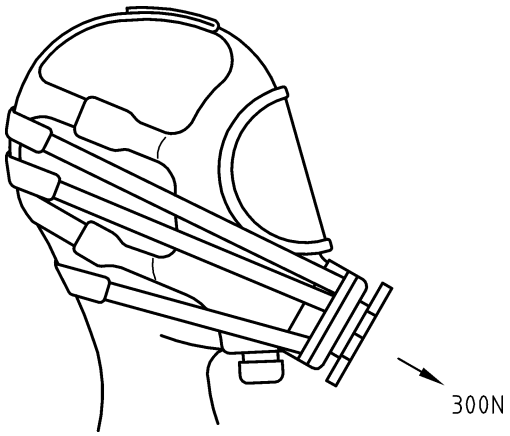


Figure 6 — Test arrangement for tensile force

6.11.2 Field of vision

Measure the field of vision using a Stoll Apertometer (see Figure 7). A diagram (see Figure 8) shall be used for the evaluation.

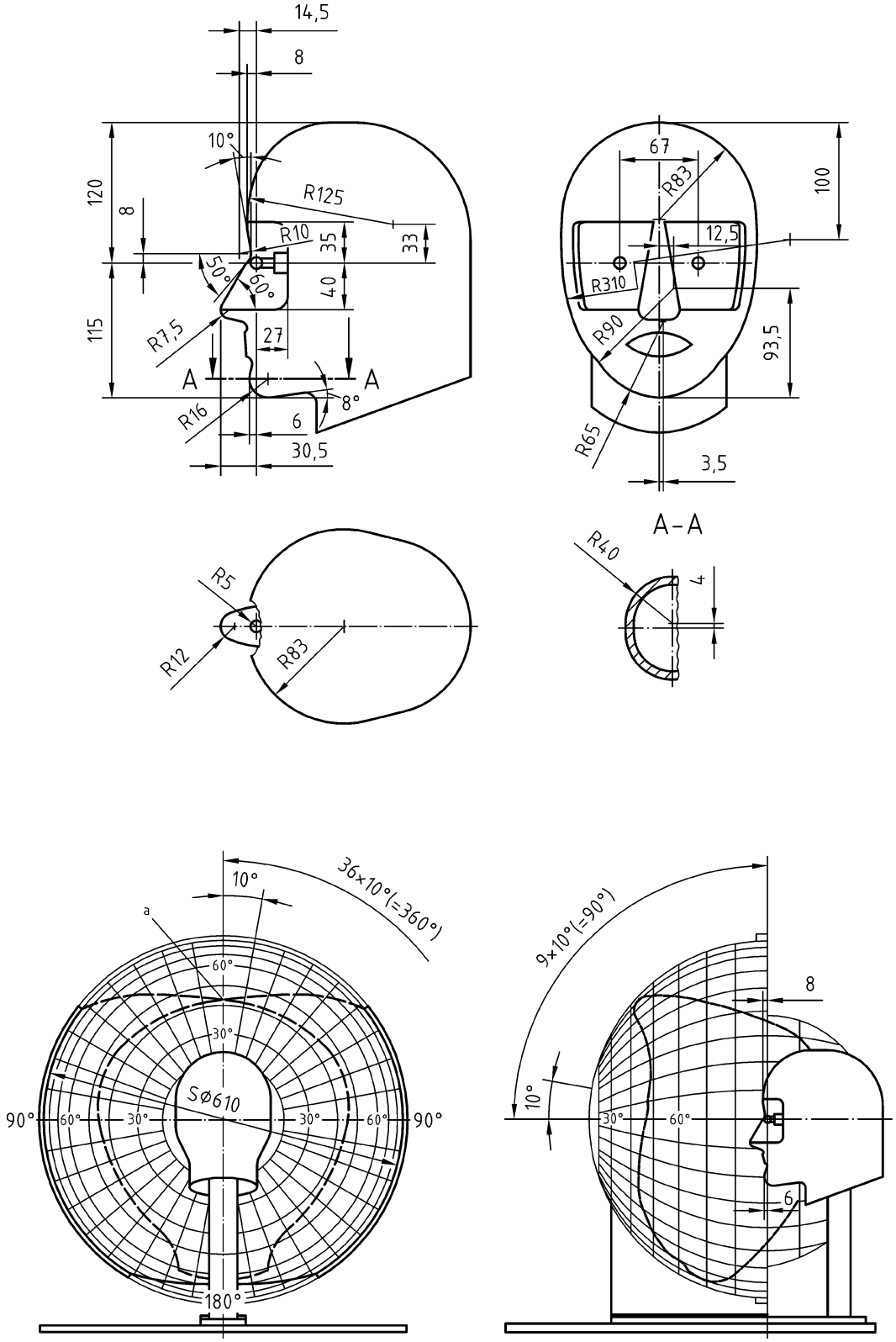
a) Fit the facepiece to the dummy head and with both eyes lit, adjust the facepiece until the outline of the visor is symmetrical on the hemi-spherical shell and the field of vision is a maximum. Adjust the tensions of the straps to obtain a reasonable secure fit.

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).

Dimensions in millimetres

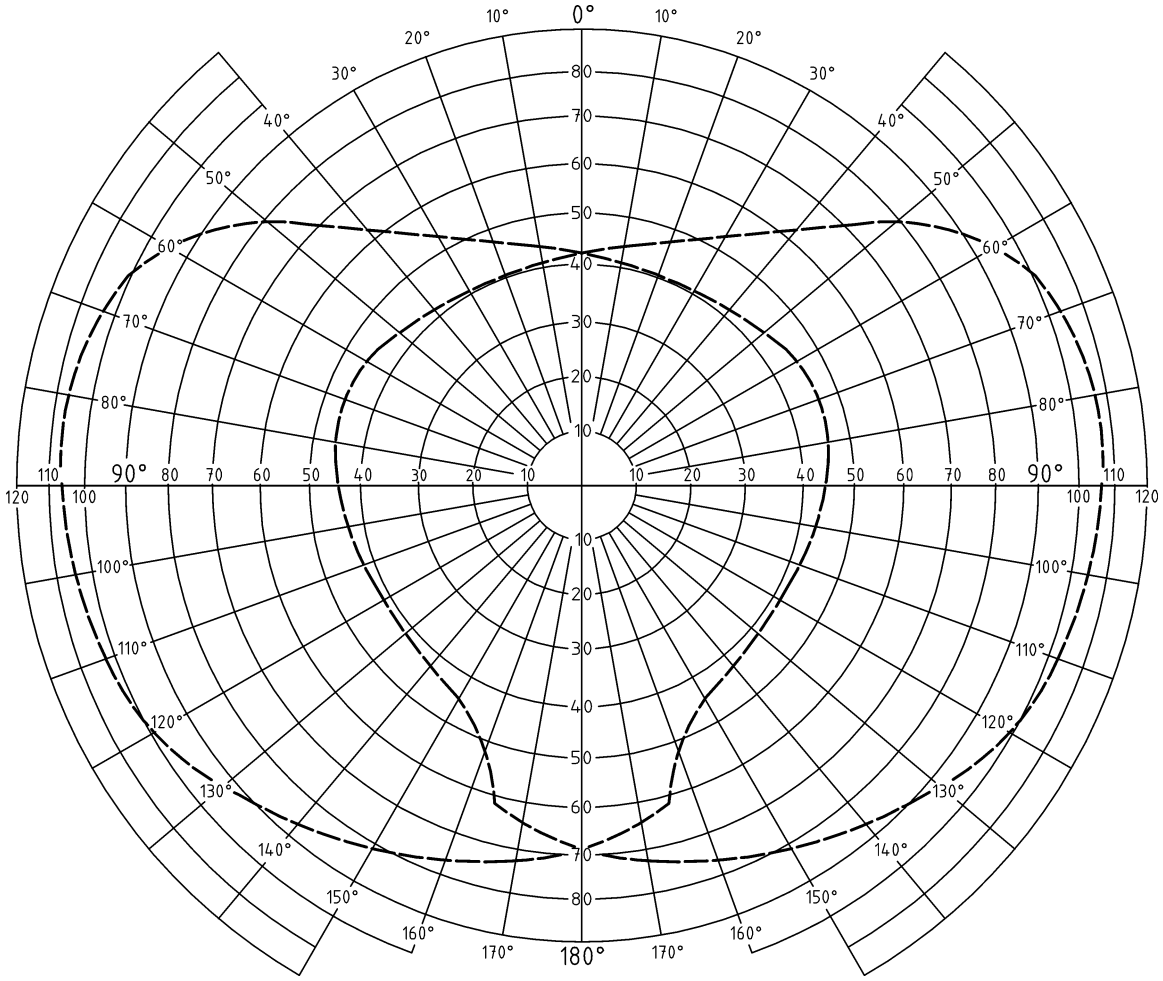


Key

a transfer the natural field of vision with the natural overlapped field of visions to the diagram

Figure 7 — Stoll Apertometer

Dimensions in millimetres



Key

Natural field of vision with natural overlapped field of vision
The areas 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^2
Natural field of vision inside of the 90° circle (78,8 %)	= 100,0 cm^2
Natural field of vision outside of the 90° circle	= 12,0 cm^2
Natural field of vision totally	= 112,0 cm^2 = 100 %
Natural overlapped field of vision	= 39,0 cm^2 = 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)	..... cm^2
Planimetered area of effective overlapped field of vision	..... cm^2
Effective field of vision (totally)	..... %
Effective overlapped field of vision	..... %

Figure 8 — Apertometer diagram (not to scale)

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

Impact resistance shall be tested using a completely assembled facepiece mounted on a dummy head such that a steel ball (22 mm diameter, 43,8 g approximately) falls normally from a height of 1,30 m on the centre of the lens.

To confirm the leak tightness of the mask before and after the test using the same dummy head a pressure of −10 mbar shall be created in the cavity of the mask and maintained for 5 s.

Five visors shall be tested.

6.11.4 Facepiece harness

6.11.4.1 General

Test three samples; all in the state as received.

6.11.4.2 Facepiece (excluding mouthpiece)

Apply a force of 150 N for 10 s to the free end of the straps in direction of pulling when the facepiece (excluding mouthpiece) is donned.

4 h after the pull test, apply a force of 30 N for 10 s to the free end of the straps and measure the permanent linear deformation.

6.11.4.3 Facepiece (is a mouthpiece)

Apply a force of 50 N for 10 s to the free end of the strap in direction of pulling when the mouthpiece is donned.

4 h after the pull test, apply a force of 30 N for 10 s to the free end of the straps and measure the permanent linear deformation.

6.11.5 Mouthpiece

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

6.12 Electrical systems, Electromagnetic compatibility (EMC)

Calibrate the apparatus prior to exposure to the electromagnetic radiation.

Check the performance of the apparatus by observation of displayed readings prior to, during and immediately post exposure to the electromagnetic radiation in accordance with EN 61000-6-1.

6.13 Resistance to temperature

6.13.1 General

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

6.13.2 Testing after storage

Place the fully assembled apparatus, with cylinder valves closed and gas cylinders charged to 50 % of the rated working pressure and the electronic control, if fitted, switched off, in an environmental chamber and heat

to 70 °C for a period not less than 3 h. Allow the temperature of the apparatus to return within a period not less than 3 h to standard laboratory conditions.

Switch on the apparatus and calibrate, if required.

Test at a pressure of 1,0 bar and a RMV of 40 l/min with an oxygen consumption of 1,78 l/min for at least 10 min, during which the performance shall remain within the limits specified.

Repeat the test at −30 °C.

6.13.3 Testing in pre-dive operation

Place the fully assembled apparatus, with cylinder valves closed and gas cylinders charged to 50 % of the rated working pressure and the electronic control, if fitted, switched off, in an environmental chamber and heat to 55 °C for a period not less than 3 h.

Open the cylinder valves, ensuring the apparatus is still at 55 °C.

Repeat the test at −20 °C.

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, where appropriate. Perform the test 30 times. If no other temperatures are indicated, the temperature of the disinfectant solution shall be 40 °C.

The apparatus shall remain functional after having been cleaned and/or disinfected.

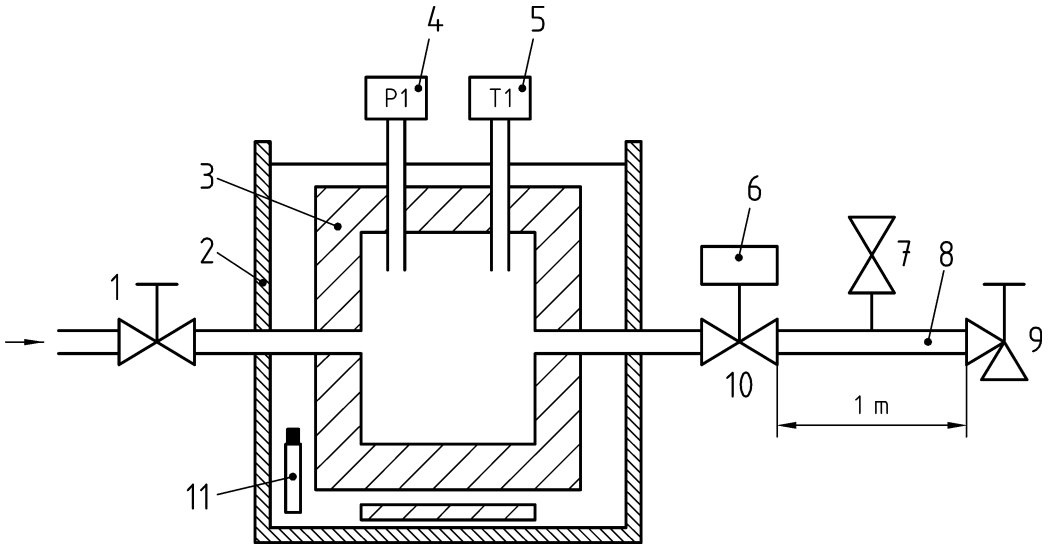
6.15 Oxygen pressure surge test

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.

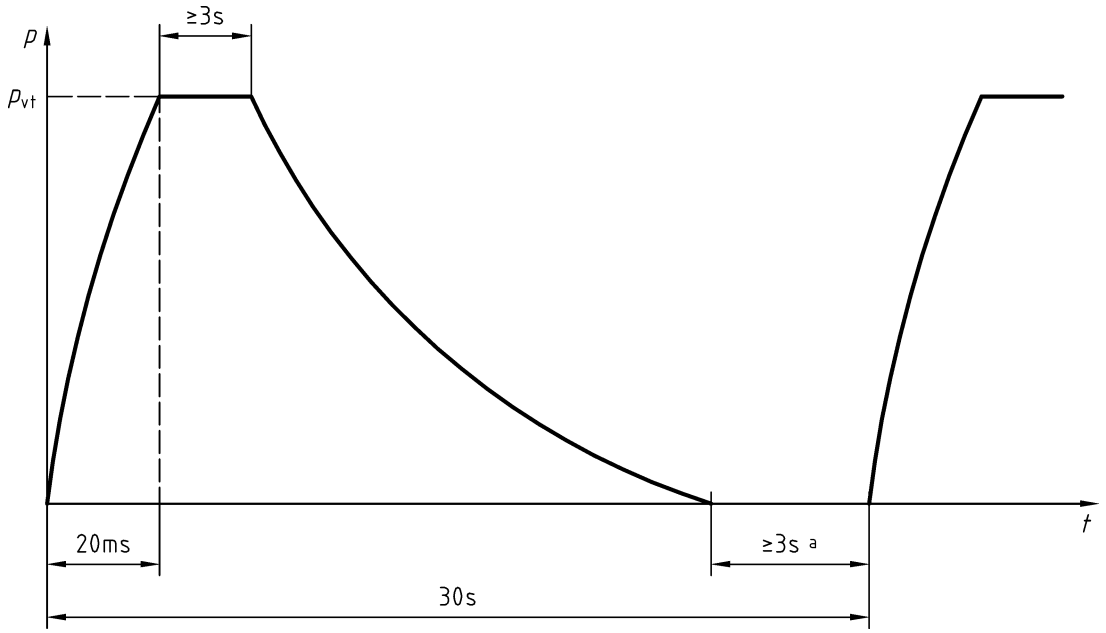
Before the test, the ignition test installation shall be checked for the required pressure rise (for examples of the test installation and pressure cycle specification, see Figures 9 and 10). For this purpose, the sample device, at the end of the 1 m length of copper tube, is replaced by a reliable pressure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



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 copper 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 for oxygen pressure surge test

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

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

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

For calibration purposes, heated oxygen at (60 ± 3) °C with the following quality shall be used:

— minimum purity 99,5 % by volume;

— hydrocarbon content ≤ 0,01 mg m^{-3}.

Each test shall be carried out as follows:

— Supply oxygen at a temperature of (60 ± 3) °C, directly into the connection of the device to be tested, by means of a copper tube having an internal diameter of 5 mm and a length of 1 m. These 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 9.

Table 9 — Test sequence (if applicable)

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

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

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

6.16 Casings and monitors

The casings and monitors shall be immersed in water and pressurised to a rate of 30 m min^{-1}. After 15 min no ingress of water shall be observed.

6.17 Sea water resistance

The complete apparatus with the gas supply in the “turned off” position shall be submerged for 8 h ± 5 min in natural sea water or artificial sea water (see Annex C) 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.

After the four complete cycles the apparatus shall still be fully functional.

6.18 Practical performance

6.18.1 General

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

The practical performance test shall assess the apparatus with regard to the requirements specified in Clause 5 where practical testing is to be performed. For each relevant requirement a qualified statement from the test subject shall be given.

6.18.2 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 requirement for medical supervision before and during the tests shall be decided by the testing authority.

6.18.3 Basic testing

Ten test dives shall be performed.

The tests shall be performed using three apparatus. Each test subject shall dive two different apparatus and each apparatus shall be dived by at least two test subjects.

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

During the test, pre-dive, during the dive and post dive, the apparatus and the information supplied by the manufacturer shall be subjectively assessed by the test subject and the test subject'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 of vision;

e) performance of the apparatus when conducting full range of head and arm movements;

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

g) facepiece comfort, ease of breathing and security of gas supply;

h) any other comments reported by the test subject.

6.18.4 Functional testing when diving

Each of the test dives shall be to a depth of at least 3 m and conducted for at least 25 min or the maximum endurance of the apparatus as stated by the manufacturer:

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

b) jumping test (feet first) from the height of 1,5 m;

c) no continuous leakage while swimming in all orientations (front and back);

d) checking of all monitors and indicators;

e) swimming at maximum speed for a distance of at least 20 m;

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

g) changing to and from an emergency breathing apparatus as defined and/or supplied by the manufacturer;

h) performance of the apparatus in all orientations when conducting full range of head and arm movements;

i) all diver operated controls shall be tested;

j) back roll entry test from a height of between 0,2 m to 1,0 m as specified by the manufacturer.

6.18.5 Pass/fail criteria

Where practical performance tests show the apparatus has imperfections related to test subject's acceptance or if during any activity by any test subject, the device shall be deemed to have failed.

The following examples are obvious reasons for concluding that an apparatus is unacceptable and not fit for use:

a) test subjects that it should fit cannot wear it;

b) it will not stay in place;

c) it compromises a function, e.g. like sight or breathing;

d) simple tasks to be performed when wearing it are impossible;

e) the subject refuses to continue the assessment due to difficulties;

f) the subject reports high levels of discomfort;

g) it prevents the wearing or use of other essential PPE.

6.18.6 Report

A record with final report of the tests performed with test persons shall be kept.

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 can 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 can be easily identified. If sub-assemblies with considerable bearing are too small to be marked or where it is impractical to mark them, the information shall be included in the information by the manufacturer.

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

7.7 Maximum depth and range of water temperature for which the apparatus will meet the requirements of this standard.

7.8 Where applicable, a warning that: "The maximum depth of the apparatus depends on the gas mixture used."

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

7.10 Pictograms may be used for marking.

8 Information supplied by manufacturer

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

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

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

a) application;

b) maximum depth and range of water temperature for which the apparatus will meet the requirements of this standard;

c) gas mixtures to be employed and maximum depth for each mixture;

d) limitations on use;

e) assembly:

    1) components;

    2) connections;

    3) safety devices;

f) assessment of risk:

    1) temperature conditions;

    2) work rates;

    3) expected inspired gas concentrations;

    4) visibility;

5) use of high oxygen content gases;

6) potential long term health effects;

g) apparatus checks:

1) prior to use;

2) post dive;

h) donning and fitting of the apparatus to a proper position on the diver;

i) use;

j) maintenance (preferably separately printed instructions);

k) storage:

1) conditions;

2) shelf lives (where applicable);

3) precautions;

l) inspection intervals.

8.4 The instructions shall include statements on:

a) purity and tolerances of gases to be used;

b) absorbent material(s) to be used and specification for each material provided;

c) 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 wishes to provide.

Annex A
(informative)

Requirement clauses and corresponding test clauses of this European Standard

Table A.1 — Comparison of requirement clauses and test clauses *(1 of 2)*

Requirement Clause		Test Clause(s)
5.1	Design	6.2, 6.3, 6.7, 6.8, 6.15, 6.18
5.2	Materials	6.2, 6.8, 6.9, 6.13, 6.18
5.3	Gas cylinder(s)	6.2
5.4	Cylinder valve(s)	6.2, 6.15, 6.18
5.5	High and medium pressure parts and connections	No specific test
5.5.1	General	6.2, 6.9, 6.18
5.5.2	Pressure reducer (if fitted)	6.2, 6.15, 6.18
5.5.3	Pressure relief system(s)	6.10.5
5.6 5.6.1 5.6.1.1	Breathing circuit Performance requirements General	No specific test
5.6.1.2	Work of breathing (WOB)	6.3.2
5.6.1.3	Respiratory pressures	6.3.2, 6.3.5
5.6.1.4	Hydrostatic imbalance	6.4
5.6.1.5	Maximum inspired partial pressure of carbon dioxide	6.3.3
5.6.1.6	Automatic volume addition system	6.3.5
5.6.2	Breathable volume	6.5.1, 6.18
5.6.3	Breathing circuit test pressure	6.5.2
5.6.4	Exhaust valve	No specific test
5.6.4.1	Maximum pressure within the breathing circuit	6.5.3.1, 6.5.3.2
5.6.4.2	Leakage	6.5.3.2
5.6.5	Inhalation and exhalation valves	6.2, 6.3.2, 6.3.4, 6.3.5, 6.5.4, 6.6.1, 6.6.2, 6.18
5.6.6	Carbon dioxide absorbent canister	6.6.1, 6.6.2
5.6.7	Inhalation temperature	6.3.4
5.6.8	Ingress of water	6.5.5
5.7	Gas control or supply system	No specific test
5.7.1	Inspired partial pressure of oxygen	6.2, 6.7, 6.18
5.7.2	Oxygen partial pressure set point maintenance	6.7
5.7.3	Alphanumeric display for inspired partial pressure of oxygen (if fitted)	6.2, 6.10.2, 6.18
5.7.4	Gas endurance	6.6.1, 6.6.3
5.8	Hose assemblies	No specific test
5.8.1	Tensile strength of high and medium pressure hoses	6.8.2
5.8.2	Flexibility of high and medium pressure hoses	6.8.3
5.8.3	Leakage of high pressure hose assembly	6.8.4

Table A.1 *(2 of 2)*

Requirement Clause		Test Clause(s)
5.8.4	Leakage of medium pressure hose assembly	6.8.5
5.8.5	Burst pressure of high pressure hose assembly	6.8.6
5.8.6	Burst pressure of medium pressure hose assembly	6.8.7
5.8.7	Breathing hose	6.8.8, 6.18
5.9	Safety devices	No specific test
5.9.1	General	6.2, 6.18
5.9.2	Pressure indicator	6.2, 6.10.1.1, 6.10.1.2, 6.10.1.3, 6.18
5.9.3	Monitors for inspired gases	No specific test
5.9.3.1	Monitor for inspired partial pressure of oxygen	6.2, 6.7, 6.10.2, 6.18
5.9.3.2	Monitor for inspired partial pressure of carbon dioxide (if fitted)	6.2, 6.10.3, 6.18
5.9.4	Active warning devices	6.2, 6.10.4.1, 6.10.4.2, 6.18
5.10	Facepiece	No specific test
5.10.1	General	6.2, 6.18
5.10.2	Facepiece harness (if fitted)	6.2, 6.11.4.2, 6.11.4.3, 6.18
5.10.3	Connection	No specific test
5.10.3.1	Half mask, full face mask and helmet	6.2, 6.11.1
5.10.3.2	Mouthpiece	6.2, 6.11.5, 6.18
5.10.4	Eyepiece and visors	6.2, 6.11.2, 6.11.3, 6.18
5.10.5	Head protection against impact (if fitted)	6.2
5.11	Body harness	6.2, 6.18
5.12	Emergency breathing system	6.2, 6.18
5.13	Electrical systems	No specific test
5.13.1	Safety of electrical systems	6.2
5.13.2	Programmable systems	6.2
5.13.3	Electromagnetic compatibility (EMC)	6.2, 6.12
5.13.4	Power source	6.2
5.14	Resistance to temperature	No specific test
5.14.2	Storage	6.13.1, 6.13.2
5.14.1	Pre-drive operation	6.13.1, 6.13.3
5.15	Cleaning and disinfecting	6.2, 6.14
5.16	Connectors	6.17, 6.18
5.17	Oxygen compatibility and cleanliness	6.2, 6.15
5.18	Pressure resistance of casings and monitors	6.13, 6.16
5.19	Sea water resistance	6.2, 6.17
5.20	Practical performance	6.18

Annex B
(normative)

Safety-critical software

B.1 General

The procedures and the requirements given in this Annex relate to safety-critical software, defined as software which, on failure or malfunction could cause, or contribute substantially to, a failure or malfunction of the re-breathing apparatus such that it no longer capable of providing the user with gases having inspired partial pressure within acceptable limits.

Software in apparatus which is provided with an independent (i.e. not dependent on software) means of maintaining breathable gas at all sections of the dive, including that needed to meet any decompression obligations, may be exempt from these requirements. However, where diver intervention is required to switch to such independent means any software controlling the device warning the diver to make this switch is safety-critical.

Specific development techniques are identified below.

These requirements broadly reflect the requirements of EN 61508-3 [14] for software safety functions suitable for Safety Integrity Level (SIL) 1 to 3. Other techniques may also be used, as identified in EN 61508-3 [14].

B.2 Requirements

B.2.1 Software shall be developed by a systematic lifecycle that addresses the following key stages:

— specification;

— design and implementation;

— testing and verification;

— integration of hardware and software;

— modification and maintenance;

— software procurement (e.g. library functions, operating systems, support tools).

B.2.2 Software configuration management shall ensure that changes are adequately managed, controlled and documented.

B.2.3 The software safety requirements (i.e. the re-breather safety functions that are implemented in software) shall be clearly specified.

B.2.4 The software safety requirements shall be reviewed by an independent person. The independent person shall be someone with sufficient knowledge of diving re-breathers and their use to be able to judge if the specification of the software safety requirements (i.e. what the software has to do) is clear, unambiguous and complete. The independent person shall not have contributed to the writing of the software safety requirements and shall have the authority to reject an inadequate specification.

Appropriate specification techniques include state transition diagrams, dataflow diagrams, and so-called ‘formal methods’. The use of appropriate computer based specification support tools is recommended.

B.2.5 The software architecture shall set out the major elements and subsystems of the software and the techniques used for the basic safety strategy.

NOTE Relevant techniques can include fault detection, exception handling, cycle time monitoring and static resource allocation.

B.2.6 Safety-critical and other software shall be adequately separated so that the other software does not interfere with the correct operation of the safety-critical software.

B.2.7 The software design method shall be capable of expressing relevant aspects such as:

— modularity;

— information flow between components;

— sequencing and timing constraints;

— concurrency;

— data structure and properties;

— design assumptions.

NOTE Possible choices of method include state transition diagrams, Petri nets, dataflow diagrams, and so-called formal methods.

B.2.8 The software design shall describe;

— the functionality of the system;

— the data handled and contained within the system;

— the relationship between the data items and system behaviour.

B.2.9 The software design shall facilitate testing by allowing functional and data items to be identified and isolated and suitable tests specified.

B.2.10 The software design shall be implemented in a way that permits verification of compliance with the design specification.

NOTE Possible choices of method include: a strongly typed programming language; a coding standard to restrict focus to a safe subset of language; use of trustworthy computer-aided support tools and language compilers; reuse of verified pre-existing code; automatic code generation.

B.2.11 The source code shall be readable and testable. All source code shall be tested against previously determined and independently reviewed acceptance criteria covering both functionality and relevant non-functional requirements such as constraints on timing, memory and performance.

NOTE Possible choices of method include: functional and black box testing; static analysis of control flow, data flow and timing; dynamic analysis using realistic test data and previously determined coverage criteria.

B.2.12 The software shall be integrated into the hardware. Previously determined and independently reviewed integration tests shall check that the software's interface with the specific hardware provides the functionality expected at the re-breather apparatus "system" level.

B.2.13 Any change to the integrated system found necessary during integration testing shall be analysed to determine all the software modules impacted and the necessary re-verification activities.

B.2.14 There shall be no change to the operational safety software unless it has been authorised by a formal modification request within the quality assurance procedures of the project.

B.2.15 The impact of a proposed software change on the re-breather apparatus safety functions shall be assessed, all affected software modules shall be identified, and all consequent re-verification activities shall be specified.

B.2.16 Over the complete software safety lifecycle the software shall be validated to demonstrate, by examination and provision of objective evidence, that the software satisfies the software safety requirements specification for the re-breather apparatus.

B.2.17 The tests shall show that all of the specified requirements for software safety are correctly performed and the software system does not perform unintended functions.

B.2.18 The results of software safety validation shall be documented for subsequent analysis and independent assessment.

Annex C
(informative)

Artificial sea water

28,0 g NaCl

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

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

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 D
(informative)

Details of significant technical changes between this European Standard and the previous edition

The significant technical changes between this European Standard and the previous edition are the following:

a) expansion of the water temperatures to be outside 4 °C to 34 °C if specified by the manufacturer;

b) inclusion of risk criteria defined in Table 1 to Table 3;

c) clarification of Table 5 — "Hydrostatic imbalance";

d) inclusion of an automatic volume addition system;

e) inclusion of additional requirements for a manual gas control or supply system for the inspired partial pressure of oxygen;

f) inclusion of pass/fail criteria;

g) inclusion of a normative Annex B "Safety-critical software";

h) clear separation of requirements and testing.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 89/686/EEC on Personal Protective Equipment

This European Standard has been prepared under a mandate given to CEN 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 Personal Protective Equipment.

Once this 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 standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard and Directive 89/686/EEC on Personal Protective Equipment

Clause(s)/sub-clause(s) of this EN	Basic Requirement (EU Directive 89/686/EEC, Annex II)	Qualifying remarks/Notes
5.1; 5.4; 5.5.1; 5.5.2; 5.5.3; 5.6.1.4; 5.6.1.5; 5.6.5; 5.6.7; 5.6.8; 5.7.3; 5.8.2; 5.8.7; 5.9.1; 5.9.2; 5.10.1; 5.10.3.1; 5.11; 5.13.1; 5.13.4; 5.14.1; 5.17; 5.18	1.2.1 Absence of risks and other inherent nuisance factors	
5.2	1.2.1.1 Suitable constituent materials	
5.1	1.2.1.2 Satisfactory surface condition of all PPE parts in contact with the user	
5.10.2; 5.11	1.3.1 Adaption of PPE to user morphology	
5.1; 5.2; 5.5.1; 5.6.3; 5.6.4.1; 5.6.4.2; 5.6.5; 5.8.1; 5.8.3; 5.8.4; 5.8.5; 5.8.6; 5.8.7; 5.10.2; 5.10.3.1; 5.10.3.2; 5.10.4; 5.13.3; 5.14.2; 5.19	1.3.2 Lightness and design strength	
5.12	1.3.3 Compatibility of different types of PPE designed for simultaneous use	
5.15; 8	1.4 Information supplied by the manufacturer	
5.5.2	2.1 PPE incorporating adjustment systems	
5.10.4	2.3 PPE for the face, eyes and respiratory tracts	
8	2.8 PPE for use in very dangerous situations	
5.16	2.9 PPE with components that can be adjusted or removed by the user	
5.1	2.10 PPE for connection to another device	
7	2.12 PPE bearing identification marks related to health and safety	
5.10.5	3.1.1 Impact caused by falling or projecting objects and collision of parts of the body with an obstacle	
5.6.1.1; 5.6.1.2; 5.6.1.3; 5.6.2; 5.6.6; 5.7.1; 5.7.2; 5.9.3.1; 5.9.3.2; 5.9.4	3.11 Safety devices for diving equipment	

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

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