Aircraft oxygen systems and equipment —

Part 6: Guidance and recommendations on the selection of materials for use with oxygen

ICS 49.090

Committees responsible for this British Standard

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

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Contents

Foreword

This Part of BS 4N 100 has been prepared by Technical Committee ACE/38 and specifies general requirements for oxygen systems and equipment for use on aircraft and ground support equipment. It partially supersedes BS 3N100 which is withdrawn upon publication of all seven parts.

BS 4N 100 consists of the following 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 of BS N 100 is classed as a guide and provides guidance and recommendations on the selection of materials for use with oxygen to minimize the risk of ignition and combustion.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 5 and a back cover.

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1 Scope

This part of BS N 100 provides guidance and recommendations on the selection of materials for use with oxygen to minimize the risk of ignition and combustion. The guidance and recommendations may be used equally well in non-aerospace applications.

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 4 N 100-2, *Aircraft oxygen systems and equipment — Tests for the compatibility of materials in the presence of oxygen.*

3 Selection of metallic materials

3.1 The selection of metals to minimize the risk of ignition and the effects of fire depends on several factors as follows:

a) the working regime i.e. gas flow conditions, rapid state changes;

b) the working environment i.e. pressure velocity, mass flow rate and temperature;

c) the level of filtration and/or the chance of particle creation within the system;

d) the nature of combustion and ability to self-quench.

When heated in 100 % oxygen under pressure, alloys of iron (steel, stainless steel) and aluminium (including aluminium bronze) evolve large quantities of energy and burn vigorously once ignitions occur. Under some circumstances, burning continues even if the pressurized oxygen is replaced by ambient air.

At much higher temperatures, copper and nickel alloys (including brass, tin-bronze, cupro-nickel, monel) will ignite but rapidly extinguish once the ignition source is removed.

Any metal that can be ignited in ambient air (magnesium, titanium for example) should never be selected.

3.2 Since 1985, various test methods have been investigated to assist with the ranking of metals for selection. Two of these methods are reported in ASTM special technical publications (STP) (see bibliography) and represent "in-use" modes of ignition as follows:

a) *Particle impact* (P.I.)

2,000 μm aluminium particle in a supersonic oxygen flow at 27.6 MPa impacts a heated target of the test material at right angles.

The ranking criterion is the maximum temperature at which ignition and consumption of the target does not occur.

b) *Promoted combustion* (P.C.)

Test material specimen subjected to the heat released by a burning aluminium promoter in oxygen at pressure. The ranking criteria are as follows:

1) the minimum oxygen pressure required to support self-sustained combustion;

2) the propagation rate.

Based on the results reported, the following table shows the relative performance of common metals used in oxygen systems. (Results obtained using samples of solid section uniform proportions).

Table 1 — Typical test results

Metal	Type	P.I. temp. °C	P.C. pressure MPa
Aluminium alloy	6061	-33	< 0.7
Aluminium bronze	7 % Al	312	< 1.4
Carbon/Alloy steel	9 % Ni	202	3.5
	Ductile cast iron		3.5
Stainless steel	17-4 PH		6.9
	14-5 PH	31	
	13-4 PH	33	
	304	47	6.9
	316	52	6.9
Copper alloys	Brass (CZ grades)	347	48.3
	Tin bronze	307	48.3
	Copper(pure)		55.2
Nickel alloys	Inconel 718	202	3.5
	Inconel 600	332	6.9
	Nickel (pure)	357	68.9
	Monel 400		55.2

Generally, the temperature limit is defined by non-metals being used in the system: the pressure is the maximum developed in the system under consideration i.e. the pressure developed at maximum operating temperature, or the setting of any protection devices (relief valve or bursting disc).

Whilst the information reflects the best data available, it is recognized that many metals have been in use for years at pressure conditions well in excess of those listed, without compromising safety. Two particular factors are involved and make a significant effect i.e. systems design and temperature/ pressure combinations experienced.

Aluminium particularly (and other metals that similarly form an oxide film) can safely be used at conditions well above P.I. and P.C. values provided that the oxide film is not breached. Typical causes are friction rubbing, impact or adjacent ignition source.

Temperature/pressure combinations, i.e. the working conditions, rarely approach the limits investigated during testing. The objective data that is available at the moment, coupled with product experience, shows that reduced temperature and/or pressure conditions during testing will enhance results. Therefore, an aluminium alloy at 14 MPa/70 °C may be used for a valve body or carbon/alloy steel at 42 MPa/70 °C for a pressure vessel, subject to the properties of other parts, the overall design and absence of contaminating particles.

System design is most important. Low velocity gas flow is inherently safer than supersonic; avoid dramatic changes of pressure (e.g. adiabatic conditions): sudden changes of gas flow direction (abrupt right angle drillings) or passage configurations (sharp edges) cause local heating and gas turbulence. Filtration is essential, not forgetting metallic debris that may be caused during assembly: absolute cleanliness is paramount at all times.

Ensure that any non-metal in the system that can be directly exposed to the oxygen flow (e.g. valve seat) is kept to a minimum and is housed in a metal with P.I. temperature and P.C. pressure as high as possible.

3.3 No metals should be used for service in an oxygen environment before being tested (see **3.2**) or compared with the ranking table. Objectivity may only be obtained by testing specific metals in a representative system to conditions offering a suitable safety margin over the proposed duty.

3.4 Metals chosen for valves and valve seats shall be non-shattering under maximum loading conditions to avoid particle contamination of the system.

3.5 Shedding caused by the rubbing of two surfaces shall be avoided by choosing metals with widely differing hardness for the two surfaces. Certain metals can cold-weld e.g. nickel; intimate contact of these metals should be avoided for moving parts. Ensure that metals chosen for mating threads will not cold-weld or gall.

3.6 Promoted combustion tests (see **3.2)** conducted using thin sections or meshes demonstrate that there is a mass/surface area effect which tends to reduce the pressures compared with those obtained from solid samples. Only pure nickel, for example, has demonstrated a similar performance.

3.7 It should be ensured that the electro-motive series potential between differing metals in contact is as small as possible. Where dissimilar metals are to be in contact, they should be insulated with gaskets or coatings of suitable material, conforming to BS N 100-2.

3.8 Corrosion is unlikely to occur where parts will only come into contact with pure, dry oxygen. Wherever moisture can occur, appropriate protective treatment, conforming to BS N 100-2, should be applied or enhanced; for example, anodizing aluminium or passivating stainless steel. Selection should take into account the corrosion effects under stress of certain metals, for example season cracking of copper/zinc alloys.

WARNING NOTE Certain protective treatments can cause toxicity problems if used in breathing systems, e.g. cadmium plating.

3.9 Where non-corrosion resistant metals are used for oxygen cylinders, the surfaces should be examined for the presence of corrosion after manufacture and at re-lifing /overhaul.

4 Selection of non-metallic materials

4.1 The selection of non-metals has historically been based on an interpretation of results from three tests known as "Pot", "Bomb" and "Impact" (see BS N 100-2). More recently, the bomb test method has been completely revised and extended, resulting in the better repeatability of the results and hence improved accuracy (see BS N 100-2). However, the demonstration of compatibility with oxygen at the desired conditions of temperature and pressure achieved using these methods does not, take into account either time based effects (soaking in oxygen/absorbed gas) or gas flow effects. Additional testing may be necessary to explore these factors.

4.2 Certain non-metallic materials, especially elastomers, degrade by contact with oxygen. Before use in oxygen systems, it should be demonstrated that the selected material is suitable for the conditions likely to occur in use. This may be achieved by reference to manufacturers' data, or by the use of artificial ageing processes.

4.3 Oxidation will occur to varying degrees, dependent on the susceptibility of the material and the temperature experienced during exposure of the material to oxygen. The oxidation will often cause an embrittling of the substance, flexible materials are likely to become embrittled more readily than rigid materials. Embrittlement originates at the surface exposed to oxygen and progresses with time through the material until the whole structure has changed. Embrittlement of materials occurring in gaseous oxygen as the result of an oxidation process is experienced as a hardening of the material which reduces its resilience and its resistance to impact and bending. Visually, the embrittlement is associated with slight surface crazing which develops into deeper cracks and a darkening in the colour of the material.

4.4 Some non-metallic materials are prone to the absorption of oxygen when continuously exposed to the gas under pressure. This will cause a lowering of the spontaneous ignition temperature (S.I.T.), BS N 100-2 refers. Consideration should be given to testing such materials both prior to, and after long term exposure to oxygen.

4.5 Materials chosen for valve-seats shall be non-shattering under maximum loading conditions to avoid particle contamination of the system.

4.6 Materials chosen for use where relative movement between surfaces is experienced during manufacture/assembly or in use, shall resist shedding and delamination to avoid risks of particle contamination of the system.

4.7 In general, non-metallic materials have lower P.I. and P.C. values than metals. However, the heat of combustion is often sufficient to ignite adjacent metals. Consequently, non- metallic materials should be kept to an essential minimum in any system. An exception to this is often found with ceramic or similar materials, where the risk is often associated with its brittleness and hence generation of system contaminating particles.

4.8 Non-metallic materials used in high-risk areas of systems (e.g. valve-seats) should be kept to as small a quantity as practical, and should be housed within a metal/non-metal of significantly higher ignition temperature.

5 Selection of combinations of materials

5.1 In addition to the effect of electro-motive series potential between different metals in contact (see **3.7**), dissimilar non-metallic materials, especially elastomers and polymers, can dissociate in such a way that constituent parts migrate across surface boundaries if in contact. For instance, over a relatively short period of time in a component's life (a few months) plasticizer has been known to leach from bromobutyl rubber and migrate to the surface of nylon plastic in contact to the extent that a bond was formed. Such effects can cause changes in physical properties as well as affecting the results of oxygen compatibility testing.

5.2 Stress, such as the shearing stress of a valve spindle on a seat, can give rise to a reaction between certain otherwise relatively inert materials. One particularly good example is fluorinated-hydrocarbon/aluminium reaction.

5.3 Materials and/or metals in combination, such as coatings and plating, have not been widely tested. Generally, it is recommended that each different material/metal is taken on its individual merits for the duty proposed. Regard should be given to the likelihood of the coating being porous, damaged or otherwise able to allow oxygen to reach the parent or base component. Each different combination or application should be assessed and, if doubt exists, offered for testing to determine oxygen compatibility, porosity, damage resistance, etc.

5.4 Care should be taken with the selection of test samples from composite materials. The choice, location and size of section may have a significant effect on the test results. The composite itself, through a combination effect, may adversely affect the S.I.T.

Bibliography

ASTM Special technical publications[1)]
Flammability and sensitivity of materials in oxygen-enriched atmospheres, Volumes 1 to 8 inclusive:
ASTM STP 812
ASTM STP 910
ASTM STP 986
ASTM STP 1040
ASTM STP 1111
ASTM STP 1197
ASTM STP 1267
ASTM STP 1319

1) Avialable from ASTM, 1916 Race Street, Philadelphia PA 19103, USA

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