BRITISH STANDARD AEROSPACE SERIES

BS 5N 100-7:2002

Aircraft oxygen systems and equipment —

Part 7: Guide to cleaning labelling and packaging

ICS 13.340.30; 49.080

Committees responsible for this British Standard

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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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Contents

Foreword

This part of BS N 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. This part provides guidance on cleaning procedures, labelling and packaging requirements.

This revision supersedes BS 4N 100-7:1999 which is withdrawn.

BS N 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.*

NOTE The prefix number before the “N” indicates the latest revision of an aerospace series standard.

Insufficient cleanliness of components used in oxygen rich systems can result in ignition of the contaminants or the components by; for example, particle or mechanical impact, adiabatic compression, etc. Control of contamination in oxygen enriched systems is essential to minimize hazards and component failures. Contamination also needs to be minimized to ensure the purity of the oxygen-enriched gases. The removal of contamination from materials and components is dependent on the system configuration, the materials used in the construction, and the types and quantities of contaminants. Many cleaning agents used in the past for cleaning oxygen service components are now prohibited for use on account of environmental damage. It is necessary to consider many factors in selecting a suitable cleaning process that is environmentally friendly, non-injurious to health and cleans to an adequate standard.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 15 and a back cover.

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1 Scope

This part of BS N 100 provides guidance on the selection of methods and apparatus for the cleaning, packaging and labelling of materials and equipment intended for service for airborne oxygen-enriched breathing systems, including oxygen storage and generation equipment. It is also applicable to associated ground support equipment and non-aerospace applications using oxygen equipment.

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 1133-19*, Packaging code — Part 19: Use of desiccants in packaging.*

BS 2540*, Specification for granular desiccant silica gel.*

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

BS 5295-0*, Environmental cleanliness in enclosed spaces — Part 0: General introduction, terms and definitions for clean rooms and clean air devices.*

BS 5295-3*, Environmental cleanliness in enclosed spaces — Part 3: Guide to operational procedures and disciplines applicable to clean rooms and clean air devices.*

BS EN ISO 14644-4:2001*, Cleanrooms and associated controlled environments — Part 4: Design construction and startup.*

BS IEC 60877*, Code of practice for procedures for ensuring the cleanliness of industrial process measurement and control equipment in oxygen service.*

BS ISO 14951-10*, Aerospace series — Space systems — Fluid characteristics — Part 10: Water.*

DEF STAN 81-75*, Issue 2, dated 25 July 97, Barrier Materials, Aluminium Foil Laminate, Flexible, Heat Sealable, Water Vapour Resistant.*

3 Definitions

For the purpose of this standard the following definitions apply.

3.1

brush cleaning

method of cleaning a hard-to-reach surface which involves physically brushing it with synthetic bristles soaked in solvent or cleaning agent

3.2

component

individual part of a unit of two or more assembled parts which have been designed to allow disassembly for servicing

3.3

contaminant

foreign or unwanted substance that can have deleterious effects on the operation, life, safety, or reliability, of an oxygen service system

3.4

de-ionized water

water, free of dissolved organics, particulates and ionized substances. It should have an electrical conductivity of 10^{-7}, Ω^{-1}, cm^{-1} or less, and have been passed through an activated carbon cartridge to remove organic contamination and particulates down to 50 µm.

3.5

fibres

particulate matter with a length of 100 µm or more, and a length to width ratio of 10 to 1, or greater

3.6
high efficiency particulate air (HEPA) filter

air filter which removes 0.3 µm diameter particles with an efficiency that exceeds 99.97% (by volume)

3.7
non-metallics

organic and inorganic materials such as ceramics, glasses, polymers, rubbers, greases and other lubricants, cloth, wool, and paper products

3.8
non-volatile residues

greases, such as hydrocarbon greases, fluorocarbon greases etc., cutting oils, cleaning agents after the volatile components have evaporated

3.9
oxygen clean component

component or item to be used in an oxygen system, which has been specially cleaned to remove and/or substantially reduce the concentrations of contaminants, in particular particles, fibres, greases and oils, to minimize the risks of fire and explosions occurring due to the presence of these contaminants; and which has been protected after cleaning from re-contamination by appropriate packaging, storage and warning labels

NOTE Oxygen cleaning is often carried out as an additional cleaning process after components, items, etc. have been cleaned, to remove burrs, swarf, flux, etc., to the appropriate engineering standards for non-oxygen systems.

3.10
particulate

finely divided solid of organic or inorganic matter, including metals

3.11
wipe cleaning

method of cleaning a surface which involves physically rubbing or swabbing it with a material such as cloth or paper moistened with, or soaked in, a cleaning solution or solvent

4 General

4.1 Work area

4.1.1 It is essential to maintain a clean work area to ensure that cleaned oxygen service components remain clean until packaged or reassembled. Ideally, the work environment should be a clean room area in accordance with BS 5295 with facilities to handle the cleaned components without danger of re-contamination. Doors from the workroom should not open to the weather and the room should be in an area remote from contaminants, particularly oil and grease. Assembly/disassembly benches should be clean and free from oil and grease and have a suitable covering which can easily be replaced. The air inside the room should be filtered to remove over 100 µm size particles and smoking or eating in the room should not be permitted. Tools and equipment should be clean and maintained for use only with oxygen service equipment. The work area should be well ventilated if in situ solvent cleaning operations are being carried out, to ensure that occupational exposure limits are not exceeded.

4.1.2 If the work room does not fully meet the requirements of BS 5295, a localized clean area for cleaning and assembling small components may be achieved using a laminar flow bench or cabinet.

NOTE Although the level of cleanliness obtained in the local area will be better than in the outside structure, it will be affected by the presence of high levels of particulates that can penetrate the laminar flow.

4.1.3 Personnel undertaking cleaning operations should have clean hands and should wear protective clean room grade gloves to prevent contamination of components after cleaning. If shoes are brought in from the outside, they should be covered to prevent the introduction of contamination into the workspace. Barrier, moisturising or cosmetic creams of any description should not be applied to the hands or face, etc., either whilst in the work area or before entering it. The protective clothing worn during cleaning should be lint free and not be worn when visiting other areas where industrial operations are taking place, particularly those associated with oil and grease. All lint producing clothing should be prohibited in the clean room area.

4.2 Disassembly of systems

4.2.1 If construction permits, assembled systems should be fully disassembled for cleaning. Individual components of oxygen-enriched systems should be cleaned as separate items just prior to assembly or packaging.

4.2.2 Cleaning an assembled system by flushing can deposit, or concentrate, contaminants in blind holes or recesses. Non-volatile cleaning agents may remain trapped and react later with oxygen. Cleaning solutions may degrade non-metallic materials inside assemblies or may cause corrosion of metallic items.

4.2.3 If construction does not permit disassembly, it is essential to bleed all pressure from the system before starting any cleaning operations. Where there is the requirement for special procedures due to the possibility of an assembled system being significantly damaged by the cleaning process, it may be more prudent and economic to replace the system rather than to clean it.

4.3 Bought-in items

4.3.1 Bought-in items such as valves, regulators etc. should preferably be cleaned by the original manufacturer prior to assembly and test. They should be supplied suitably packaged to prevent re-contamination and labelled as oxygen-clean, see Clause **10**. The purchaser should specify if certificates of cleanliness are to be supplied with these items, and should assess the suppliers' cleaning processes and written procedures.

4.3.2 Where bought-in items have to be cleaned by the purchaser, they should, if possible, be disassembled following the manufacturer's instructions, inspected for damage, cleaned and tested for cleanliness, reassembled, and finally tested for correct functionality.

4.4 Cleaners

4.4.1 Two major cleaning process options are available for cleaning oxygen service equipment; aqueous based cleaning methods with ultrasonic agitation, or solvent based systems which may involve wiping, brushing or vapour/ultrasonic cleaning.

4.4.2 Where necessary, prior to final cleaning to oxygen clean standards, a coarse cleaning process may be employed to remove gross contamination due to cutting fluids, swarf, burrs, fluxes, etc.

4.4.3 Mechanical cleaning methods such as abrasive blasting, tumbling, grinding and wire brushing are generally very aggressive and should be avoided on finished-machined items. They can damage sealing surfaces, remove or damage protective coatings, and work harden metal surfaces.

4.5 Selection of aqueous-based cleaning formulations

4.5.1 There are many proprietary aqueous cleaning formulations available that can be considered as being possibly suitable for cleaning oxygen service equipment. Ideally, an aqueous cleaning formulation should fulfil all of the following requirements:

a) all areas of a component cleaned to a fully acceptable level;

b) no significant corrosion or erosion of components;

c) no non-oxygen compatible residues left on the surface of the components;

d) environmentally friendly (low waste disposal costs) and non-toxic.

4.5.2 The cleaning efficacy of an aqueous-based cleaning solution will depend upon its composition. As much information as possible should be gained from the supplier of the cleaning solution concerning the nature and identity of the active ingredients. The basic ingredient of most aqueous-based cleaners is a primary detergent, usually an alkali such as sodium or potassium hydroxide. Where lower pH solutions are required because of potential corrosion problems, borax, sodium bicarbonate or sodium sesquicarbonate may be used to replace hydroxides as the basic builder ingredient. If aluminium alloy components are to be cleaned, it is preferable to use a solution with silicate as its primary ingredient. Silicates are less corrosive to aluminium alloys and will have an inhibiting effect on the action of more aggressive alkalis. Although phosphates have been widely used in aqueous based formulations in the past, they are environmentally unfriendly and should not be used. Cleaners should be supplied in liquid concentrate form, since there is the possibility of particulate dispersion in the airspace when dissolving powder concentrates. This could have the consequence of contaminating components or creating a health hazard to personnel in the work area.

4.5.3 Most aqueous-based cleaning solutions contain surfactants whose primary purpose is to reduce the surface tension. The lower the surface tension the easier it is for the solution to wet the surface and to penetrate into blind holes and crevices. Where components with complex geometry, blind holes or crevices etc. are to be cleaned, surface tension reducing surfactants should be incorporated into the cleaner formulation (see **4.5.7**).

4.5.4 Practical tests[1] should be carried out to determine the efficacy of the cleaning formulation. The solution should be made up to the concentration recommended by the manufacturer (or supplier of the cleaner) and operated under the prescribed conditions. A selection of typical components should be processed through the cleaning cycle and assessed for cleanliness in accordance with Clause **6**.

4.5.5 Aqueous-based-cleaners having strongly acidic or alkaline properties can damage metal components, particularly those made from aluminium alloys, either during the cleaning process itself, or after its completion if the cleaner is not neutralized and removed by water rinsing. Corrosion, erosion, surface embrittlement, or discoloration are potential side effects of aqueous-based cleaning processes. Suitable inhibitors may be incorporated in the cleaner formulation to reduce corrosion of metallic components. This may be of special importance if there is the possibility of galvanic corrosion arising, due to dissimilar metals being used in the manufacture of components. Where there is the possibility of significant corrosion occurring, it is most important to maintain an adequate concentration of corrosion inhibitor in the cleaner. If the cleaner becomes spent or is too dilute, the reduced concentration of inhibitor can increase rather than decrease corrosion damage.

4.5.6 Practical tests[1] should be carried out to determine the corrosivity of the cleaning formulation. A selection of typical components should be processed through the cleaning cycle and assessed for corrosion damage. This may be carried out by microscopic examination of the surface or by weight loss tests using a sensitive laboratory balance.

4.5.7 Most aqueous-based cleaners contain detergents and surfactants (of a hydrocarbon nature) that are not oxygen compatible. Residues left by aqueous based cleaning solutions should be tested in accordance with BS 4N 100-2 for oxygen compatibility. If, as is very likely to be the case, a cleaning formulation is used which contains surfactants, then it is essential that all traces of the cleaning solution are removed from the cleaned components by careful rinsing in water. Some proprietary aqueous-based cleaning formulations contain alcohols or other flammable ingredients. These should not be used for cleaning oxygen service equipment.

4.5.8 The manufacturer or supplier of the cleaners should be consulted before adopting an aqueous-based cleaning process. Most currently available aqueous-based cleaners are relatively environmentally friendly and have low toxicity levels but data should be sought from the manufacturer for confirmation. For example, aqueous-based cleaners that contain chromium compounds should be avoided due to the difficulties and costs in effluent disposal. In-house trials should be carried out, as described in **4.5.4** and **4.5.6**, to ensure the overall suitability of the process for cleaning oxygen service equipment.

4.6 Selection of solvent cleaners

4.6.1 Solvent cleaners can damage plastics, rubbers and elastomers. Solvents may be absorbed into the walls and may be expelled when the components are later pressurized with oxygen or other gases. Many solvents used for cleaning have high vapour pressure and volatility and may pose a health hazard to personnel undertaking cleaning operations if the workspace is insufficiently well ventilated. Low vapour pressure solvents are difficult to remove from very small blind holes and minute gaps between bolted surfaces and fasteners etc. Solvents that are flammable should not be used as they pose a fire-explosion hazard if not entirely removed from the cleaned components.

4.6.2 The solvents 1,1,1-trichloroethane (TCA) and 1,1,2-trichlorotrifluoroethane (CFC-113) have been widely used in the past for oxygen cleaning. However, these solvents are no longer permitted under European legislation and Montreal Protocol obligations so that alternatives have to be used. Ideally, a solvent cleaner should have the following characteristics:

a) wide solvency range so that all contaminants can be removed from oxygen service components to a fully acceptable level;

b) compatible with all metallic or non-metallic materials to be cleaned;

c) does not leave non-oxygen compatible residues on the surface of the components;

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1) See BCGA TR3 1999

d) non-flammable;

e) suitable for wipe/brush or vapour/ultrasonic cleaning;

f) low toxicity;

g) almost odourless;

h) fast drying;

i) inexpensive – can be easily recycled by distillation.

It is considered unlikely that any single, or class of alternative solvents will become available that can provide all of these advantages and satisfy the requirements of current or future environmental legislation. Each of the possible alternative solvents that satisfy environmental legislation will have a different combination of this range of characteristics. The choice of solvents for final consideration should be made initially on the basis that the solvents are environmentally acceptable and can clean to an adequate level for oxygen service components without causing significant material damage or posing unmanageable danger. Many possible solvents can be ruled out on the basis that they cannot remove the particular contamination, known or suspected to be present1). Other solvents are flammable, leave non-oxygen compatible residues or damage the components being cleaned – so should not be considered. Solvents that have relatively high toxicity may be considered if proper arrangements are made to control the vapour emissions and monitor the workspace atmosphere.

4.6.3 Trichloroethylene has environmentally friendly characteristics, is an effective cleaning agent for oxygen service equipment but poses serious health and safety problems unless used in a completely enclosed system. n-propylbromide may be suitable for some oxygen cleaning applications but the solvent has limited solvency for commonly used lubricants in oxygen service equipment1). Recently developed hydrofluoroether (HFE) solvents such as 1-methoxynonafluorobutane and hydrofluorocarbon (HFC) solvents such as 1,1,1,2,3,4,4,5,5,5-decafluoropentane are environmentally acceptable (under current legislation). Both of these solvents may be considered to have acceptable oxygen compatibility and not damaging to many metals and non-metals. However, they are expensive and have limited solvency for many contaminants that may be present. HFE and HFC based azeotropes with trans 1,2-dichloroethylene (also currently considered to be environmentally acceptable) have increased solvency power which makes them generally suitable for cleaning oxygen service equipment1). The addition of 1,2-dichloroethylene, however, decreases the toxicity threshold of the solvent blend so that greater care is required to ensure that occupational exposure limits are not exceeded.

4.6.4 The possibility that cleaning solvents might not be completely removed from the components should be borne in mind. Any residues left after solvent cleaning operations should be tested in accordance with BS 4N 100-2 for oxygen compatibility. If the solvent cleaner is not fully oxygen compatible, the components should be given a final rinse with an oxygen compatible solvent which is capable of removing the solvent cleaner and any residues resulting from it. Where blended solvents, chosen primarily for cleaning efficacy (e.g. solvents containing trans 1,2-dichloroethylene), are used it may be necessary to employ a final rinse stage using a component solvent from the blend, which itself is fully oxygen compatible.

4.6.5 The manufacturer or supplier of solvents should be consulted in regard to oxygen compatibility etc. and practical trials1) carried out to assess cleaning efficacy, material compatibility and vapour emission control before adopting a solvent cleaning process. The trials should be carried out under the conditions specified by the manufacturer of the solvent and cleanliness of the processed components determined using the procedures given in Clause **6**.

4.7 Lubricants

4.7.1 Mechanical components are normally assembled with lubricants on seals, threads and moving surfaces. The lubricant manufacturer should be consulted to ensure that cleaning agents and methods are effective in removing the lubricant and will not damage components.

4.7.2 Oxygen compatible lubricants for servicing cleaned components should be selected in accordance with BS 4N 100-2.

4.8 Media for wipe and brush cleaning

4.8.1 Material used for wipe media should ensure low particle generation and be compatible with the solvent or cleaning solution so that chemical extractables are low. The lint free media should not abrade or scratch the surface of the component and should be absorbent enough to retain sufficient solvent or solution for cleaning. Given the serious consequences which might ensue if debris of a hydrocarbon nature were to remain on oxygen service components after wipe cleaning operations, the wipe media used should be specifically manufactured with high absorbency, extra low particulates, debris production, and chemical extractables.

4.8.2 Brushes used for heavy-duty oxygen cleaning operations or where there are hard-to-reach spaces, should be manufactured from synthetic bristles, specially designed for the purpose and of high quality manufacture. Non-abrasive, thoroughly pre-cleaned bristles may be suitable provided the brush remains saturated with solvent.

4.8.3 The manufacturer or supplier of cleaning media should be consulted before adopting specific media for wipe or brush cleaning applications.

4.9 Record of cleaning

Instances of cleaning individual components should be recorded in a log for reference and as a permanent record. This is particularly important for components with critical dimensional tolerances and where there is the possibility of significant corrosion/erosion taking place with aqueous-based cleaning. (see **4.5.5**). Repeated cleaning cycles will have a cumulative effect on the total amount of damage to components. Each record should include:

a) date;

b) component identification;

c) cleanliness specification;

d) method of cleaning;

e) inspection results.

5 Cleanliness limits

5.1 General

Users should take great care to determine the appropriate limits for their particular application. This decision should be made on the basis of criticality of use, oxygen pressure, flow rates, gas velocity and the known or suspected nature of the contamination. The manufacturer or supplier of specific equipment such as pressure gauges, transducers or regulators should be consulted to ascertain recommended cleanliness limits. Regulators, for example, with very small diameter capillaries may have stringent cleanliness limits owing to the danger of blockage by residues or particulates. In general, the cleanliness limits for non-volatile residues and particulates should be considered separately.

NOTE Cleanliness limits have no validity unless they can be achieved and verified in practice.

5.2 Non-volatile residues and particulates

5.2.1 In general, the cleanliness limits for non-volatile residues and particulates should be considered separately.

5.2.2 The range of limits for non-volatile residues commonly encountered, includes:

11 mg/m^2, (1 mg/ft^2)	NASA KSC-C-123F SAE ARP1176, Level A
22 mg/m^2, (2 mg/ft^2)	SAE ARP1176, Level B
33 mg/m^2, (3 mg/ft^2)	SAE ARP1176, Level C
100 mg/m^2, (10 µg/cm^2)	NES 372
500 mg/m^2	Compressed Gases Association (US) and BCGA
No value specified	EN 12300 (component only required to pass white light/UV light tests, etc.)

5.2.3 In considering the presence of particulates, it is recommended that the higher standards adopted for aerospace systems should be considered (NASA JSC/WSTF Specification No. 022). These standards range from clean level 50 to clean level 300 where the number refers to the maximum particle size allowed in micrometres.

NOTE A poorer quantitative cleanliness level adopted previously for the presence of particulates, is that no particles larger than 1 000 µm should be present with no more than 30 particles between 750 µm and 1 000 µm and no more than 100 particles between 500 µm and 750 µm/m^2.

The qualitatively assessed limits for particulates, commonly encountered in practice, include the following:

a) absence of visible soiling from entrained particles when clean gas is passed through pipework, valves, etc., and allowed to impact on white lint free cloth;

b) absence of visible particles when surfaces are viewed under white light and ultraviolet (UV) light.

6 Verification of cleanliness

6.1 Selection of tests

The following methods of verifying cleanliness include both qualitative and quantitative tests. In many cases it may not be possible to carry out quantitative tests because they require laboratory facilities. Although qualitative tests are useful for quickly obtaining an indication that a component has been adequately cleaned, they cannot, however, indicate with any degree of certainty that a component is clean to the appropriate oxygen service standard. A failure under a qualitative test is significant but a “pass” is not proof that the component is oxygen clean. Some quantitative test results may be misleading since they represent average levels for the surface examined. There is the possibility that there may be relatively high concentrations of contaminant in certain areas even though the average figure cited is low. Properly trained personnel who have experience in interpreting the results should carry out these tests.

6.2 Quantitative tests

A test-solvent flush sample is obtained by flushing a suitable test-solvent, of high purity, over (or through) the cleaned item(s). It is preferable to flush the test-solvent over the disassembled components rather than through the assembled unit (see **4.2**). The test-solvent should be chosen with care; i.e. it should ideally have similar or better solvency for greases or oil contaminants than 1,1,2-trichlorotrifluoroethane, it should not contaminate the items being tested and should be easily removed and non-flammable. Since test flush solvents will be used in much smaller quantities than general cleaning solvents, it may be permissible, if legislation permits, to use solvents having higher solvency but less good environmental properties and lower toxicity thresholds. The HFE and HFC azeotrope solvents referred to in **4.6.3** may be suitable for use as test flush solvents. Possible tests on the solvent flush sample include:

a) evaporation to dryness, followed by weighing, with a high sensitivity balance, to determine the non-volatile residue content;

b) particle counting and sizing, using an automatic liquid-borne particle counter or by microscopic examination of a filter membrane after filtration (high intensity illumination is required);

c) spectroscopic analysis for the presence of hydrocarbons and other contaminants.

6.3 Qualitative tests

6.3.1 Visual inspection using white light can be used to detect the presence of some oils, greases, corrosion, erosion, staining, swarf, particulates, lint fibres etc. The cleanliness of certain internal surfaces such as pipe bores, may be inspected using a boroscope. It is essential that any instrument used is oxygen clean so that the introduction of inadvertent contamination is avoided during inspection.

6.3.2 UV light exposure causes most hydrocarbon or organic oils to fluoresce. Inspection is carried out by directing a light source of wavelength 0.36 µm to 0.39 µm at the surface from a distance of around 150 mm in total or near darkness. Any evidence of fluorescence indicates unacceptable surface cleanliness.

NOTE This method will not detect silicone or fluorocarbon greases.

6.3.3 The cleanliness of items possessing a proportionally large surface area may be inspected by wiping the surface with a lint-free cloth or other wipe media. The wipe can then be inspected for contamination using the techniques described in **6.3.1** and **6.3.2**. If it has been previously ascertained that the wipe media has low chemical extractables, it can be soaked in test-solvent for spectroscopic analysis of removed contamination (see **6.2**).

6.3.4 Where aqueous-based cleaning is being carried out, the water-break test is a simple and effective way of indicating surface cleanliness. A horizontal surface is wetted with a fine atomized spray of purified water. If the surface is contaminated, a continuous film will not form or will rapidly break up into small beads of water. Properly applied, the water break test is able to detect contamination to around mean levels of between 30 mg/m^2 to 60 mg/m^2. To prevent false indications of cleanliness, it is essential that all traces of detergents or surface active agents should be removed from the surface by rinsing, before the test is carried out.

6.4 Gaseous entrainment

6.4.1 Assembled systems, e.g. pipes, valves, etc., may be tested by pressurizing them with a gas of known cleanliness (see BS 4N 100-3) and testing the gases emerging at the far end for particulate contamination, oil mist concentration, and for volatile hydrocarbons and solvents.

NOTE This test is effective for testing for the presence of substances, such as particulates and volatile hydrocarbons and solvents, which can easily become entrained in the gas flow; but may fail to detect less volatile substances such as greases, and contamination in blind legs of pipework.

6.4.2 If nitrogen or other non-life supporting gases are used for this test, it is essential that they should be flushed from the system before the system is put into use.

7 Aqueous-based cleaning procedures

7.1 Selection and sequence of stages in aqueous-based cleaning

The particular sequence of stages adopted for an aqueous-based cleaning process will largely depend upon whether there are any components that present particular cleaning difficulties. On the basis that a variety of components are to be cleaned and that some of them will have complex geometry, fine meshes, blind holes or recesses, a suitable process consists of the following stages1):

a) spraying blind holes, passageways or crevices with cleaning solution from a fine jet nozzle;

b) ultrasonic cleaning in the aqueous cleaning solution;

c) rinsing in tap and de-ionized water employing spraying and ultrasonification;

d) verifying cleanliness with water break test (see **6.3.4**);

e) drying;

f) final inspection of component cleanliness.

If the geometry of the components is such that there are no significant blind holes or recesses to clean, then spraying operations need not be included in the process cycle.

7.2 Spraying

Where there are small diameter blind holes or recesses, spraying cleaning solution into them with a fine jet is the most effective method of cleaning1). (e.g. using a 0.7 mm internal diameter needle fitted to a nozzle attachment with a flow rate of approximately 2×10^{-3} dm^3/s). Varying the internal diameter of the needle will allow the linear velocity of the cleaning solution to be easily altered for a given flow rate. Experimentation is required to determine the most effective spray velocity, needle diameter, distance between the needle and component, and the total spray time. A suitable shield should be used to contain the sprayed solution within the cleaning tank.

7.3 Ultrasonic cleaning with aqueous solutions

7.3.1 Power ultrasound assists cleaning through the effect of cavitation. Commercially available ultrasonic cleaning baths operate at a fixed frequency between 20 kHz and 80 kHz. There is, however, no industrially recognized term for expressing cleaning power. Although the electrical power input will affect the cleaning power, other factors such as transducer matching, physical construction of the tank and the nature of the cleaning solution will be important. The ultrasonic intensity in the bath will not be uniform since it varies considerably with distance from the transducers. For these reasons, cleaning trials should be carried out to determine whether a particular tank can clean to the required standard and to identify the optimum orientation and positioning of components for efficient cleaning. To avoid promoting erosion and corrosion, components placed in the bath should not be allowed to directly contact the surface of the tank to which the transducer(s) are attached.

7.3.2 Cleaning solution, made up to the recommended concentration with de-ionized water, should be heated up in the tank to the specified temperature, typically 60 °C.

NOTE Because of the energy introduced into the solution by ultrasonification, prolonged cleaning operations may cause the temperature of the solution to increase to the extent that cooling coils are required.

Before cleaning operations are carried out, it is necessary to de-gas the cleaning solution by running the bath ultrasonification for a period of 10 min or for as long as recommended by the manufacturer. Baskets of stainless steel are usually used to contain the components being cleaned. These baskets may be slowly moved through the cleaning solution during ultrasonification to obtain a more uniform cleaning of the components. Following consultation with the supplier of the cleaning solution and the manufacturer of the ultrasonic tank, trials should be carried out to determine the cleaning time necessary for particular components which are contaminated with known or suspected contaminants. Cleaning times of between 5 min to 15 min are typical for many aqueous-based cleaning processes for oxygen service components. Extended cleaning times, especially at low ultrasonic frequencies, should be avoided as they will promote erosion and corrosion of the components being cleaned.

7.4 Rinsing

7.4.1 If, cleaning solutions containing surfactants have been used, it is essential to rinse the components very thoroughly. An effective and economical rinsing cycle for cleaned components consists of the following steps1):

a) rinse in flowing tap water to remove bulk of carried over cleaner;

b) individually spray any blind holes, small crevices and internal passageways with de-ionized water for 5 s using a fine needle jet (e.g. 0.7 mm internal diameter needle with a flow rate of approximately 2×10^{-3} dm^3/s);

c) final rinse in high quality de-ionized water with ultrasonic agitation for 2 min to 5 min.

NOTE De-ionized water used for rinsing should conform to BS ISO 14951-10.

7.4.2 If the tank is periodically drained and refilled, the rinse water quality will initially be very high but will become gradually of poorer quality until it is replenished. It is much more satisfactory to either meter a portion of the rinse tank and continually replace it with fresh de-ionized pure water or to use a re-circulating system to filter the water and to pass it through selective ion exchange resins. Monitoring the condition of the final rinse water can be readily carried out by measuring electrical conductivity and using a previously calibrated chart showing the relationship between conductivity and concentration of cleaner residue in the rinse water. If the quality of the water were to deteriorate to the extent that it contained between 100 mg/dm^3 to 1 000 mg/dm^3 of cleaner residue, then false results would be likely with a water break test for surface cleanliness. Samples taken from the rinse water should be placed in a white dish and visually examined for particulates with a white light source held a short distance away. Rinse water in a satisfactory condition should show no visible evidence of particles being present.

7.4.3 The use of suitable filtration equipment may be necessary to reduce water consumption costs and/or to conform to effluent discharge requirements.

7.5 Drying

7.5.1 Suitable drying processes may include air ovens, vacuum ovens, drying tunnels, purging with pre-warmed nitrogen, and air knives. Hot air dryers should incorporate a HEPA (high efficiency particulate arresting) filter to ensure that significant particulate re-contamination of components is avoided. Non-metallic components should generally not be dried at temperatures, which exceed 60 °C, and the temperature of metallic components should normally be restricted to 120 °C. The existence of narrow passages, crevices, blind holes or meshes in components can cause problems in drying. If components have any of these features and normal drying cannot be carried out by heating to above 100 °C because of the possibility of material damage, then vacuum drying may be necessary. Vacuum drying should be carefully carried out to ensure that all the components become adequately heated up and that there is no possibility of ice formation, and thus water retention, in internal passageways. The oven should be clean and should be purged prior to use with clean and particulate free (no particles present greater than 100 µm) air or inert gas.

7.5.2 The effectiveness of the drying process can be assessed by weighing cooled components after successive periods of drying. An adequate drying time is indicated by an unchanging weight on further drying. The balance used should preferably be sensitive to less than 0.1 mg.

NOTE Properly drying components after aqueous cleaning is important for two main reasons. Any water left on the components could lead to corrosion problems, and secondly, if the component operates at a very low temperature the water could freeze, resulting in equipment malfunction.

7.6 Verification of cleanliness after aqueous-based cleaning

The water-break test (see **6.3.4**) should be carried out immediately after final rinsing has taken place to indicate whether the components have been properly cleaned. After drying and cooling, the components should be carefully inspected (see **6.3.1** and **6.3.2**) to check that they remain uncontaminated. If there is any suspicion that re-contamination might have occurred, the components should be re-cleaned or a test-solvent flushed through/over the dried component to obtain a sample for analysis (see **6.2**).

NOTE Exposing cleaned components to an industrial atmosphere for even very short periods of time may cause sufficient re-contamination for them to fail the water break test.

8 Solvent cleaning procedures

8.1 Vapour degreasing/ultrasonic tank installations

Component cleaning with high vapour pressure solvents such as HFE and HFC based azeotropes should be carried out using specially designed installations. These installations usually incorporate both ultrasonic and vapour degreasing units and have built into them sophisticated controls and chiller units. The work is first passed through a vapour blanket into the ultrasonic cleaning tank with liquid solvent and then withdrawn through the vapour blanket. Sufficient time should be allowed during the cleaning process for the components to fully heat up and emerge dry from the vapour blanket. Great care should be exercized to ensure that vapour emission into the atmosphere is reduced to a low level and that occupational exposure limits are not exceeded. To this end, the equipment should be installed in as draught free position as possible. To avoid displacing vapour from the tank by a piston effect, it is recommended that the workload should not exceed 50 % of the horizontal cross section of the sump into which it is being placed. Collapse of the vapour blanket (work-shock) can also occur if too many components are being introduced at the same time. The installed unit should have large enough work handling capabilities for safe and satisfactory operation.

NOTE It is inadvisable to attempt to convert vapour degreasing equipment designed originally for use with solvents such as 1,1,2-trichlorotrifluoroethane or 1,1,1-trichloroethane, to use with HFE or HFC azeotrope solvents.

8.2 Wipe and brush cleaning

8.2.1 Wipe and brush cleaning should be carried out using tested and approved media that is fully compatible with the solvent used. (see **4.8**). As little solvent as possible should be used for wipe cleaning and great care taken to avoid contaminating fresh solvent with used wipe media. Where cleaning is being carried out in confined spaces, pre-impregnated wipes should be used so that vapour emission of solvent from open containers is avoided. Sealed packages made of solvent compatible material, containing ready-for-use pre-impregnated wipes should be prepared in a well-ventilated and monitored area. After use, contaminated wipe cleaning media should be immediately stored in sealed packages or containers to minimize vapour emission and disposed of later (see **8.5**).

8.2.2 Two or three containers of solvent may be used for brush cleaning operations. The containers are partly filled with fresh clean solvent and using the brush, the components are thoroughly cleaned in the first container. After shaking off any surplus solvent, the component is then rinsed in the solvent contained in the second container. This is repeated if a third container of solvent is being used. Finally, after again shaking off any surplus solvent, the component is dried in an oven maintained at a suitable temperature or by using a portable hot air blower, approved for use with oxygen service components.

WARNING Great care should be taken when wipe or brush cleaning components to ensure that the occupational exposure limits for the solvent are not exceeded. The workspace should be properly monitored and suitable ventilation installed. There is particular danger in carrying out any wipe or brush cleaning operations in enclosed spaces such as small aircraft cockpits.

8.3 Cleaning pressure gauges and transducers

Because of the presence of small internal holes and passageways, special procedures may be required for cleaning pressure gauges and transducers. They should be flush cleaned using fresh solvent, introduced, if necessary, through small diameter (solvent compatible) tubing. The manufacturer or supplier of pressure gauges or transducers should be consulted to determine suitable cleaning procedures. Practical trials and cleanliness verification procedures should be carried out.

8.4 Verification of cleanliness after solvent cleaning

The components should be carefully handled in gloved hands and inspected (see **6.3.1** and **6.3.2**) to check that they are clean. If there is any suspicion that the cleanliness falls below the standard adopted for oxygen clean components (see Clause **5**), the components should be re-cleaned or a test-solvent flushed through/over the component to obtain a sample for analysis (see **6.2**).

8.5 Disposal of spent solvent and wipe media

Used or spent solvent should be disposed of in a fully labelled container provided and kept for the purpose. Different solvents should not be mixed together or further contaminated with other substances. Arrangements should be made with either the supplier of the solvent or with a legitimate waste disposal company to remove or recover the solvent and to remove wipe media waste from site.

9 Packaging

NOTE All packaging materials which may make contact with the item to be packed, should be of the same cleanliness as the item and free from loose particles. Materials that have been impregnated with substances that may give rise to greases, oils, or other contaminants, should not be used.

9.1 The item to be packed should have polythene caps or plugs as appropriate, fitted to all ports/openings. It should then be wrapped in low-density polyethylene of minimum 65 µm thickness, either in sheet form or lay-flat tube, closing the package with tape or heat sealing. If the item is of, or has an external component of, a polymer material which is subject to degradation due to direct sunlight (UV), the wrapping material should be of an opaque form (e.g. polythene coated Kraft paper [paper outside] or black polythene).

NOTE If the item has sharp edges, these should be shrouded using expanded polythene skin or similar to prevent puncture of the wrapping. Polyethylene closed cell film may be used as a primary wrap.

9.2 The item should then be placed in a barrier made from one of the materials specified in Table 1, of at most 2 g/m^2/24 hr water vapour transmission rate (W.V.T.R). Where practicable, the barrier should be of lay-flat form, heat-sealed to form the envelope.

Rigid containers made from materials specified in Table 2 are an alternative which may be cost effective if a re-usable container is required. Seals for rigid containers are specified in Table 3.

NOTE The material supplied should not give off any vapours or gases that may be hazardous.

9.3 If desiccant is used it should be included inside the barrier, but outside the wrapping. Desiccant should be contained in linen bags, and should conform to BS 2540 (silica gel). If taped in place, the tape should cover the head and tail bands of the linen bags only. The quantity of dessicant shall be calculated in accordance with BS 1133:Section 19.

9.4 To prevent relative movement between the item and container, the item may be placed in a container with dunnage or suitable clamping, which will not damage the contents, puncture the packing or barrier. Examples of dunnage materials are: polyethylene closed cell film (bubblewrap), custom made blocking/bracing, moulds etc.. If the item is particularly fragile, over-packing with cushioning material (foam) and an outer container should be considered.

10 Labelling and storage

10.1 A clean label clearly stating the cleanliness condition of the item should be securely and visibly attached to all layers of the package. The labels should also show the date of inspection and identify the item with its model and serial number. Wording of the label is at the user's discretion, but should include, in accordance with BS IEC 60877, information similar to the following example.

"Cleaned for oxygen service. Do not use unless cleanliness has been maintained until time of use. Keep free from oil and grease".

WARNING It is essential to avoid the use of adhesive labels or tape directly on components. Contaminants arising from adhesive may lead to an explosion and could cause corrosion of metallic components.

10.2 After labelling, the packaged components or systems should be placed in a storage area which has clean surfaces and is maintained free of industrial levels of contamination.

The storage area should be kept solely for the purpose of storing packaged oxygen service components/systems.

11 Unwrapping

It is essential that possible contaminants on the outside of the package are removed prior to the barrier being breached. Hands should be clean and clean room gloves worn, where necessary. Packaging should not be opened until the components are ready to assemble or install. A final inspection of each component should be made before installation to check that cleanliness has been maintained.

WARNING Failure to maintain cleanliness will result in failure of the equipment and may lead to an explosion.

Table 1 — Materials for use as barrier

Material	Thickness μm	WVTR g/m^2/24 hr
Low density polyethylene film[a]	125	4
	250	2
	500	1
Aluminium foil laminate	Type 1 i.a.w Def. Stan 81-75	0.2

[a] Required thickness may be produced from multiple layers of 125 μm or greater.

Table 2 — Rigid container materials

Materials	Thickness mm	WVTR g/m^2/24 hr
GRP/Rigid polyurethane foam/GRP sandwich	16	1.7
GRP/Expanded polystyrene/GRP sandwich	16	1.5
ABS	3	0.8
GRP Epoxy and polyester resin	6	0.75 to 2.0
Polyethylene	3.4	0.052
HD Polyethylene and Polypropylene	3.0	0.4

Table 3 — Gaskets and "O" rings (seals for rigid containers)

Materials	Thickness mm	WVTR g/m length of seal/24 hr	Type
Expanded natural rubber	3	15×10^{-4}	Gaskets
Expanded neoprene	3	13×10^{-4}	
Solid rubber (hard)	3	12×10^{-4}	
Solid rubber (medium)	3	30×10^{-4}	
Expanded PVC	6	24×10^{-4}	
Expanded silicone rubber	3	66×10^{-4}	
Cork, processed	2	72×10^{-4}	
Fluorocarbon rubber	2.5 mm diameter	9.6×10^{-4}	"O" Ring
Nitrile rubber	2.5	42×10^{-4}	
Silicone rubber	2.5	96.0×10^{-4}	
Polyurethane rubber	2.5	138×10^{-4}	

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2) May be obtained from CGA website: www.cganet.com/publications.asp.

3) May be obtained from British Compressed Gases Association, 14 Tollgate, Eastleigh, Hampshire, SO53 3TG UK; tel. 023 8064 1488.

4) May be obtained from American Technical Publishers Ltd, 27 - 29 Knowl Piece, Wilbury Way, Hitchin, Herts, SG4 0SX, UK; tel. 01462 437933.

5) May be obtained from ILI, Index House, Ascot, Berkshire, SL5 7EU, UK; tel. 01344 636400.

6) May be obtained from NASA, White Sands Test Facility, Las Cruces, New Mexico, USA.

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