



Standard Guide for the Selection of Cleaning Agents for Oxygen Systems¹

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1. Scope

1.1 The purpose of this guide is to establish a procedure to select cleaning agents, both solvents and water-based detergents, for oxygen service. This includes of laboratory-scale tests for cleaning effectiveness, materials compatibility and oxygen compatibility.

1.2 The effectiveness of a particular cleaning agent depends upon the method by which it is used, the nature and type of the contaminants, and the characteristics of the article being cleaned, such as size, shape, and material. Final evaluation of the cleaning agent should include testing of actual products and production processes.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- D471 Test Method for Rubber Property—Effect of Liquids
- D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
- D1193 Specification for Reagent Water
- D1460 Test Method for Rubber Property—Change in Length During Liquid Immersion
- D2512 Test Method for Compatibility of Materials with Liquid Oxygen (Impact Sensitivity Threshold and Pass-Fail Techniques)
- D2863 Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
- D2934 Test Method for Compatibility of Vulcanized Rubber

Seals--Compatibility with Service Fluids (Withdrawn 1993)³

- D4809 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter (Precision Method)
 - G5 Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements
 - G31 Practice for Laboratory Immersion Corrosion Testing of Metals
 - G59 Test Method for Conducting Potentiodynamic Polarization Resistance Measurements
 - G63 Guide for Evaluating Nonmetallic Materials for Oxygen Service
 - G72 Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment
 - G74 Test Method for Ignition Sensitivity of Materials to Gaseous Fluid Impact
 - G93 Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments
 - G94 Guide for Evaluating Metals for Oxygen Service
 - G121 Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents
 - G122 Test Method for Evaluating the Effectiveness of Cleaning Agents
- #### 2.2 CGA Document:
- CGA Pamphlet G-4.1 Cleaning Equipment for Oxygen Service

3. Significance and Use

3.1 The purpose of this guide is to provide information that may be considered when selecting and qualifying a cleaning agent for an oxygen system.

3.2 Insufficient cleanliness can result in the ignition of contaminants or components by a variety of mechanisms. Therefore, an acceptable level of contamination for each condition of use in oxygen service should be defined. The acceptable level of contamination may depend on various factors, such as:

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

- 3.2.1 The nature and type of the contaminants,
- 3.2.2 The location and degree of contamination,
- 3.2.3 The type of substrate material,
- 3.2.4 The configuration and end use of the equipment or part to be cleaned, and
- 3.2.5 The operating parameters of the oxygen system (pressure, temperature, phase, concentration, fluid velocity, etc.).

4. Selection of Cleaning Agent

4.1 Before a specific cleaning agent is selected for testing, the following attributes should be considered.

- 4.1.1 Toxicity,
- 4.1.2 Carcinogenicity,
- 4.1.3 Recyclability,
- 4.1.4 Waste disposal,
- 4.1.5 Ozone depletion,
- 4.1.6 Inertness (flammability and combustibility),
- 4.1.7 Corrosivity and compatibility with metallic and non-metallic engineering materials,
- 4.1.8 Availability and technical support from supplier,
- 4.1.9 Cost effectiveness, and
- 4.1.10 Compliance with local, state and federal regulations.

4.2 It is desirable that the cleaning agent could be applied by a variety of methods, such as wiping, immersion, spraying, etc. Consequently, the cleaning agent manufacturer's instructions for applying the cleaner shall be considered.

5. Selection of Substrate Materials

5.1 Substrate materials used for cleaning effectiveness and compatibility tests should be representative of those used in the end application.

5.2 *Metallic Materials:*

5.2.1 Metallic materials commonly used in oxygen systems are listed in Guide **G94**.

5.2.2 Alloys representative of numerous applications in oxygen systems and suitable for inclusion in a test protocol are as follows:

- 5.2.2.1 304 stainless steel,
- 5.2.2.2 Aluminum alloy 6061 (or 5051),
- 5.2.2.3 Carbon steel 1018,
- 5.2.2.4 Admiralty brass CDA 443,⁴
- 5.2.2.5 Monel 400,
- 5.2.2.6 4130X low alloy steel,
- 5.2.2.7 Inconel 718,
- 5.2.2.8 Copper,
- 5.2.2.9 Tin-bronze, and
- 5.2.2.10 Cobalt alloy 188.

5.3 *Nonmetallic Materials:*

5.3.1 Nonmetallic materials commonly used in oxygen service are discussed in Guide **G63**.

5.3.2 Nonmetallic materials representative of numerous applications in oxygen systems and suitable for inclusion in a test protocol are as follows:

- 5.3.2.1 Ethylene Propylene Rubber (EPDM),
- 5.3.2.2 Perfluoroelastomer (Kalrez[®], Chemraz[®]),
- 5.3.2.3 PCTFE, Polychlorotrifluoroethylene (Kel-F[®]),
- 5.3.2.4 Chloroprene Rubber (Neoprene),
- 5.3.2.5 Polyamid Polymer (Nylon),
- 5.3.2.6 PTFE, Polytetrafluoroethylene (Teflon[®]), and
- 5.3.2.7 Fluoroelastomer (Viton[®] A, Fluorel).

6. Cleaning Effectiveness Tests

6.1 *Selection of Test Contaminants:*

6.1.1 Numerous contaminants encountered in oxygen systems that could result from manufacturing, assembly, fabrication, and construction processes are listed in Practice **G93**. Typical contaminants include:

- 6.1.1.1 Hydrocarbon oils and greases,
- 6.1.1.2 Fluorinated fluids and greases,
- 6.1.1.3 Inks,
- 6.1.1.4 Machine cutting oils,
- 6.1.1.5 Carbon deposits,
- 6.1.1.6 Silicone oils and greases,
- 6.1.1.7 Phosphate esters,
- 6.1.1.8 Waxes,
- 6.1.1.9 Dye penetrants,
- 6.1.1.10 Chlorotrifluoroethylene based oils and greases.

6.1.2 Among typical contaminants, hydrocarbons are the prime candidates for the test protocol. When dealing with other contaminants, the user should attempt to classify the type of contamination expected on the equipment to be cleaned.

6.1.3 As a preliminary test, a mixture of common cutting oils may be used as a contaminant. It may be carried in a suitable volatile solvent as a means to introduce it into a system. In addition, vacuum pump oil, or a compressor oil are suggested as contaminants for the evaluation program. In a more refined test at later stages, fluorinated oils/greases, dye penetrants, or a mixture of as many contaminants as necessary may be prepared in a suitable solvent. Eventually, actual contaminants encountered on an engineering component or system for oxygen service shall be evaluated for removal efficiency.

6.2 *Test Methods:*

6.2.1 A suggested starting level of contamination is 1000 mg/m². This is a hydrocarbon level that is consistent with contamination levels associated with final cleaning and it is twice the acceptable level specified for oxygen service in CGA pamphlet G-4.1. Heavily contaminated surfaces with levels in excess of 1000 mg/m² must be precleaned using more aggressive cleaning agents with mechanical scrubbing (Practice **G93**). Precleaning is not a cleaning step with which this guide is concerned.

6.2.2 Contaminants may be applied to the specimens by any of the means specified in Practice **G121**.

6.2.3 The cleaning effectiveness of a cleaning agent shall be evaluated using the test method outlined in Test Method **G122**.

6.2.4 A test basis shall be established for each contaminated sample by using an acceptable solvent as a control cleaning agent.

⁴ Available from the Copper Development Association, 405 Lexington Ave, New York, NY 10017.

7. Material Compatibility Tests

7.1 If a cleaning agent's ability to remove the selected contamination is deemed promising, additional testing (see Sections 8.2 and 8.3) should be performed to evaluate its compatibility with the oxygen systems.

7.2 *Metallic Materials:*

7.2.1 Significant corrosion damage may occur during cleaning operations. Corrosion rates may be affected by temperature, contaminants, degree of aeration, concentration and presence of residual stress (see Note 1). To avoid this, assessments should be made of the corrosion severity of cleaning environments for the engineering materials of interest. Weight gain-loss measurements can be performed as per Practice G31. Where applicable, Test Method G5 can be applied (see Note 2).

7.2.2 The electrochemical technique of potentiodynamic polarization resistance (Practice G59) can be used to determine the corrosion rate of conductive cleaning agents on metal substrates. The corrosion rate (in mils per year, mpy) should be determined using the solution parameters which would be used in actual cleaning practices. The cleaning solution may be tested: (1) as-is; (2) deaerated; (3) aerated. It is recommended, however, that the corrosion test be performed under as-is conditions in order to simulate the actual cleaning process. The pH and conductivity of the cleaning agent should be measured both before and after the corrosion test. If these property values change, the test is considered invalid. A separate experiment should be performed.

NOTE 1—The presence of residual stresses may promote stress corrosion cracking in susceptible materials. Information in the technical literature on corrosion rates and stress corrosion cracking may be used in evaluating corrosion susceptibility. Further testing, as outlined later in this guide, may be necessary.

NOTE 2—In order to reflect the actual material property, samples for corrosion tests should not be wet ground with 600-grit SiC papers to expose fresh surface. The surface roughness of test samples should be either in compliance with that recommended in Practice G121, or, if possible, commensurate with that of the actual engineering components.

7.3 *Nonmetallic Materials:*

7.3.1 When exposed to the cleaning agent under actual use conditions of temperature, time, concentration etc., some of the nonmetallics are susceptible to degradation and may experience physical, mechanical, chemical and possibly thermal property changes. These changes are typically characterized by swelling, distortion, cracking, crazing, blistering, embrittlement and decomposition temperature shift. To evaluate the compatibility of cleaning agents with nonmetallic materials, refer to Test Methods D471, D543, D1460, and Method D2934.

7.3.2 Corrosion rates of less than 63.5 micrometer per year (2.5 mpy) are usually desirable. However, to avoid setting up unduly conservative criteria which may eliminate potential cleaning agents, estimation of corrosion rate can be made based upon realistic, total accumulated contact time of the cleaner with a component or system throughout its service life. The rate of corrosion should be determined based upon the maximum allowable dimensional variations of the component or system.

8. Residue Analysis

8.1 Although CFC-based cleaning solvents pose ozone-depleting potential they usually have a fast evaporation rate and do not leave measurable quantities of non-volatile residues after complete evaporation. On the other hand, non-CFC based cleaning agents, especially water-based detergents, exhibit a much slower evaporation rate. Moreover, they often leave a significant amount of residue after complete drying of the surfaces. If residues are not reduced to acceptable levels, they are susceptible to ignition or combustion, or both, during oxygen service, which may lead to a fire. As a result, a water or solvent rinsing, after final cleaning by non-CFC based cleaning agents is sometimes an essential step in the water-based detergent cleaning process.

8.2 A quantitative determination of the cleaning agent's rinsability can be made by assessing the amount of residue remaining after complete drying. This assessment can be accomplished by weight measurement using the procedures described in 8.2.1, 8.2.2 and 8.2.3. When the amount of residue is low and cannot be accurately determined by weight measurement, the residue may be extracted by flushing, rinsing, or immersing in a low-residue solvent, such as Type II reagent water (Specification D1193). The rinsing solvent can be examined by analytical methods such as UV spectroscopy, total organic carbon analysis, ion chromatography, high performance liquid chromatography, etc.

8.2.1 A fixed quantity of the cleaning solution is prepared in the concentration to be used in actual cleaning operations, weighed, and placed in beakers. The solution is completely dried and the remaining residue is weighed to determine the weight percent residue. See Note 3.

8.2.2 A fixed quantity of the cleaning solution is prepared in the concentration to be used in actual cleaning operations, and placed in a beaker of known mass. The solution is emptied, leaving the walls of the beaker wetted with the solution. The beaker is then allowed to dry and the weight of the residue is determined. See Note 3.

8.2.3 A test, similar to 8.2.2, is performed with the exception that the recommended number of water or solvent rinses are performed before the amount of residue is determined. The same procedures can be used with metal coupons chosen to represent typical materials used in the system or components to be cleaned.

NOTE 3—A sufficient quantity of solution ranging from 100 to 1000 mL may be required in order to yield satisfactory statistical confidence.

8.3 *Oxygen Compatibility Test:*

8.3.1 The following methods may be used to evaluate the oxygen compatibility of the residues: an oxygen impact test per Test Method D2512, an oxygen index test per Test Method D2863, a heat of combustion test per Test Method D4809, an autoignition temperature test per Test Method G72, and a pneumatic impact test per Test Method G74.

9. Keywords

9.1 chlorofluorocarbon; cleaning; compatibility; contaminant; detergent; non-volatile residue; oxygen-enriched environment; oxygen system; ozone depletion; rinsing; solvent

REFERENCES

(1) The following are additional sources of information:

F331 Standard Test Method for Nonvolatile Residue of Halogenated Solvent Extract from Aerospace Components (Using Rotary Flash Evaporator)

G88 Standard Guide for Designing Systems for Oxygen Service
“Alternatives to Chlorofluorocarbon Fluids in the Cleaning of Oxygen and Aerospace Systems and Components,” *ASTM STP 1181*, Eds. C. J. Bryan and K. Gebert-Thompson, 1993.

ASM Metals Handbook, Vol 5 Metal Cleaning

IGC Pamphlet 33/86/E Cleaning of Equipment for Oxygen Service Guideline

“Solvent-Based Cleaning: A Viable Alternative for Precision Cleaning,” A. E. Walter and J. W. Parker, *Precision Cleaning*, pp. 26–34, February, 1994.

NAVSEA Report on Aqueous Oxygen Cleaning Products and Process, Naval Sea Systems Command, 2531 Jefferson Davis Hwy, Arlington, VA 22242–5160.

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