

# Aircraft oxygen systems and equipment —

## Part 2: Tests for the compatibility of materials in the presence of oxygen

ICS 49.090

# Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee ACE/38, Aircraft oxygen equipment, upon which the following bodies were represented:

- British Airways
- British Compressed Gases Association
- Civil Aviation Authority
- Health and Safety Executive
- Ministry of Defence
- Society of British Aerospace Companies Limited
- South Bank University

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|          |                  |                                                                    |
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## Foreword

This Part of BS 4N 100 has been prepared by Technical Committee ACE/38 and specifies the general requirements for oxygen systems and equipment for use on aircraft and ground support equipment.

It partially supersedes BS 3N 100 which is withdrawn upon publication of all seven parts.

BS 4N 100 consists of the following seven separate parts:

- *Part 1: Design and installation;*
- *Part 2: Tests for the compatibility of materials in the presence of oxygen;*
- *Part 3: Testing of equipment and systems;*
- *Part 4: Guide to the physiological factors;*
- *Part 5: Guide to fire and explosion hazards associated with oxygen;*
- *Part 6: Guidance and recommendations on the selection of materials for use with oxygen;*
- *Part 7: Guide to cleaning, labelling and packaging.*

This Part specifies the general test requirements for airborne oxygen breathing systems and tests for the compatibility of materials in the presence of oxygen, including oxygen storage and generation equipment and associated ground support equipment.

NOTE The latest revision of an aerospace series standard is indicated by a prefix number.

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### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 19 and a back cover.

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## 1 Scope

This part of BS N 100 specifies methods of test and interpretation of results for verifying conformance of non-metallic materials for use in oxygen enriched atmospheres.

## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

BS 1016-105, *Methods for analysis and testing of coal and coke — Determination of gross calorific value*.

BS ISO 4589-2, *Plastics. Determination of burning behaviour of oxygen index — Part 2: Ambient temperature test*.

BS N 3, *Specification for gaseous breathing oxygen supplied for airborne application*.

BS N 100-7, *Aircraft oxygen systems and equipment — Part 7: Guide to cleaning, labelling and packaging*.

Def Stan 16-1, *Oxygen; liquid and gaseous (breathing) for aircraft systems*.

## 3 Definitions

For the purposes of this standard the following definitions apply:

### 3.1

#### **non-metallic materials**

natural or synthetic polymeric materials which may be in different physical forms, e.g. thin sheet, fibres, particulates, and blocks

NOTE The term may also be applied to semi-solids, e.g. pastes, lubricants, greases, and to liquids.

### 3.2

#### **spontaneous ignition temperature (SIT)**

minimum temperature at which the rate of evolution of combustible volatiles, from the thermal decomposition of a non-metallic material, reaches the lower flammability limit concentration of combustible volatiles in a pure oxygen (oxygen enriched) environment and undergoes spontaneous ignition

### 3.3

#### **specific spontaneous ignition temperature**

spontaneous ignition temperature at a defined pressure of oxygen (usually 13.2 MPa)

### 3.4

#### **statistically defined spontaneous ignition temperature**

arithmetic mean ignition temperature of several experimental runs minus twice the standard deviation calculated from the experimental values.

### 3.5

#### **heat of combustion**

heat evolved per unit mass when a material is completely burnt in 2.5 MPa to 3.5 MPa of oxygen at constant pressure. It is normally measured in a bomb calorimeter (see BS 1016:Part 105 for a description of the test apparatus and method of test)

### 3.6

#### **critical oxygen index**

minimum concentration of oxygen in a flowing mixture of oxygen and nitrogen at 0.1 MPa that will just support flaming combustion from top ignition (see BS ISO 4589-2)

## 4 General

### 4.1 Introduction

NOTE 1 The compatibility of a non-metallic material with oxygen in a particular application is normally assessed by use of its specific SIT, the critical oxygen index, the heat of combustion, its record of use in similar applications and the quantity involved. However, recent research indicates that the SIT alone provides exactly the same rank order of materials regarding correlation linking the SIT with the heat of combustion and the critical oxygen index. In some circumstances, a knowledge of all three parameters may help to decide which non-metallic material to select.

NOTE 2 In the earlier editions of BS N 100 the criteria for selecting a non-metallic material were primarily based on the “bomb test” (providing data to calculate the statistically defined SIT) and material performance in pass/fail tests referred to as the “pot test” and the “liquid oxygen impact test”. The three defined tests had specific uses. The pot test was used to assess materials used in oxygen atmospheres up to a pressure of 0.4 MPa. The bomb test was used for the assessment of a material’s performance in oxygen atmospheres at pressures in the range 0.4 MPa to 20.8 MPa. The liquid oxygen impact test was used to support decisions about a material’s compatibility with gaseous oxygen, when pressures of 20.8 MPa to 34.6 MPa were to be employed.

NOTE 3 The liquid oxygen impact test was also used to assess the suitability of a material for use with liquid oxygen.

Gaseous oxygen used in these tests shall conform to BS N 3.

Liquid oxygen used in these tests shall conform to Def Stan 16-1.

The sample shall be submitted to the tester using Form 1 in Annex A.

### 4.2 The pot test

NOTE The pot test was originally developed to simulate the dynamic conditions found in very low pressure hoses, aviators’ oxygen masks and similar equipment.

**4.2.1** The apparatus shall consist of a horizontal tube furnace, a flow meter and a borosilicate glass ignition tube, fitted with a thermocouple and a suitably terminated glass rod.

**4.2.2** The oxygen atmosphere shall be held at pressures below 0.69 MPa.

**4.2.3** Maintain the flow rate of oxygen at  $2 \times 10^{-3} \text{ m}^3 \text{ minute}^{-1}$  at atmospheric pressure. Heat the furnace to the selected temperature between 273 K and 673 K and maintain it for 15 minutes. Introduce a fresh 60 mg block sample into the hot oxygen stream. Remove the sample after 2 minutes and examine it for signs of ignition. Repeat the test, using fresh samples each time, with temperature increments of 20 K per test until either ignition or 673 K is reached. When a sample is found to have ignited, reduce the test temperature by 5 K steps until no ignition occurs. Repeat the test a succession of five times at this temperature, during which no ignition shall occur.

A recorded temperature of not less than 523 K is required for materials intended for use up to 0.4 MPa, when tested six times in succession without ignition.

### 4.3 The bomb test

NOTE The bomb test was originally developed to test materials used for oxygen service at pressures substantially above 0.4 MPa. (See also clause 6.)

**4.3.1** Expose a sample to progressive ramped heating while in a high pressure oxygen atmosphere, i.e. 13.2 MPa. Contain the sample in a pressure vessel designed to withstand pressures exceeding those of the test conditions.

**4.3.2** The bomb shall be a stainless steel pressure vessel with a custom-built electric heater. The element of the heater shall be wound on to a borosilicate glass tube and covered in heat-resistant cement. A borosilicate combustion tube shall be situated horizontally inside the pressure vessel, to hold the test sample in a borosilicate combustion boat. A chromel-alumel thermocouple shall be inserted through the flanged end of the pressure vessel and be permanently fixed in place in the combustion tube so that the centre of the combustion boat can be positioned directly below the tip of the thermocouple. The nose of the bomb, remote from the flange, shall be fitted with a removable plug and PTFE sealing gasket, to provide access to the interior of the bomb for each test.

**4.3.3** Insert block samples of  $(60 \pm 2)$  mg into the bomb and seal and purge it to remove air and any previous products of decomposition. Fill the vessel with oxygen to the test pressure of 13.2 MPa. Increase the sample temperature at a rate of not less than  $20 \text{ K min}^{-1}$  up to the temperature at which ignition occurs or 673 K, whichever is the lower. The ignition temperature shall be determined by noting the sample temperature at which a sudden increase in the rate of temperature rise occurs. The pressure in the bomb shall be maintained at the set test pressure throughout the heating period.

**4.3.4** The statistically defined SIT (3.4) for each test sequence shall be determined by calculating the arithmetic mean and the standard root mean square deviation of a minimum of six ignition temperatures.

**4.3.5** The maximum permitted working pressure for a material shall be determined from Table 1 and this value shall be used to declare the compatibility of the material in oxygen at a maximum working temperature of 363 K (90 °C), with respect to fire hazard.

**Table 1 — Determination of maximum working pressure**

| Minimum statistically defined SIT at 13.2 MPa                                                      |     | Maximum working pressure at 363 K<br>(90 °C) (MPa absolute) |
|----------------------------------------------------------------------------------------------------|-----|-------------------------------------------------------------|
| K                                                                                                  | °C  |                                                             |
| 473                                                                                                | 200 | 0.4                                                         |
| 503                                                                                                | 230 | 1.1                                                         |
| 523                                                                                                | 250 | 2.1                                                         |
| 573                                                                                                | 300 | 4.1                                                         |
| 623                                                                                                | 350 | 10.1                                                        |
| 648                                                                                                | 375 | 15.1                                                        |
| 673                                                                                                | 400 | 20.8                                                        |
| 673                                                                                                | 400 | 34.6 <sup>1)</sup>                                          |
| <sup>1)</sup> Both bomb and impact tests are required for working pressures greater than 20.8 MPa. |     |                                                             |

## 4.4 Liquid oxygen impact test

### 4.4.1 Principle

This test requires the sample to be mixed with abrasive material (carborundum powder or silicon carbide), immersed in liquid oxygen and subjected to the impact of a known mass falling vertically from a pre-determined height on to the sample. The required drop height of the mass is 1.37 m. The total mass is 9.1 kg, thus the impact energy is 122 J.

### 4.4.2 Apparatus

**4.4.2.1 Impact test machine**, of a typical construction which is illustrated in Figure 1, consisting of two vertical columns down which the mass (drop weight) slides. The test machine is housed in a steel cabinet. The release mechanism is controlled from outside the cabinet and the door carries a periscope through which the results of impact are observed.

NOTE The apparatus should have low temperature strength and be protected against corrosion. A suitable material for use in its construction is stainless steel 304S15 in accordance with BS 970:Part 1, alternatively grade 1.4301 of BS EN 10088-1.

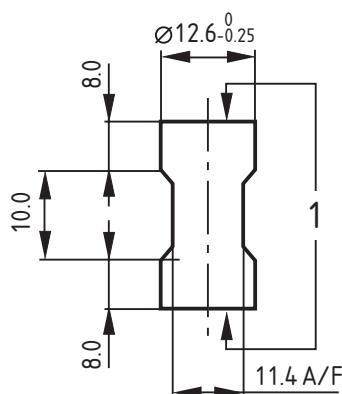
**4.4.2.2 Sample holders**, made from 0.08 mm gauge nickel foil by pressing the foil into a brass former with a brass rod. The resultant “cup” is to be a sliding fit onto the end of a 12.6 (0/–0.25) mm diameter striker pin (see Figure 0). When the cup is in position on the anvil with the striker pin resting on the sample, liquid oxygen has to be able to enter and surround the sample with minimum loss of the abrasive material.

**4.4.2.3 Abrasive material**, 80 to 100 mesh, Carborundum (silicon carbide) rigorously cleaned by heating to 600 °C for 2 h, cooled in a desiccator and then protected by storing in a glass-stoppered bottle.

NOTE A desiccant may be considered necessary if long term storage is envisaged.

**4.4.2.4 Liquid oxygen**, in accordance with 4.1.

Dimensions in millimetres



**Key**  
1 Faces square and parallel.

Figure 0 — Detail of striker pin

#### 4.4.3 Procedure

**4.4.3.1** Cover the bottom of the inside of a nickel cup with abrasive material, place the test sample on the powder and pour on more abrasive material until the sample is covered.

**4.4.3.2** See that the drop weight is in the required position (4.4.1) and that the safety pin is securely fixed.

**4.4.3.3** Transfer the nickel cup, with contents, to the baseplate, placing it immediately under the striker pin. Adjust this pin so that it rests lightly on the surface of the abrasive material.

**4.4.3.4** Gently tighten the pin retaining screw in the bridge against one of the flats, with minimum pressure, so that the pin can only move vertically along the length of the flat, approximately 10 mm, thus preventing the pin bouncing out of the bridge immediately after impact with consequent damage to the bridge.

**4.4.3.5** Slowly pour liquid oxygen into the reservoir, until the boiling rate decreases to a constant low level.

**4.4.3.6** Support the drop weight, remove the safety pin, and while still supported advance the release pin.

**4.4.3.7** Refill the liquid oxygen reservoir until it overflows.

**4.4.3.8** Close the cabinet door, observe the liquid oxygen reservoir through the periscope and pull the release lever. The drop weight shall impact the striker pin while the sample material is still covered with liquid oxygen.

**4.4.3.9** Through the periscope observe for signs of ignition or detonation.

NOTE Ignition may be indicated by a hardly visible flash to a brighter one.

WARNING. The audibility of any detonation varies from a sound just distinguishable from the background of the impact to a very loud, sharp, bang.

**4.4.3.10** Remove the nickel cup and note any odour which indicates that some oxidation has occurred to the sample that did not produce a flash or detonation.

**4.4.3.11** Repeat the operations 4.4.3.1 to 4.4.3.10 until a clear detonation occurs or until a maximum of ten times.

NOTE The reservoir and striker pin, when in use, soon become coated with moisture and ice that will inhibit reaction by absorbing energy. Frequent cleaning is necessary as is the inspection of the striker pin for splitting or distortion.