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Respiratory protective devices – Breathing gases for diving and hyperbaric applications – Requirements and test methods

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 16, an inside back cover and a back cover.

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Foreword

Publishing information

This British Standard is published by BSI and came into effect on 28 February 2011. 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.

Supersession

This British Standard supersedes BS 8478:2006, which is withdrawn.

Information about this document

This standard specifies requirements for the composition and purity of breathing gases, other than compressed air, for diving and hyperbaric applications. Compressed air for breathing apparatus is specified in BS EN 12021.

The toxic and harmful effects of impurities in breathing gases are increased at hyperbaric pressures. The limiting levels of impurities specified in this standard, which are given as values corrected to normal atmospheric pressure, have been reduced to allow for this effect.

This is a full revision of the standard, and introduces the following principal changes.

a) Requirements for the composition of oxygen compatible air and the composition of nitrogen depleted air have been added.

b) Requirements for the composition of helium for making breathing gas mixtures has been added.

c) Requirements for the mixing of gases have been added.

d) Requirements for freedom from particulate contamination are no longer specified.

e) The maximum permissible water content in breathing oxygen, oxygen and nitrogen gas mixtures, oxygen and helium gas mixtures and oxygen, helium and nitrogen gas mixtures has been raised from $5\ \mathrm{mg\cdot m^{-3}}$ to $15\ \mathrm{mg\cdot m^{-3}}$.

f) For oxygen and helium gas mixtures, the maximum carbon monoxide content has been reduced from 1 ppm to 0.2 ppm, and the maximum content of “other non-toxic gases” has been reduced from <1% to <0.5%.

g) The sampling requirements have been changed.

h) The test method for oil content has been changed so that it no longer requires the use of trichloro-trifluoro-ethane as, under the Montreal Protocol on Substances that Deplete the Ozone Layer [1], the manufacture of this substance is not permitted.

i) Methods have been added for stain detector tube and stain system analysis for carbon monoxide, carbon dioxide, water and oil content in gases derived from compressed air (see **5.14**).

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this 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.

In particular, attention is drawn to the Control of Substances Hazardous to Health Regulations 2002 (as amended).

1 Scope

This British Standard specifies requirements and test methods for the composition and purity of breathing gases, other than compressed air as specified in BS EN 12021, for use in diving and hyperbaric applications.

The standard is applicable to the following categories of breathing gas mixtures:

a) breathing oxygen;

b) oxygen compatible air;

c) nitrogen depleted air;

d) oxygen and nitrogen gas mixtures;

e) oxygen and helium gas mixtures;

f) oxygen, helium and nitrogen gas mixtures.

The standard also specifies requirements and test methods for the purity of helium for use in making breathing gas mixtures.

The standard is not applicable to compressed gases for medical use, or to gases for use in high altitude breathing apparatus.

NOTE The composition and purity of compressed air is specified in BS EN 12021.

2 Normative references

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

BS EN 1089-3, *Transportable gas cylinders – Gas cylinder identification (excluding LPG) – Part 3: Colour coding*

BS EN ISO 7225, *Gas cylinders – Precautionary labels*

BS EN ISO 13769, *Gas cylinders – Stamp marking*

BS ISO 8573-2, *Compressed air – Part 2: Test methods for oil aerosol content*

HEALTH AND SAFETY EXECUTIVE. *Workplace exposure limits.* Guidance Note EH 40. Sudbury: HSE Books.

HEALTH AND SAFETY EXECUTIVE. *Occupational exposure limits for hyperbaric conditions.* Hazard Assessment Document EH 75/2. Sudbury: HSE Books.

3 Terms and definitions

For the purposes of this British Standard the following terms and definitions apply.

3.1 oxygen compatible air

compressed natural breathing air where the level of impurities has been reduced to make it suitable for use in gas mixtures containing oxygen concentrations greater than 22%

NOTE 1 Oxygen compatible air is also known in the diving industry as "oil free air", "clean air" or "double filtered air".

NOTE 2 When oxygen compatible air is mixed with oxygen the mixture may be known as "nitrox".

NOTE 3 When oxygen compatible air is mixed with helium the mixture may be known as "trimix".

3.2 nitrogen depleted air

compressed natural breathing air from which some nitrogen has been removed and where the levels of impurities have been reduced, to make it suitable for use in, or as, a gas mixture containing oxygen concentrations greater than 22%

NOTE Nitrogen depleted air may also be known as "nitrox".

3.3 oxygen and nitrogen gas mixture

gas mixture produced by mixing oxygen and nitrogen, capable of supporting human life under appropriate diving or hyperbaric conditions

NOTE 1 This definition does not cover gas mixtures produced using oxygen compatible air or nitrogen depleted air.

NOTE 2 Oxygen and nitrogen gas mixtures may also be known as "nitrox".

3.4 oxygen and helium gas mixture

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

NOTE Oxygen and helium gas mixtures may be known as "heliox".

3.5 oxygen, helium and nitrogen gas mixture

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

NOTE Oxygen, helium and nitrogen gas mixtures may be known as "trimix".

3.6 bundle of cylinders

assembly of cylinders that are fastened together and that are interconnected by a manifold

4 Requirements

4.1 Freedom from toxic components

The gas shall be tested in accordance with **5.5** or **5.7**. If in the test any constituents of the gas are identified that are not listed in Table 1 to Table 7, these constituents shall be checked against the list of substances for which workplace exposure limits are given in HSE Guidance Note EH 40. No constituent listed in EH 40 shall be present at a level in excess of one tenth of the eight hour workplace exposure limit given in EH 40.

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 to take account of the increased pressure and/or duration shall be applied.

NOTE At ambient pressures greater than 10 bar the level of contaminants needs to be less than one tenth of the workplace exposure limit given in EH 40. Therefore, the calculations given in EH 75/2 need to be applied.

4.2 Freedom from odour

A sample of a gas which has been shown to conform to **4.1** shall be assessed in accordance with **5.3**. If there is any odour classified by any of the assessors as "unsatisfactory" the gas shall be deemed not to conform to the standard.

4.3 Composition of breathing oxygen

When tested using the methods specified in Table 1, the composition of the gas shall conform to the requirements specified in Table 1.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 1 **Composition of breathing oxygen**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)	>99.5	**5.9**
Water (mg·m^{-3})	≤15	**5.4**
Carbon dioxide (ppm)	≤5	**5.5** or **5.6**
Carbon monoxide (ppm)	≤1	**5.5** or **5.6**
Oil (mg·m^{-3})	<0.1	**5.13**
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤30	**5.5** or **5.6**
Total chlorofluorocarbons and halogenated hydrocarbons (ppm)	≤2.0	**5.5** or **5.7**
Total other non-toxic gases (%) [A)]	<0.5	**5.8**

[A)] These gases include argon and other group 18 noble gases.

4.4 Composition of oxygen compatible air

The composition of the oxygen compatible air shall conform to the requirements specified in Table 2. The air shall be tested using the test methods specified in Table 2.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 2 **Composition of oxygen compatible air**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)	21 ±1 [A)]	**5.9**
Nitrogen (%)	Remainder	—
Water (mg·m^{-3})	≤25	**5.4** or **5.14**
Carbon dioxide (ppm)	≤500	**5.5**, **5.6** or **5.14**
Carbon monoxide (ppm)	≤3	**5.5**, **5.6** or **5.14**
Oil (mg·m^{-3})	<0.1	**5.13** or **5.14**

[A)] Tolerance value is a percentage of the total gas mixture.

4.5 Composition of nitrogen depleted air

The composition of the nitrogen depleted air shall conform to the requirements specified in Table 3. The nitrogen depleted air shall be tested using the test methods specified in Table 3.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 3 **Composition of nitrogen depleted air**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)		**5.9**
Mixtures containing <40% by volume	Stated [A] ±0.5 [B]	
Mixtures containing ≥40% by volume	Stated [A] ±1.0 [B]	
Nitrogen (%)	Remainder	—
Water (mg·m^{-3})	≤25	**5.4** or **5.14**
Carbon dioxide (ppm)	≤500	**5.5**, **5.6** or **5.14**
Carbon monoxide (ppm)	≤3	**5.5**, **5.6** or **5.14**
Oil (mg·m^{-3})	<0.1	**5.13** or **5.14**

[A] As stated by the supplier.

[B] Tolerance value is a percentage of the total gas mixture.

4.6 Composition of oxygen and nitrogen gas mixtures

When tested using the methods specified in Table 4, the composition of the gas mixture shall conform to the requirements specified in Table 4.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 4 **Composition of oxygen and nitrogen gas mixtures**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)		**5.9**
Mixtures containing <40% by volume	Stated [A] ±0.5 [B]	
Mixtures containing ≥40% by volume	Stated [A] ±1.0 [B]	
Nitrogen (%)	Remainder	**5.11**
Water (mg·m^{-3})	≤15	**5.4**
Carbon dioxide (ppm)	≤5	**5.5** or **5.6**
Carbon monoxide (ppm)	≤3	**5.5** or **5.6**
Oil (mg·m^{-3})	<0.1	**5.13**
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤30	**5.5** or **5.6**
Total other non-toxic gases (%) [C]	<1	**5.8**

[A] Percentage as stated by the supplier.

[B] Tolerance value is a percentage of the total gas mixture.

[C] These gases include argon and other group 18 noble gases.

4.7 Composition of oxygen and helium gas mixtures

When tested using the methods specified in Table 5, the composition of the gas mixture shall conform to the requirements specified in Table 5.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 5 **Composition of oxygen and helium gas mixtures**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)		**5.9**
Mixtures containing ≤10% by volume	Stated[A)] ±0.25[B)]	
Mixtures containing >10% to ≤20% by volume	Stated[A)] ±0.5[B)]	
Mixtures containing >20% by volume	Stated[A)] ±1.0[B)]	
Helium (%)	Remainder	**5.12**
Water ($mg \cdot m^{-3}$)	≤15	**5.4**
Carbon dioxide (ppm)	≤5	**5.5** or **5.6**
Carbon monoxide (ppm)	≤0.2	**5.5** or **5.6**
Oil ($mg \cdot m^{-3}$)	<0.1	**5.13**
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤30	**5.5** or **5.6**
Hydrogen (ppm)	≤10	**5.10**
Total other non-toxic gases (%)[C)]	<0.5	**5.8**

[A)] As stated by the supplier.

[B)] Tolerance value is a percentage of the total gas mixture.

[C)] These gases include argon and other group 18 noble gases.

4.8 Composition of oxygen, helium and nitrogen gas mixtures

When tested using the methods specified in Table 6, the composition of the gas mixture shall conform to the requirements specified in Table 6.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

4.9 Helium

WARNING. Helium is specified in this standard as a gas for mixing with other gases to produce an appropriate breathing gas for diving. Helium is an asphyxiant; it should never be used alone as a breathing gas.

When tested using the methods specified in Table 7, the composition of the gas shall conform to the requirements specified in Table 7.

NOTE All values specified, with the exception of water and oil, are proportions by volume of dry gas. The value specified for oil is a mass per unit volume of dry gas.

Table 6 **Composition of oxygen, helium and nitrogen gas mixtures**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)		**5.9**
Mixtures containing ≤10% by volume	Stated [A] ±0.25 [B]	
Mixtures containing >10% to ≤20% by volume	Stated [A] ±0.5 [B]	
Mixtures containing >20% by volume	Stated [A] ±1.0 [B]	
Helium (%)	Stated [A] ±1.0 [B]	**5.12**
Nitrogen (%)	Remainder	**5.11**
Water (mg·m^{-3})	≤15	**5.4**
Carbon dioxide (ppm)	≤5	**5.5** or **5.6**
Carbon monoxide (ppm)	≤0.2	**5.5** or **5.6**
Oil (mg·m^{-3})	<0.1	**5.13**
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤30	**5.5** or **5.6**
Hydrogen (ppm)	≤10	**5.10**
Total other non-toxic gases (%) [C]	<1	**5.8**

[A] As stated by the supplier.

[B] Tolerance value is a percentage of the total gas mixture.

[C] These gases include argon and other group 18 noble gases.

Table 7 **Composition of helium**

Component	**Concentration at 1.013 bar and 20 °C**	**Test method specified in subclause**
Oxygen (%)	<0.1	**5.9**
Helium (%)	>99.9	**5.12**
Water (mg·m^{-3})	≤15	**5.4**
Carbon dioxide (ppm)	≤5	**5.5** or **5.6**
Carbon monoxide (ppm)	≤0.2	**5.5** or **5.6**
Oil (mg·m^{-3})	<0.1	**5.13**
Total volatile non-substituted hydrocarbons (vapour or gas) as methane equivalent (ppm)	≤30	**5.5** or **5.6**
Hydrogen (ppm)	≤10	**5.10**
Total other non-toxic gases (%) [A]	Remainder	**5.8**

[A] These gases include argon and other group 18 noble gases.

4.10 Mixing of gases

Where any of the gases specified in Table 1 to Table 7 are mixed to produce a diving breathing gas, the resultant gas mixture shall be tested for oxygen content in accordance with **5.9**. The oxygen content shall conform to the relevant value as given for the particular gas mixture in Table 3 to Table 6, as applicable.

Where any of the gases specified in Table 5 to Table 7 are mixed to create a diving breathing gas, the resultant gas mixture shall be tested for helium content in accordance with **5.12**. The helium content shall conform to the relevant value as given for the particular gas mixture in Table 5 or Table 6, as applicable.

NOTE As the purity and contaminant levels of the gases used for mixing are specified in Table 1 to Table 7 it is only the ratio of the mixing that needs to be confirmed. Therefore, post mixing, only the oxygen and, where applicable, the helium content need to be tested to confirm that the correct mixture has been achieved.

5 Test methods

WARNING 1. Care should be taken to ensure that the gas stream issuing from an outlet port is vented safely to waste when tests are carried out on gases containing more than 21% oxygen or less than 12% oxygen as these could otherwise give rise to oxygen enrichment or oxygen depletion respectively.

WARNING 2. Gas samples should not be taken directly from a high pressure source as this can be hazardous. The pressure of the gas being sampled should always be reduced by means of a pressure regulator.

5.1 General

All gas analysis results shall be corrected to 1.013 bar [1] and 20 °C.

5.2 Sampling

Samples shall be taken from a pressure receptacle (cylinder), or from the point of supply (charging connection).

Samples shall be taken and analysed at least every six months or more frequently if there has been a change in, or concerns relating to, the production process.

NOTE Stored gases that have been shown to conform to this standard do not need to be retested. However, if the gases have been stored for an extended period of time it is recommended that the oxygen level is checked prior to use.

5.3 Method for assessment of odour

WARNING. Assessments should always be carried out under close supervision by a person qualified in first aid, in case an assessor should become unwell.

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[1] 1 bar = 10^5 Pa.

5.3.1 Assessors

At least two assessors shall assess each gas mixture. The assessors shall be non-smokers and shall be free from symptoms of upper respiratory tract infection. The assessors shall be instructed to avoid environments containing tobacco smoke and to avoid using perfumed products, including perfumed soap, deodorant or aftershave, for the 12 h preceding the assessment. They shall also be instructed to wear clothing that is free from odours such as perfumed detergents or fabric softeners and tobacco smoke.

The assessors shall wash their hands in unperfumed soap immediately before the assessment, and shall wear eye protection and ear protection during the assessment. The assessors shall have a break of not less than 30 min in fresh air, away from the laboratory, between assessments of different gas mixtures.

5.3.2 Apparatus

5.3.2.1 *Glass beakers*, 200 ml capacity, which have been washed in hot water and unperfumed detergent and allow to air dry. A fresh beaker shall be used for each assessment.

5.3.3 Procedure

For each assessor, a regulated flow of the gas being assessed shall be passed into a beaker (**5.3.2.1**) and the assessor shall sniff the gas, taking short breaths only.

The assessor shall rate the gas as follows:

- *Satisfactory*: Gas has no detectable odour, or has a slight odour that, in the opinion of the assessor, could be easily tolerated for an extended period of time.
- *Unsatisfactory*: Gas has an unpleasant odour, or one that, in the opinion of the assessor, could not be tolerated for an extended period of time.

If the gas has any odour, the assessor shall give a brief description, e.g. oily, acidic, musty or sulfurous.

The assessors’ ratings, and descriptions of any odour, shall be recorded in the test report.

5.4 Method for determination of water content

5.4.1 Apparatus

5.4.1.1 *Direct reading hygrometer*, of one of the following types:

- cooled mirror dew point;
- electrolytic;
- capacitance;
- piezoelectric.

The hygrometer shall have a current certificate of calibration demonstrating traceability to a national or international standard of measurement which, in the UK, is the responsibility of the National Physical Laboratory (NPL).

When not in use the hygrometer shall be purged with a dry gas having a water content <2 mg·m^{-3}.

5.4.1.2 *Sample lines*, made of an impermeable material, such as stainless steel, or a material of low permeability, such as polytetrafluoroethylene.

NOTE The sample lines should be kept as short as is practicable, with a minimum number of joints.

5.4.2 Procedure

Fit an open sample line to the outlet of the hygrometer to minimize any back diffusion of water vapour through the outlet port.

Pass a sample of the gas under test into the hygrometer in accordance with the manufacturer's instructions. Measure and record the temperature and pressure of the gas.

Operate the hygrometer in accordance with the manufacturer's instructions and record the reading.

5.4.3 Calculations

Correct the reading obtained from the hygrometer to a water content at 1.013 bar and 20 °C, expressed in milligrams per cubic metre (mg·m^{-3}).

Record the corrected value in the test report.

5.5 Method for determination of infra-red active trace contaminants

*COMMENTARY ON **5.5***
*The determination of oil content as described in **5.13** may be carried out as part of this determination. It is not necessary to run a separate test.*

5.5.1 Principle

An infra-red spectrometer is used to determine the infra-red absorption spectrum of the gas. As oxygen, nitrogen and helium have no oscillating dipole moments they do not have an infra-red absorption spectrum. Thus, the infra-red absorption spectrum produced in the test can be used to identify trace impurities.

5.5.2 Apparatus

5.5.2.1 *Scanning infra-red spectrometer*, fitted with a gas cell with a minimum optical path length of 10 m.

5.5.3 Materials

5.5.3.1 *Reference samples of the relevant trace contaminants*.

5.5.4 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the spectrometer, and measure the infra-red absorption spectrum, in accordance with the manufacturer's instructions.

Identify trace contaminants in the gas using the relevant infra-red frequency bands as given in Table 8.

For each contaminant identified, calibrate the apparatus in accordance with the manufacturer's instructions using the relevant reference sample, or samples, (**5.5.3.1**). Use this calibration to determine the concentration of the contaminant.

5.5.5 Calculations

Correct the concentrations of trace contaminants to 1.013 bar and 20 °C, expressed in parts per million (ppm).

Record the corrected values in the test report.

Table 8 **Infra-red absorbance bands**

Band	**Compound**	**Frequency band(s)** cm^{-1}
1	Ethane (under methane peak)	3 200 to 2 700
2	Carbon dioxide	3 750 to 3 550 2 400 to 2 250 800 to 600
3	Carbon monoxide	2 250 to 2 000
4	Nitrous oxide	3 500 to 3 450 2 600 to 2 500 2 250 to 2 150
5	Freon 12 (dichlorodifluoromethane)	1 180 to 1 060 940 to 850
6	Freon 22 (chlorodifluoromethane)	1 180 to 1 060 860 to 760
7	Freon 134a (1,1,1,2-tetrafluoroethane)	1 300 to 1 100
8	Ethylene (Interferes with freon 12)	1 100 to 840
9	Acetylene	820 to 650
10	Methane	1 380 to 1 200
11	Water	4 050 to 3 400 2 000 to 1 300
12	Solvent region	1 300 to 600

5.6 Method for determination of CO, CO$_2$ and volatile non-substituted hydrocarbons

5.6.1 Apparatus

5.6.1.1 *Infrared gas analyser(s)*, using the absorption bands 1, 2 and 3 identified in Table 8. The equipment shall be calibrated in accordance with the manufacturer's instructions.

5.6.2 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce sample(s) of the gas under test into the measuring equipment(s) in accordance with the manufacturer's instructions and record the CO and CO_2 content and volatile non-substituted hydrocarbon content as methane equivalent.

5.6.3 Calculations

Correct the concentrations of CO and CO_2 and volatile non-substituted hydrocarbon to 1.013 bar and 20 °C, and express the concentration as parts per million by volume of the whole sample.

Record the corrected value in the test report.

5.7 Method for determination of trace contaminants

5.7.1 Apparatus

5.7.1.1 *Gas chromatograph or mass spectrometer*, with reference spectra.

5.7.2 Materials

5.7.2.1 *Reference samples of the relevant trace contaminants*.

5.7.3 Procedure

Measure and record the temperature and pressure of the gas sample. Pass a sample of the gas under test through the apparatus. Identify the trace contaminant(s) by use of the reference spectra (**5.7.1.1**).

For each contaminant identified, calibrate the apparatus in accordance with the manufacturer's instructions using the relevant reference sample, or samples, (**5.7.2.1**). Use this calibration to determine the concentration of the contaminant.

5.7.4 Calculations

Correct the concentration of each gas to 1.013 bar and 20 °C, and express the concentration in parts per million by volume of the whole sample.

Record the corrected values in the test report.

5.8 Method for determination of other non-toxic gases

5.8.1 Apparatus

5.8.1.1 *Gas chromatograph or mass spectrometer*, with reference spectra.

5.8.2 Materials

5.8.2.1 *Reference samples of the relevant non-toxic gases*.

5.8.3 Procedure

Measure and record the temperature and pressure of the gas sample. Pass a sample of the gas under test through the apparatus. Identify the trace contaminant(s) by use of the reference spectra (**5.8.1.1**).

For each contaminant identified, calibrate the apparatus in accordance with the manufacturer's instructions using the relevant reference sample, or samples, (**5.8.2.1**). Use this calibration to determine the concentration of the contaminant.

5.8.4 Calculations

Correct the concentration of each gas to 1.013 bar and 20 °C, and express the concentration as a percentage by volume of the whole sample.

Record the corrected values in the test report.

5.9 Method for determination of oxygen concentration

5.9.1 Apparatus

5.9.1.1 *Oxygen measurement equipment*.

For gas mixtures containing ≥40% oxygen the equipment shall be able to measure gaseous oxygen levels to ±1.0%.

For gas mixtures containing <40 % oxygen the equipment shall be able to measure gaseous oxygen levels to ±0.5%.

For gas mixtures containing ≤20% oxygen the equipment shall be able to measure gaseous oxygen levels to at least ±0.25%.

For pure oxygen (i.e. as specified in Table 1) the equipment shall be able to measure gaseous oxygen levels to ±0.25%.

The equipment shall be calibrated in accordance with the manufacturer's instructions.

5.9.2 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the measuring equipment in accordance with the manufacturer's instructions and record the oxygen content.

5.9.3 Calculations

Correct the concentration of oxygen to 1.013 bar and 20 °C, and express the concentration as a percentage by volume of the whole sample.

Record the corrected value in the test report.

5.10 Method for determination of hydrogen concentration

5.10.1 Apparatus

5.10.1.1 *Gas chromatograph*, fitted with a sample loop and a suitable detector, such as a helium ionization detector or a thermal conductivity detector. The gas chromatograph shall be calibrated in accordance with the manufacturer's instructions.

5.10.2 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the gas chromatograph using the sample loop, and measure the concentration of hydrogen in accordance with the manufacturer's instructions.

5.10.3 Calculations

Correct the concentration of hydrogen to 1.013 bar and 20 °C, and express the concentration as a percentage by volume of the whole sample.

Record the corrected value in the test report.

5.11 Method for determination of nitrogen concentration

5.11.1 Apparatus

5.11.1.1 *Nitrogen measurement equipment*, able to measure gaseous nitrogen levels to an accuracy of 0.1% (e.g. a respiratory gas mass spectrometer). The equipment shall be calibrated in accordance with the manufacturer's instructions.

5.11.2 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the measuring equipment in accordance with the manufacturer's instructions and record the nitrogen content.

5.11.3 Calculations

Correct the concentration of nitrogen to 1.013 bar and 20 °C, and express the concentration as a percentage by volume of the whole sample.

Record the corrected value in the test report.

5.12 Method for determination of helium concentration

5.12.1 Apparatus

5.12.1.1 *Helium measurement equipment*, able to measure gaseous helium levels to at least ±1.0% (e.g. a helium gas analyser or a respiratory gas mass spectrometer). The equipment shall be calibrated in accordance with the manufacturer's instructions.

5.12.2 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the measuring equipment in accordance with the manufacturer's instructions and record the helium content.

5.12.3 Calculations

Correct the concentration of helium to 1.013 bar and 20 °C, and express the concentration as a percentage by volume of the whole sample.

Record the corrected value in the test report.

5.13 Method for determination of oil content

*COMMENTARY ON **5.13***
*The determination of oil content as described in **5.13** may be carried out as part of the determination of infra-red active contaminants as described in **5.5**. In that case would not be necessary to run a separate test.*

5.13.1 General

The oil content shall be determined either in accordance with BS ISO 8573-2 or by using an infra-red spectrometer to determine the infra-red spectrum of the gas under test in accordance with **5.13.2** to **5.13.4**. In the latter case the spectrum produced shall be used to identify and quantify traces of oil as n-hexane equivalent.

5.13.2 Apparatus

5.13.2.1 *Scanning infra-red spectrometer*, fitted with a gas cell with a minimum optical path length of 10 m. The equipment shall be calibrated in accordance with the manufacturer's instructions.

5.13.3 Procedure

Measure and record the temperature and pressure of the gas under test. Introduce a sample of the gas under test into the spectrometer and measure the peak height in the frequency band 3000 cm^{-1} to 2800 cm^{-1}.

Determine the concentration of oil in the sample, in milligrams per cubic metre ($mg \cdot m^{-3}$), as n-hexane equivalent.

5.13.4 Calculation

Correct the concentration of oil to 1.013 bar and 20 °C.

Record the corrected value in the test report.

5.14 Method for stain detector tube and stain system analysis

5.14.1 Apparatus

5.14.1.1 *Reagent tubes specific for detection of carbon monoxide, carbon dioxide, and water.*

5.14.1.2 *Reagent tube or deposition system for detection of oil.*

5.14.2 Procedure

Set up the apparatus in accordance with the manufacturer's instructions. Pass a sample of the gas under test through the apparatus. Take a reading from the scale on the tube or deposition system.

5.14.3 Calculation and expression of results

For each reading, add the maximum error for the relevant substance, as specified by the manufacturer of the testing system, to the reading obtained. Compare this value with the maximum value specified in Table 2 or Table 3 as applicable. If the sum of the reading plus the error is less than or equal to the value given in Table 2 or Table 3, the level of the substance concerned shall be deemed to conform to the standard. If the sum is greater than the value given in Table 2 or Table 3, the level of the substance concerned shall be deemed not to conform to the standard.

6 Marking and labelling of cylinders and bundles of cylinders supplied filled by a manufacturer

6.1 Marking

The marking on each cylinder or bundle of cylinders shall conform to BS EN 1089-3 and BS EN ISO 13769.

6.2 Labelling

The labelling on each cylinder or bundle of cylinders shall conform to BS EN ISO 7225 and shall include the following additional information:

a) the number and date of this British Standard, i.e. BS 8478:2011 [2];

b) the content of oxygen, nitrogen and helium, as applicable.

c) date of filling of cylinder or bundle.

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[2] Marking BS 8478:2011 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.

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

Other publications

[1] UNITED NATIONS ENVIRONMENT PROGRAMME. *The Montreal Protocol on Substances that Deplete the Ozone layer* (as adjusted and/or amended). Nairobi, Kenya: UNEP, 2000.

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