Diver's breathing gas standard and the frequency of examination and tests

HSE information sheet

Diving Information Sheet No 9 (rev2)

Introduction

This diving information sheet (DVIS) is part of a series of information sheets providing guidance on diving at work. It identifies the correct standard to be used for assessing the quality of divers' breathing gas taking into account the 2014 version of BS EN 12021. It details the requirements for breathing gas composition and also provides guidance on the frequency of tests.

Unit symbols and measurement

Throughout this DVIS extracts from EH40/2005 *Workplace Exposure Limits*[1] and BS EN 12021:2014 *Respiratory equipment – Compressed gases for breathing apparatus* [2] are shown as ml m^{-3}, mg m^{-3} and ppm (parts per million by volume).

Legislation

The Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH)[3] and the associated Approved Code of Practice (ACOP) and guidance[4] apply.

Standard for divers' breathing gases

BS EN 12021:2014[2] supersedes the previous 1998 version of the standard and is the appropriate standard for compressed breathing gases used by divers. The 2014 version of the standard provides details of the composition of breathing air, as well as the following breathing gases:

- oxygen compatible air;
- nitrogen depleted air;
- oxygen enriched air;
- breathing oxygen;
- oxygen and nitrogen gas mixtures;
- oxygen and helium gas mixtures;
- oxygen, helium and nitrogen gas mixtures.

Standards for divers' breathing air

The standards for breathing air in BS EN 12021:2014[2] are detailed in Table A:

Table A Composition of breathing air

Component	Concentration at atmospheric pressure
Oxygen	In the range of (21 +/- 1) %
Carbon dioxide	Less than or equal to 500 ml m^{-3} (500 ppm by volume)
Carbon monoxide	Less than or equal to 5 ml m^{-3} (5 ppm by volume)
Oil	Less than or equal to 0.5 mg m^{-3} (Droplets or mist)
Odour/taste	No significant odour or taste
Liquid water	None present

Water content

There should not be any free liquid water content in the breathing gas. The breathing gas must have a dew point sufficiently low to prevent condensation and freezing. The dew point is the temperature where water vapour condenses into liquid water [3]. The allowable water content of diver's breathing air is shown below in Tables B and C:

Table B Water vapour content of high pressure breathing air

Nominal maximum supply pressure	**Maximum water content of air at atmospheric pressure**
40 to 200 bar	Less than or equal to 50 mg m^{-3}
Greater than 200 bar	Less than or equal to 35 mg m^{-3}
Compressors used for charging high pressure cylinders greater than 200 bar	Less than or equal to 25 mg m^{-3}

Water vapour content for breathing air supplied at pressure up to 40 bar

The maximum water content of air supplied at 40 bar and below, ie low pressure air compressor supplies for surface supplied diving equipment and compression chambers is provided in Table C below:

Table C Water vapour content for breathing air up to 40 bar

Nominal maximum supply pressure (bar)	**Maximum water content of air at atmospheric pressure and 20 °C mg m^{-3}**
5	290
10	160
15	110
20	80
25	65
30	55
40	50

Other methods of establishing the maximum permitted water content have been developed. The details are outside the scope of this DVIS, but can be obtained from HSE Research Report 427 Moisture levels in compressed breathing air[6].

Standards for divers' breathing gas – oxygen and nitrogen gas mixtures (nitrox)

The standards for breathing mixtures of oxygen and nitrogen in BS EN 12021:2014[2] are detailed in Table D:

Table D Composition of oxygen and nitrogen mixes

Component	**Concentration at 1013mb and 20 °C**
Oxygen mixes containing <20% by volume ≥20% by volume	(Stated[a] +/- 0.5[b])% (Stated [a] +/- 1.0[b])%)
Nitrogen	Remainder
Water	≤ 15 mg m^{-3}
Carbon Dioxide	≤ 5 ml m^{-3} (ppm)
Carbon Monoxide	≤ 3ml m^{-3} (ppm)
Oil	≤ 0.1 mg – m^{-3}
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent	≤ 30 ml m^{-3}
Other non-toxic gases [c]	< 1%
[a] Percentage as stated by the supplier	
[b] Tolerance value is a percentage of the total gas mixture	
[c] These gases include argon and all other noble gases	

Table D is applicable to oxygen and nitrogen mixtures provided by industrial gas suppliers.

Nitrox mixtures may also be generated by diving contractors themselves using membrane systems, decanting/gas booster systems, or other methods to produce nitrogen depleted air and oxygen enriched air.

Standards for divers' breathing gas – oxygen and helium gas mixtures (heliox)

The standards for breathing mixtures of oxygen and helium in BS EN 12021:2014[2] are detailed in Table E:

Table E Composition of oxygen and helium mixes

Component	Concentration at 1013mb and 20 °C
Oxygen mixes containing ≤ 10% by volume 10% to ≤ 20% by volume ≥20% by volume	 (Stated [a] +/- 0.25 [b])% (Stated [a] +/- 0.5 [b])% (Stated [a] +/- 1.0 [b])%
Helium	Remainder
Water	≤ 15 mg m^{-3}
Carbon Dioxide	≤ 5 ml m^{-3} (ppm)
Carbon Monoxide	≤ 0.2 ml m^{-3} (ppm)
Oil	≤ 0.1 mg m^{-3}
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent	≤ 30 ml m^{-3} (ppm)
Hydrogen	≤ 10 ml m^{-3} (ppm)
Other non-toxic gases [c]	< 0.5%
[a] Percentage as stated by the supplier	
[b] Tolerance value is a percentage of the total gas mixture	
[c] These gases include argon and all other noble gases	

Nitrogen, water and carbon dioxide content applicable to diver gas recovery (reclaim) system compressor samples

The standards for breathing mixtures of oxygen and helium in Table E above are fully applicable to the heliox mixtures provided for saturation diving operations by industrial diving gas suppliers. It is recognised that heliox mixtures found within diver gas recovery (reclaim) systems may have higher levels of moisture, nitrogen and carbon dioxide content than the maximum levels specified in Table E.

Nitrogen

In common with most gases, the physiological effects of nitrogen are related to its partial pressure at the depth it is being inhaled. A maximum of 5% nitrogen content in reclaim gases for depths up to 350 m would be acceptable.

Water content

There is a risk that increased moisture levels may lead to increased corrosion rates inside pressure vessels and pressurised pipework. Where pressure vessels and pressurised pipework are likely to contain higher levels of moisture than the maximum levels specified in Table E (eg inside reclaim systems), it is important for diving contractors to have arrangements in place to ensure that suitable examination, testing and certification of all such plant and equipment is periodically undertaken at an appropriate frequency.

The increased moisture content within reclaim system gas is unlikely to cause internal freezing of regulators and valves etc when gas expands through the system. This is because reclaim systems are not high pressure systems and, in addition, the Joule-Thompson effect means that heliox does not cool on expansion. Nevertheless, the provision of heated gas supplies should also be considered when diving is carried out in cold waters. Divers breathing gas will require active heating for dives deeper than 150 meters.

When operating using breathing gas supplied from a gas recovery (reclaim) system the maximum water vapour content of diver's breathing gas is shown in Table F.

Table F Water vapour content for reclaim system breathing gas up to 40 bar

Nominal maximum supply pressure (bar)	Maximum water content of reclaim system gas at atmospheric pressure and 20 °C mg m^{-3}
10	410
15	280
20	200
25	175
30	145
40	110

Note: Reclaim gas based on dewpoint of 0 °C

Carbon dioxide

The source for diver reclaim make-up gas should comply with the requirements of BS EN 12021:2014 for carbon dioxide levels. The circulating gas supply within the reclaim system should be operated to minimise the carbon dioxide levels. Carbon dioxide levels within the circulating gas of diver reclaim systems should normally be limited to a maximum partial pressure of 5 mbar at the depth of the diver (ie 5000 ml m^{-3} (ppm) when the diver is on the surface, corresponding to 0.5% SEV (surface equivalent value)). With the exceptions of nitrogen, water vapour and carbon dioxide the standards for breathing mixtures of oxygen and helium in Table E should be applied to saturation diving diver reclaim systems.

Other contaminants

A risk assessment should be carried out to establish if any other contaminants should be tested for in addition to those specified in BS EN 12021:2014[2].

Compressor lubricant safety data sheet and/ or the compressor manufacturer's operation and maintenance manuals should be checked to see if there are any specific substances that should be tested for. In addition, the location of the compressor inlet should be checked in order to ensure that contaminated gas is not drawn in. If you do identify potential sources of contamination (such as ventilation exhausts) and cannot re-locate the compressor inlet, then you should determine the likely contaminants. If there is any doubt, additional tests for the likely contamination and more frequent tests may be necessary.

For UK application, where the gas is to be used for breathing at ambient pressures greater than 10 bar and/or periods in excess of 8 hours, the calculations given in EH 75/2 Occupational exposure limits for hyperbaric conditions should be applied to take account of the increased pressure and/or duration.

Frequency of tests

A competent person (see Note 2) should carry out the breathing gas tests. The purpose of periodic testing is to make sure that the control measures you have put in place are delivering the gas quality required by BS EN 12021:2014[2] (as required by the appropriate tables above). The frequency of tests should be based on a risk assessment, but tests should take place at least every three months where the source of the divers' breathing gas is a compressor system (including a reclaim compressor system unless deemed 'oil free' by the original equipment manufacturer), and more often when the quality of the breathing gas cannot be assured to these levels.

Additional methods of assuring gas quality

Monitor filter life by measuring running hours or the volume of cylinders filled. Both of these methods rely on the contamination not exceeding the levels assumed by the manufacturer in setting the recommended hours or throughput.

A more reliable method of assurance is for continuous in-line gas quality monitoring.

One technique is to continuously monitor the moisture content of the filter cartridge. Filter cartridges are usually designed so that the drying element becomes saturated before there is any deterioration of the other elements. Monitoring the moisture content of the gas at the filter outlet can indicate when the filter has reached the end of its life.

Carbon monoxide (CO) can be produced within a compressor as a result of breakdown of the lubricating oil caused by pyrolysis (chemical decomposition by heat). Pyrolysis can occur when the system is hot, but not necessarily overheating and the resulting short term high levels of CO would not necessarily be identified during periodic sampling. To minimise this hazard a CO catalyst in the filter system and/or online monitoring for CO content should be considered.

Do not modify any filtration systems or compressors without seeking advice from the compressor and/or filter manufacturer.

Checking contents of breathing mixtures

Experience shows that it is possible for a gas mixture to be supplied which does not correspond to thecylinder markings. All diving breathing mixtures should be checked on receipt and re-checked immediately prior to connecting them to a diving gas supply or breathing apparatus charging system.

Notes

1 Workplace Exposure Limits (WELs) are Occupational Exposure Limits (OELs) set under COSHH,[3] in order to help protect the health of workers.

2 A 'competent person' is a person having a combination of training, knowledge and experience that will mean they can do the job required in a safe and efficient manner, using the test apparatus provided for the task. The duty holder will have to decide who the 'competent person' will be.

3 Where the apparatus is used and stored at a known temperature the pressure dew point shall be at least 5°C below the likely lowest temperature.

Where the conditions of usage and storage of any compressed air supply is not known the pressure dew point shall not exceed -11°C

References

1 *EH40/2005 Workplace Exposure Limits: Containing the list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations 2002* www.hse.gov.uk

2 *BS EN 12021:2014 Respiratory equipment – Compressed gases for breathing apparatus* www.bsigroup.com

3 *The Control of Substances Hazardous to Health Regulations 2002* www.legislation.gov.uk

4 *Control of substances hazardous to health (Sixth edition). The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance L5 (Sixth edition) HSE Books 2013 ISBN 978 0 7176 65822* www.hse.gov.uk

5 *EH 75/2 Occupational exposure limits for hyperbaric conditions : Hazard assessment document HSE Books 2000 ISBN 978 0 7176 1899 6*

6 *HSE Research Report 427 Moisture levels in compressed breathing air* www.hse.gov.uk

7 *Respiratory protective equipment at work – a practical guide* HSG 53: (Fourth edition) HSE Books 2013 ISBN 978 0 7176 6454 2 www.hse.gov.uk

Further reading

Commercial diving projects inland/inshore. Diving at Work Regulations 1997. Approved Code of Practice and guidance L104 (Second edition) HSE Books 2014 ISBN 978 0 7176 6593 8 www.hse.gov.uk/pubns/books/l104.htm

Commercial diving projects offshore. Diving at Work Regulations 1997. Approved Code of Practice and guidance L103 (Second edition) HSE Books 2014 ISBN 978 0 7176 6592 1 www.hse.gov.uk/pubns/books/l103.htm

Recreational diving projects. Diving at Work Regulations 1997. Approved Code of Practice and guidance L105 (Second edition) HSE Books 2014 ISBN 978 0 7176 6594 5 www.hse.gov.uk/pubns/books/l105.htm

Media diving projects. Diving at Work Regulations 1997. Approved Code of Practice and guidance L106 (Second edition) HSE Books 2014 ISBN 978 0 7176 6595 2 www.hse.gov.uk/pubns/books/l106.htm

Scientific and archaeological diving projects. Diving at Work Regulations 1997. Approved Code of Practice and guidance L107 (Second edition) HSE Books 2014 ISBN 978 0 7176 6596 9 www.hse.gov.uk/pubns/books/l107.htm

The Diving at Work Regulations 1997 SI 1997/2776 The Stationery Office 1997 ISBN 0 11 065170 7

Are you involved in a diving project at work? A brief guide to complying with health and safety law. Leaflet INDG266(rev 2) www.hse.gov.uk/pubns/indg266.htm

Further information

For information about health and safety, or to report inconsistencies or inaccuracies in this guidance, visit www.hse.gov.uk/. You can view HSE guidance online and order priced publications from the website. HSE priced publications are also available from bookshops.

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory, unless specifically stated, and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance.

This leaflet is available at: http://www.hse.gov.uk/pubns/dvis9.pdf.