BS 8547:2016

BSI Standards Publication

Respiratory equipment – Breathing gas demand regulator used for diving to depths greater than 50 metres – Requirements and test methods

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Contents

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2016. It was prepared by Subcommittee PH/4/7, *Underwater breathing apparatus*, under the authority of Technical Committee PH/4, *Respiratory protection*. A list of organizations represented on these committees can be obtained on request to their secretary.

Relationship with other publications

BS EN 250 gives the requirements for demand regulators to a depth of 50 m. Similarly, BS EN 15333-1 gives the requirements for demand regulators to a depth of 60 m. This British Standard gives requirements for demand regulators in self-contained diving apparatus (BS EN 250) beyond 50 m and for demand regulators in umbilical supplied apparatus (BS EN 15333-1) beyond 60 m.

Information about this document

This British Standard uses the principle of gas density to cover all depth and gas mixtures used below 50 m. The intention of this British Standard is to define the performance requirements for demand diving regulators without imposing a maximum depth limit.

Presentational conventions

The provisions of this British Standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

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

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard specifies minimum performance requirements for diver carried breathing gas demand regulators for open-circuit and saturation gas reclaim systems used for diving to depths greater than 50 m.

This British Standard defines additional requirements for breathing performance and helium compatibility to those already given in BS EN 250 and BS EN 15333-1.

NOTE The basic requirements for diving apparatus and demand regulators as per BS EN 250 and BS EN 15333-1 have been retained. The exception here is for the breathing performance which is revised in this British Standard to cover the requirement for use at depths greater than 50 m.

This British Standard specifies a test method for helium compatibility with a demand regulator and a test method for measuring the work of breathing (WOB) and respiratory pressures of a demand regulator.

This British Standard does not cover auxiliary emergency breathing systems; they are covered in BS EN 250:2014, Annex B.

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.

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

BS EN 250:2014, *Respiratory equipment – Open-circuit self-contained compressed air diving apparatus – Requirements, testing, marking*

BS EN 12021, *Respiratory equipment – Compressed gases for breathing apparatus*

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

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS EN 132 and the following apply.

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

[SOURCE: BS EN 250:2014, **3.9**]

3.2 demand regulator
device which consists of a pressure reducer connected to a single demand valve that is fitted to a face piece

[SOURCE: BS EN 250:2014, **3.19**, modified]

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

[SOURCE: BS EN 250:2014, **3.8**]

3.4 dive/pre-dive control
switch on the demand regulator that in the pre-dive position prevents free-flow when not connected to the respiratory tract

[SOURCE: BS EN 250:2014, **3.26**]

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

[SOURCE: BS EN 250:2014, **3.2**]

3.6 medium pressure
pressure between the pressure reducer and the demand valve

[SOURCE: BS EN 250:2014, **3.3**]

3.7 rated working pressure
maximum working pressure of the respective components

[SOURCE: BS EN 250:2014, **3.4**]

3.8 reference pressure
equilibrium pressure which exists in the face piece when there is no respiratory flow at the end of exhalation

[SOURCE: BS EN 250:2014, **3.5**]

3.9 respiratory minute volume (RMV)
product of the tidal volume and breathing frequency measured in litres per minute

[SOURCE: BS EN 250:2014, **3.10**]

3.10 respiratory pressure
differential pressure in the face piece relative to the reference pressure measured during inhalation and exhalation

[SOURCE: BS EN 250:2014, **3.6**]

3.11 work of breathing (WOB)
external work expended during one breath divided by the tidal volume of that breath, measured in Joule per litre

NOTE 1 This is equivalent to volume average respiratory pressure (kPa). This WOB is, in general, proportional to the area bounded by a pressure volume diagram. Work associated with positive pressures during inhalation does not count towards the total WOB.

[SOURCE: BS EN 250:2014, **3.12**, modified]

NOTE 2 This is specific work, i.e. the work undertaken in ventilating one litre of gas.

4 Demand regulator requirements

4.1 General

Where the demand regulator is part of a self-contained breathing apparatus it shall conform to BS EN 250 for a cold water regulator, except for the requirements in BS EN 250:2014, **5.7.1** which shall be replaced by **4.2** and **4.3**.

Where the demand regulator is part of an umbilical supplied apparatus it shall conform to BS EN 15333-1, except for the requirements in BS EN 15333-1:2008, **5.7.1** which shall be replaced by **4.2** and **4.3**.

*NOTE Providing the regulator has already achieved the requirements in BS EN 250 or BS EN 15333-1, preconditioning as specified in BS EN 250:2014, **6.2.1** or BS EN 15333-1:2008, **6.1.1** is not required prior to conducting tests in accordance with this British Standard.*

The demand regulator shall be provided with a pressure relief system.

4.2 Dive/pre-dive control

If the demand regulator is fitted with a separate dive/pre-dive control, this shall be a two-position switch. If this is a rotational control, the rotation shall not be greater than 180°. The pre-dive setting shall be clearly defined and shall be marked accordingly. Demand regulators which incorporate a dive/pre-dive control shall be tested with the control set to dive position.

4.3 Demand regulator performance

4.3.1 Breathing performance

The breathing performance shall be determined at simulated respiratory minute volume (RMV) up to 75 $L \cdot min^{-1}$ ambient temperature and pressure (ATP).

The performance shall be determined with air at an ambient pressure of 6.0 bar and at the maximum pressure specified by the manufacturer using a gas mixture containing helium and greater than 2% oxygen with a density at that pressure of 7.66 $g \cdot L^{-1}$.

NOTE See Annex A for further information on gas density and gas mixtures.

4.3.2 Work of breathing and respiratory pressure

The WOB at the maximum and minimum sensitivity (measured in $J \cdot L^{-1}$) shall not be greater than a value of:

$$WOB = 0.5 + 0.03 \times RMV$$

The positive WOB during inhalation shall not be greater than 0.3 $J \cdot L^{-1}$.

The peak respiratory pressure during inhalation and exhalation shall be within the range of ±25 mbar.

Pressure spikes (during inhalation) with no measurable positive WOB shall not be greater than 10 mbar. Pressure peaks (during inhalation) with measurable positive WOB shall not be greater than 5 mbar.

4.3.3 Free-flow

When tested in accordance with Clause **5**, the demand regulator shall not free-flow with the sensing diaphragm in the position tested, except for a temporary free-flow of 10 s maximum.

4.4 Helium compatibility

The demand regulator shall be compatible for use with helium. When tested in accordance with **5.5**, it shall:

a) not leak;

b) remain functional; and

c) show no signs of degradation.

5 Testing

5.1 Nominal values and tolerances

Unless otherwise specified, the values shall be subject to a limit deviation of ±5%.

5.2 Test gases

Testing shall be carried out with compressed gas conforming to BS EN 12021.

Gas densities shall be determined assuming the gas is dry and using the values in Table 1.

Table 1 **Gas densities for tests**

Gas	Density at 1 bar (0 m) and 0 °C ($g \cdot L^{-1}$)
Air	1.2762
Helium	0.1764
Oxygen	1.4102
Nitrogen	1.2346

5.3 Breathing system test

5.3.1 Principle

This test method measures the WOB and respiratory pressures of a demand regulator.

5.3.2 Apparatus

5.3.2.1 *Test chamber*

5.3.2.2 *Breathing simulator and associated test equipment*

5.3.2.3 *Calibration test orifice*

5.3.2.4 *Demand regulator under test*

5.4 Test equipment calibration

5.4.1 Breathing simulator

The breathing simulator shall produce a sinusoidal waveform and be capable of simulated RMV at ATP as indicated in Table 2.

5.4.2 Respiratory pressure measurement

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

5.4.3 Calibration

5.4.3.1 The performance characteristics of the breathing simulator test equipment shall be verified by the use of a calibration test orifice as shown in Figure 1.

5.4.3.2 This calibration test orifice shall be inserted into the test equipment in place of a demand regulator.

5.4.3.3 The test chamber shall be pressurized dry using air to 6.0 bar absolute.

5.4.3.4 The breathing simulator test equipment shall be set at a ventilation rate of 62.5 $L \cdot min^{-1}$ as per Table 2.

5.4.3.5 The respiratory pressure at the calibration orifice shall be measured and the performance shall be determined from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced (tidal) volume.

5.4.3.6 The pressure-volume diagram shall be analysed in accordance with Figure 2.

5.4.3.7 The recorded WOB shall be 3.3 $J \cdot L^{-1}$. The recorded inhalation pressure shall be –25 mbar. The recorded exhalation pressure shall be +25 mbar.

5.4.4 Method

5.4.4.1 The demand regulator shall be rigged as though the diver's head is in an upright position.

5.4.4.2 Demand regulators which incorporate adjustable sensitivity controls shall be tested with the settings both at minimum and maximum.

5.4.4.3 The demand regulator shall be supplied with the relevant test gas (see **5.2**).

5.4.4.4 The demand regulator shall be supplied with high pressure gas at the rated working pressure of the demand regulator as specified by the manufacturer and repeated at 50 bar.

5.4.4.5 The test chamber shall be filled with water at 4^{-0}_{+2} °C. There shall be at least 0.2 m of water above the demand regulator to preclude surface effects.

5.4.4.6 Compress the test chamber to the test pressure.

5.4.4.7 The demand regulator shall be tested at 50 bar supply pressure with the breathing simulator set at all the ventilation rates shown in Table 2 and at the maximum working pressure with a ventilation rate of 62.5 $L \cdot min^{-1}$.

5.4.4.8 The respiratory pressure at the mouth shall be measured and the performance shall be determined from the pressure-volume diagram generated by plotting the low (respiratory) pressure against the displaced (tidal) volume. The test duration shall be such as to obtain steady-state performance.

5.4.4.9 The pressure-volume diagram shall be analysed in accordance with Figure 2.

5.4.5 Test report

A test report including the WOB and respiratory pressures shall be produced.

Table 2 **Breathing simulator settings**

Displaced (tidal) volume	**Breathing frequency**	**Ventilation rate**	**Maximum work of breathing**
L	Min^{-1}	$L \cdot min^{-1}$	$J \cdot L^{-1}$
1.0	10	10.0	0.80
1.5	15	22.5	1.18
2.0	20	40.0	1.70
2.5	25	62.5	2.38
3.0	25	75.0	2.75

Figure 1 **Calibration test orifice**

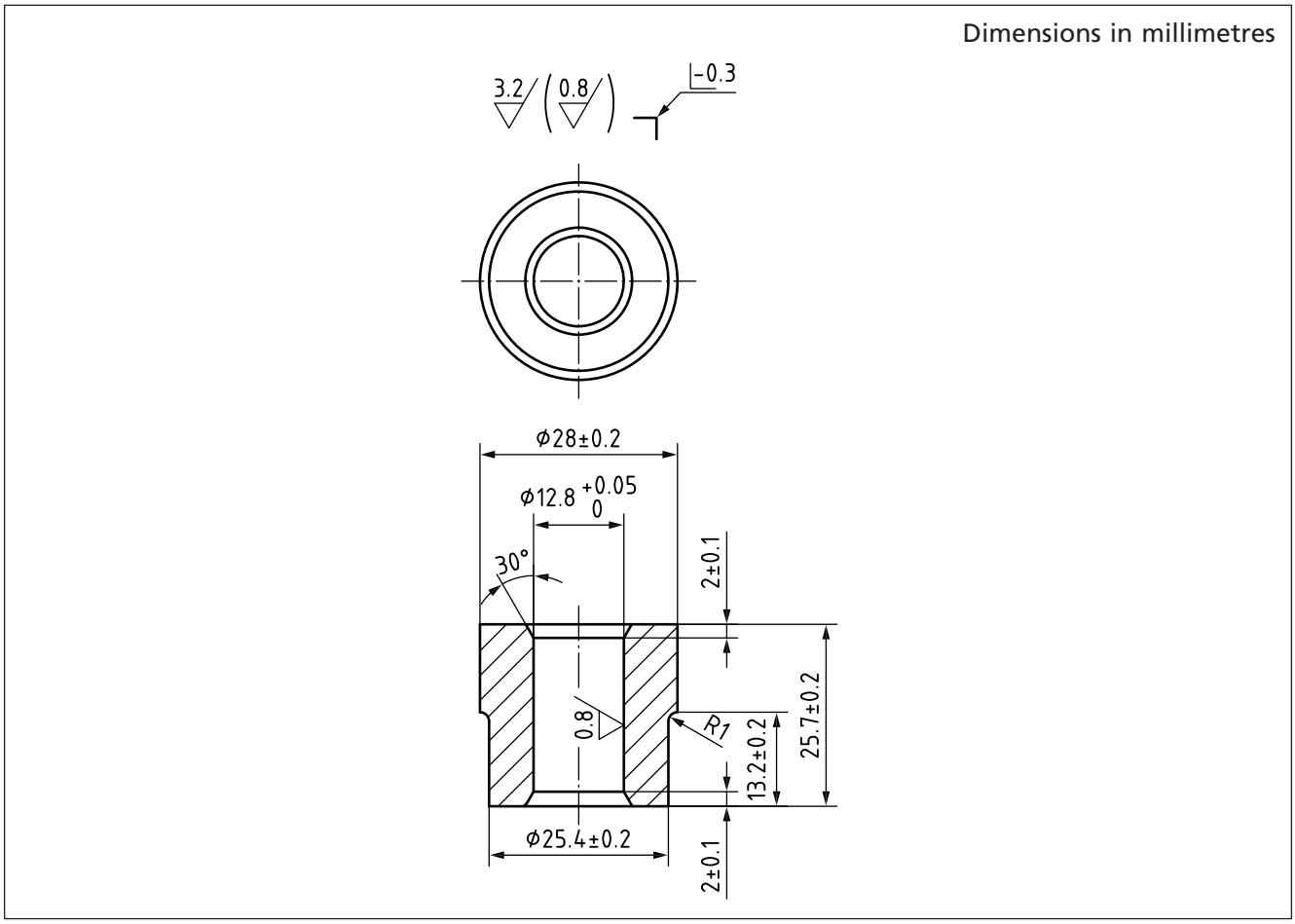
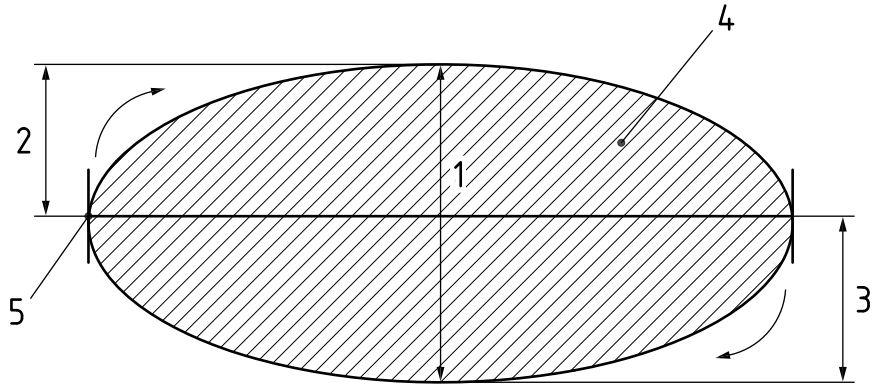


Figure 2 **Analysis of pressure (y axis) volume (x axis) loops**



Key

1 Peak-to-peak respiratory pressure
2 Peak inspired respiratory pressure
3 Reference pressure
4 Peak expired respiratory pressure
5 Work of breathing

5.5 Test for helium compatibility

5.5.1 Principle

This test method checks helium compatibility with a demand regulator.

5.5.2 Apparatus

5.5.2.1 *Demand regulator under test*

5.5.2.2 *Gas supply containing greater than 90% helium*

5.5.2.3 *Device for measuring the medium pressure of the demand regulator*

5.5.2.4 *Tank for immersing regulator under test*

5.5.3 Method

5.5.3.1 The device for measuring the medium pressure shall be fitted.

5.5.3.2 The demand regulator shall be connected to the gas supply.

5.5.3.3 The test shall be undertaken at two pressures: the maximum working pressure of the regulator and at 50 bar.

5.5.3.4 For each test pressure, the demand regulator shall be immersed, purged for 5 s and left immersed for a minimum of 2 h.

5.5.3.5 After stabilization no visual leakage of gas shall be observed for the duration of test; the medium pressure shall be monitored and remain within ±5% of the starting pressure.

5.5.3.6 Post immersion the demand regulator shall be visually inspected for degradation.

5.5.4 Test report

A test report shall be produced.

6 Marking

The apparatus sub-assemblies shall be marked in accordance with BS EN 250:2014, Clause **7** or BS EN 15333-1:2008, Clause **7**, as appropriate.

The demand regulator shall be marked with BS 8547:2016 [1)] and the maximum depth of use in metres.

NOTE It should be marked as "60 m" for example.

7 Information to be supplied to the user

The information supplied shall be in accordance with BS EN 250:2014, Clause **8** or BS EN 15333-1:2008, Clause **8**, as appropriate. The manufacturer shall include a statement on:

a) the maximum depth of use; and

b) gas mixtures that may be used and the maximum depth and density for each mixture.

[1)] Marking BS 8547:2016 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

Annex A (informative) Gas density and gas mixtures

A.1 Gas density

There are a range of standard conditions for defining gas density, but the two in most common use are at a temperature of 0 °C and a pressure of either 1.013 bar or 1.000 bar (see Table A.1). In this British Standard, gas densities have been determined using a standard pressure of 1.000 bar.

Gas density for any diving gas mixture may be calculated using equation A.1.

$$D = PO_2 \times DO_2 + PHe \times Dhe + PN_2 \times DN_2 \quad (A.1)$$

where:

D Density

P Partial pressure

O_2 Oxygen

He Helium

N_2 Nitrogen

Table A.1 **Gas densities**

Gas	Density at 1.013 bar and 0 °C ($g \cdot L^{-1}$)	Density at 1.000 bar (0 m) and 0 °C ($g \cdot L^{-1}$)
Air	1.2928	1.2762
Helium	0.1787	0.1764
Oxygen	1.4285	1.4102
Nitrogen	1.2506	1.2346

A.2 Performance requirements and density

When a demand regulator is tested at 6.0 bar in accordance with BS EN 250:2014, **5.7.1**, the gas density is 7.66 $g \cdot L^{-1}$. To ensure that demand regulators for depths greater than 50 m have a comparable breathing performance to that defined in BS EN 250, the test gas density should also be 7.66 $g \cdot L^{-1}$.

NOTE 1 This allows for an acceptable level of performance and covers the majority of recognized diving practices.

The test gas density of 7.66 $g \cdot L^{-1}$ specified in this British Standard is intended to define demand regulator performance rather than mixtures that are acceptable or proposed for diving.

NOTE 2 When gas at a density of 7.66 $g \cdot L^{-1}$ is breathed, it might result in respiratory limitation and carbon dioxide retention. The user might then become hypercapnic and be predisposed to narcosis and oxygen toxicity.

Breathing gas density for diving and hyperbaric operations should not be greater than 6.3 $g \cdot L^{-1}$; the ideal density is less than 5.2 $g \cdot L^{-1}$.

A.3 Example gas mixtures

Example test gas mixtures which should be used to achieve a nominal density of 7.66 $g \cdot L^{-1}$ are shown in Table A.2. Test gas mixtures shown in Table A.2 should not be used for diving.

NOTE Typical diving gas mixtures are shown in Table A.3.

Table A.2 **Example test gas mixtures to achieve a density of 7.66 g·L^{-1}**

Pressure bar	**Depth** m	**O_2** %	**PO_2** bar	**He** %	**PHe** bar	**N_2** %	**PN_2** bar	**Density** g·L^{-1}
6	50	23.3	1.40	0.0	0.00	76.7	4.60	7.66
7	60	20.0	1.40	16.6	1.16	63.4	4.44	7.66
8	70	17.5	1.40	29.1	2.33	53.4	4.27	7.66
9	80	15.6	1.40	38.8	3.50	45.6	4.10	7.66
10	90	14.0	1.40	46.6	4.66	39.4	3.94	7.66
11	100	12.7	1.40	53.0	5.83	34.3	3.77	7.66
12	110	11.7	1.40	58.3	7.00	30.0	3.60	7.65
13	120	10.8	1.40	62.8	8.17	26.4	3.43	7.65
14	130	10.0	1.40	66.6	9.32	23.4	3.28	7.66
15	140	9.3	1.40	70.0	10.50	20.7	3.11	7.66
16	150	8.8	1.40	72.9	11.66	18.4	2.94	7.66
17	160	8.2	1.40	75.5	12.83	16.3	2.77	7.66
18	170	7.8	1.40	77.7	13.99	14.5	2.61	7.66
19	180	7.4	1.40	79.8	15.17	12.8	2.43	7.65
20	190	7.0	1.40	81.7	16.34	11.3	2.26	7.65
21	200	6.7	1.40	83.3	17.50	10.0	2.10	7.65
26	250	2.0	0.53	89.2	23.18	8.8	2.29	7.66
31	300	2.0	0.63	93.7	29.04	4.3	1.33	7.66
36	350	2.9	1.06	97.1	34.94	0.0	0.00	7.66
41	400	0.9	0.35	99.1	40.66	0.0	0.00	7.66

NOTE The columns shaded highlight the percentage composition of the test gas.

Table A.3 **Example diving gas mixtures**

Pressure bar	**Depth** m	**O_2** %	**PO_2** bar	**He** %	**PHe** bar	**N_2** %	**PN_2** bar	**END** m	**Density** $g \cdot L^{-1}$
5	40	21.0	1.05	35.0	1.75	44.0	2.20	17.8	4.51
6	50	18.0	1.08	45.0	2.70	37.0	2.22	18.1	4.74
		20.0	1.20	40.0	2.40	40.0	2.40	20.4	5.08
7	60	18.0	1.26	50.0	3.50	32.0	2.24	18.4	5.16
		18.0	1.26	45.0	3.15	37.0	2.59	22.8	5.53
		20.0	1.40	43.0	3.01	37.0	2.59	22.8	5.70
8	70	15.0	1.20	55.0	4.40	30.0	2.40	20.4	5.43
		18.0	1.44	50.0	4.00	32.0	2.56	22.4	5.90
9	80	10.0	0.90	70.0	6.30	20.0	1.80	12.8	4.60
		16.0	1.44	56.0	5.04	28.0	2.52	21.9	6.03
10	90	10.0	1.00	70.0	7.00	20.0	2.00	15.3	5.11
		14.0	1.40	60.0	6.00	26.0	2.60	22.9	6.24
11	100	10.0	1.10	75.0	8.25	15.0	1.65	10.9	5.04
		11.0	1.21	73.0	8.03	16.0	1.76	12.3	5.30
16	150	3.0	0.48	97.0	15.52	0.0	0.00	–10.0	3.41
21	200	2.0	0.42	98.0	20.58	0.0	0.00	–10.0	4.22

NOTE 1 Equivalent narcotic depth (END) is based on PN_2 only.

NOTE 2 The columns shaded highlight the percentage composition of the diving gas.

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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