

# PUBLIC SAFETY

## Public Access to CGA G-4.1

### *Cleaning Equipment for Oxygen Service*

The 1985 edition of CGA G-4.1 is incorporated by reference into law at 49 CFR 178.338-15 which requires that “a cargo tank constructed for oxygen service must be thoroughly cleaned to remove all foreign material in accordance with CGA G-4.1.” This is an example of a section in the Code of Federal Regulations that is impossible to understand without access to the text of the incorporated regulation.

The CGA G-4.1 standard is available from the Compressed Gas Association. The standard is not available from the usual retail outlets, such as TechStreet or IHS Global. The electronic version of the 1985 standard costs \$117, but it only works on certain Windows operating systems due to the Digital Rights Management plugin required for the Adobe PDF reader. The paper version of the standard costs \$138. Ordering from CGA is somewhat hit or miss: when Public.Resource.Org placed an order for \$1,549 worth of standards on May 16, 2012, although our credit card was charged the organization forgot to ship the standards, and it took a month and several phone calls to get them to send the documents.

The current version of CGA G-4.1 is the 2009 edition. The current edition costs only \$99 for hardcopy. This pattern of pricing the older, obsolete version required by law at higher prices than the current version is fairly typical of standards bodies, an example of extracting rent from their monopoly position as providers of key portions of our legal corpus.

The cleaning methods spelled out in CGA G-4.1 apply to much more than cargo tanks, and are of general applicability to storage tanks, pressure vessels, cylinders, regulators, welding torches, pipelines, compressors, and pumps. The standard specifies mechanisms for steam, hot water, caustic, and acid cleaning, as well as modern techniques such as solvent washing (including ultrasonic cleaning).

Material in standards such as CGA G-4.1 represent best current practices and are thus an invaluable educational tool. They also represent the legally-mandated standards that should be available to be consulted by journalists or other “outsiders” wishing to monitor the performance of those involved in these hazardous activities. However, only **9 libraries in the entire country** list this standard as being available in the WorldCat catalog, and only 5 of those carry the mandated 1985 edition.

### ***Public Safety Analysis:***

*Carl Malamud, Public.Resource.Org*

*July 9, 2012*

# CERTIFICATE

## By Authority Of THE UNITED STATES OF AMERICA Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. HEED THIS NOTICE: Criminal penalties may apply for noncompliance.



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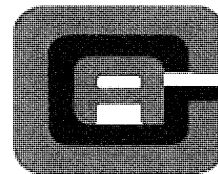


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**CGA G-4.1—1985  
(OBSOLETE)**

**CLEANING EQUIPMENT  
FOR OXYGEN SERVICE**

**THIRD EDITION**



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THIRD EDITION: 1985

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Contents	Page
1 Scope .....	1
2 Objectives.....	1
3 Planning requirements .....	1
3.1 Supervision.....	1
3.2 Selecting procedures.....	2
4 Precleaning .....	2
5 Steam or hot water cleaning.....	3
5.1 Materials .....	3
5.2 Steam cleaning.....	3
5.3 Hot water cleaning.....	3
5.4 Removal of cleaning agents .....	3
6 Caustic cleaning .....	3
6.1 Materials .....	4
6.2 Caustic cleaning procedures .....	4
6.3 Rinsing.....	4
6.4 Drying .....	5
7 Acid cleaning .....	5
7.1 Selection of cleaning agent .....	5
7.2 Equipment .....	5
7.3 Cleaning procedure .....	5
7.4 Rinsing.....	5
7.5 Drying .....	6
8 Solvent washing (including ultrasonic cleaning).....	6
8.1 Solvent washing .....	6
8.2 Ultrasonic cleaning .....	6
8.3 Materials .....	6
8.4 Washing equipment.....	6
8.5 Control of solvent cleanliness .....	6
8.6 Removal of solvents .....	8
9 Vapor degreasing .....	8
9.1 Equipment .....	8
9.2 Materials for vapor degreasing.....	8
9.3 Vapor degreasing procedure .....	9
10 Mechanical cleaning.....	9
10.1 Blast cleaning .....	9
10.2 Wire brushing or grinding .....	9
10.3 Tumbling.....	9
10.4 Swabbing, vacuuming .....	9
10.5 Blowing and purging .....	10
11 Inspection.....	10
11.1 Approval of quality control procedures and standards .....	10
11.2 Inspection procedures .....	10
12 Packaging and labeling .....	12
12.1 Protection from recontamination.....	12
12.2 Labeling .....	12

13 Personnel safety.....	12
13.1 Instructions and supervision .....	12
13.2 Dangerous chemicals .....	12
13.3 Protective equipment.....	13
13.4 Proper ventilation.....	13
13.5 Special situations.....	13
14 References .....	14

#### List of Illustrations

##### Table

Table 1—Chemical and physical properties of cleaning solvents .....	7
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## 1 Scope

The cleaning methods described in this pamphlet are intended for cleaning equipment used in the production, storage, distribution, and use of liquid and gaseous oxygen. Examples of such equipment (illustrative of the primary intent of this publication) are: stationary storage tanks, cargo tanks, and tank cars; pressure vessels such as heat exchangers and rectification columns; and associated piping, valves, and instrumentation. The cleaning methods, however, are not limited to the above equipment and with proper consideration or modification may be utilized in cleaning other oxygen service equipment such as cylinders, cylinder valves, regulators, welding torches, pipelines, compressors and pumps.

NOTE: CGA C-10, *Recommended Procedures for Changes of Gas Service for Compressed Gas Cylinders*, [1]<sup>1</sup> includes the conversion of cylinders to oxygen service. Where the requirements for this conversion differ from the recommendations of CGA G-4.1, the recommendations of CGA C-10 should take precedence.

## 2 Objectives

### 2.1

Oxygen equipment and systems, including all components and parts thereof, must be adequately cleaned to remove harmful contamination prior to the introduction of oxygen. Harmful contamination would include both organic and inorganic materials such as oils, greases, paper, fiber, rags, wood pieces, coal dust, solvents, weld slag, rust, sand, and dirt, which if not removed, could cause a combustion reaction in an oxygen atmosphere or result in an unacceptable product purity.

### 2.2

This publication presents methods for cleaning oxygen service equipment. When properly used, these cleaning methods and subsequent inspections will result in the degree of cleanness required for the safe operation of oxygen service equipment and the necessary product purity required in CGA G-4.3, *Commodity Specification for Oxygen*. [2] Suggested levels of contamination and ways of determining if a component or system is sufficiently clean to be used in oxygen service are given along with procedures for keeping such equipment clean before being placed in service.

### 2.3

Cleaning a component or system for oxygen service involves the removal of combustible contaminants including the surface residue from manufacturing, hot work, and assembly operations, as well as the removal of all cleaning agents and the prevention of recontamination before final assembly, installation, and use. These cleaning agents and contaminants include solvents, acids, alkalies, water, moisture, corrosion products, non-compatible thread lubricants, filings, dirt, scale, slag, weld splatter, organic material (such as oil, grease, crayon, and paint), lint, and other foreign materials.

### 2.4

The removal of injurious contaminants can be accomplished by cleaning all parts and maintaining this condition during construction, by completely cleaning the system after construction, or by a combination of the two.

## 3 Planning requirements

### 3.1 Supervision

An individual skilled in the techniques required for oxygen service cleaning shall be responsible for monitoring the cleaning operation and determining if a component or system is clean so that it can function safely in an oxygen environment. Where piping systems with multiple branches are involved, it is of paramount importance that the cleaning procedures be well established, suitably integrated with the sequence of construction opera-

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<sup>1</sup> NOTE: References in this document are shown by bracketed numbers and are listed in the order of appearance. See Section 14, References.

tions, and precisely followed, since it may be neither practical nor possible to inspect such a system completely for cleanness after construction and final cleaning.

## **3.2 Selecting procedures**

### **3.2.1**

The type, possible location, and degree of contamination should initially be estimated in order to decide on the most practical method of cleaning, inspecting, and testing. In addition, the arrangement of passages must be studied so that cleaning, washing, or draining practices can be adjusted to make sure that dead end passages and possible traps are adequately cleaned.

### **3.2.2**

The cleaning procedure selected, which includes removal of the cleaning agent, will depend on several factors:

- 1) The type of the contaminants
- 2) The location and degree of contamination
- 3) The arrangement of passages with respect to their ability to be flushed and drained
- 4) The effectiveness of the cleaning agent in removing the contaminants
- 5) The compatibility of the cleaning agent with the contaminants, metals, and materials involved
- 6) The availability and cost of cleaning agents and cleaning methods, and the availability of personnel experienced in handling these materials
- 7) The speed and effectiveness of cleaning and the desired level of cleanness

### **3.2.3**

A list of typical cleaning procedures would include:

- 1) Steam cleaning (including hot water and detergents)
- 2) Vapor degreasing
- 3) Solvent washing (including ultrasonics)
- 4) Alkaline (caustic) cleaning
- 5) Acid cleaning
- 6) Mechanical cleaning (blast cleaning, wire brushing, etc.)
- 7) Purging

### **3.2.4**

A detailed cleaning procedure in accordance with the instructions of the manufacturer of the cleaning agent should be specified to the satisfaction of both the manufacturer and the purchaser of the oxygen equipment and followed throughout the project.

## **4 Precleaning**

Prior to cleaning, component materials not compatible with the cleaning agent shall be removed or isolated. Gross amounts of foreign material such as scale, dirt, grit, solid objects, and hydrocarbons shall be removed. Removal may be accomplished by grinding, wire brushing, blast cleaning, sweeping, vacuuming, swabbing, etc.

## 5 Steam or hot water cleaning

Steam or hot water cleaning is the use of steam or hot water propelled through a nozzle or sprayhead and usually assisted by a detergent to remove contaminants such as dirt, oil, and loose scale.

### 5.1 Materials

The steam or hot water should be clean and oil-free. In most steam or hot water cleaning operations, a detergent solution is combined with the steam or hot water to provide an acceptable level of final cleanness. The detergents selected shall be suitable for the contaminants involved and shall also be compatible with the surfaces being cleaned.

### 5.2 Steam cleaning

#### 5.2.1 Equipment

The equipment used may consist of a steam and water supply, a length of hose, and a steam lance with or without a spray nozzle.

#### 5.2.2 Steam cleaning procedure

Either plant steam or steam from a portable steam generator can be used. If a steam lance is used, the detergent solution may enter the steam gun by venturi action and mix with the steam. Steam removes oils, greases, and soaps by first "thinning" them with the heat. Dispersion and emulsification of the oils then occur, followed by dilution with the condensed steam. The system should provide control over the steam, water, and detergent flows so that the full effects of the detergent's chemical action, the heat of the steam, and the "abrasive" action of the pressure jet are attained for maximum cleaning efficiency.

##### 5.2.2.1

If the steam is clean and free of organic material, a secondary cleaning operation with a solvent or alkaline degreaser may not be required in cases where the initial contamination is not heavy or is readily removed with steam.

### 5.3 Hot water cleaning

#### 5.3.1 Equipment

Cleaning with a hot detergent solution may utilize a spray system or a cleaning vat with suitable agitation of either the solution or the parts to be cleaned.

#### 5.3.2 Hot water cleaning procedure

Hot detergent solution cleaning can be used where a steam temperature is not necessary to free and fluidize contaminants. Proper consideration shall be given to the size, shape, and the number of parts to be cleaned so as to assure adequate contact between the surfaces to be cleaned and the detergent solution. The solution temperature should be in accordance with the recommendation of the manufacturer of the cleaning agent.

### 5.4 Removal of cleaning agents

Most detergents are water soluble and are best removed by prompt flushing with sufficient quantities of hot or cold clean water, as appropriate, before the cleaning agents have time to precipitate. The equipment is then dried by purging with dry oil-free air or nitrogen which may be heated to shorten the drying time.

## 6 Caustic cleaning

Caustic cleaning is cleaning with solutions of high alkalinity for the removal of heavy or tenacious surface contamination followed by a rinsing operation.

## 6.1 Materials

There are many effective materials available for caustic cleaning. They are basically alkalies and are water soluble and nonflammable, and may be harmful in contact with the skin or eyes or if swallowed. The cleaning agents should be chosen so that they do not react chemically with the materials being cleaned.

### 6.1.1

The water that is used for rinsing should be free of oil and other hydrocarbons and should contain no particles larger than those acceptable on the cleaned surface. Filtration may be required. It may be desirable to analyze the water to determine the type and quantity of impurities. Some impurities may cause undesirable products or reactions with the particular caustic cleaner used.

## 6.2 Caustic cleaning procedures

The cleaning solution can be applied by spraying, immersion flushing, or hand swabbing.

### 6.2.1

Spraying works well, but requires a method whereby the cleaning solution reaches all areas of the surface. It is also desirable to have provisions for draining the solution faster than it is introduced to avoid accumulation.

### 6.2.2

Immersion or flushing should be total rather than partial since the solution tends to dry on the surface that is exposed to air.

### 6.2.3

Hand swabbed surfaces should be rinsed before the cleaning solution dries.

### 6.2.4

Generally, cleaning solutions perform better when warm. Depending upon the particular solution, this temperature will be in the range of 100 °F to 180 °F (37.8 °C to 82.2 °C). The cleaning solution can be reused until it is too weak or too contaminated as determined by pH or concentration analysis. Both decrease as the solution weakens. Experience will establish when a cleaning solution has become too weak or too contaminated to effectively clean contaminated surfaces.

## 6.3 Rinsing

The cleanness attained will only be as good as the rinsing job. All of the contaminants may be held in suspension in the cleaning solution. However, if the cleaning solution is not completely flushed from the surface being cleaned, the contaminant in any remaining solution will redeposit on the surface during the drying operation. The surface must not be allowed to dry between the cleaning phase and the rinsing phase. If this happens, it is very likely that the film or residue will not be adequately removed during the rinsing phase.

### 6.3.1

Frequently, some type of agitation during rinsing is required. This may be by mechanical brushing, fluid impingement, agitation of the parts being cleaned, etc.

### 6.3.2

The water rinse is often warmed to help remove the cleaning solution and aid in the drying process. A method of determining when the rinsing is complete is to monitor the pH of the outlet rinse water. The pH approaches that of the original rinse water as the rinsing progresses.

## 6.4 Drying

If drying is not completed with the residual heat in the metal, it can be completed with dry oil-free air or nitrogen. If it is desirable that the equipment be maintained in a dry atmosphere before installation or use, the dew point of the contained atmosphere should not be above  $-30^{\circ}\text{F}$  ( $-34.4^{\circ}\text{C}$ ).

## 7 Acid cleaning

This cleaning procedure removes oxides and other contaminants by immersion in a suitable acid solution, usually at room temperature.

### 7.1 Selection of cleaning agent

The type of cleaning agent selected will depend, in most cases, on the material to be cleaned. The following general guidelines can be used:

#### 7.1.1

Phosphoric acid based cleaning agents can be used for all metals. These agents will remove oxides, light rust, light oils, and fluxes.

#### 7.1.2

Hydrochloric acid based cleaning agents are recommended for carbon and low alloy steels only. These agents will remove rust, scale, and oxide coatings and will strip chromium, zinc, and cadmium platings. Certain acid solutions, including hydrochloric or nitric acids, should contain an inhibitor to prevent harmful attacks on base metals. Hydrochloric acid should not be used on stainless steel since it may cause stress corrosion.

#### 7.1.3

Chromic acid based cleaning agents and nitric acid based cleaning agents are recommended for aluminum, copper, and their alloys. These agents are not true cleaning agents but are used for deoxidizing, brightening, and for removing black smut which forms during cleaning with an alkaline solution. Some agents are available as liquids and others as powders, and are mixed in concentrations of 5% to 50% in water, depending on the cleaning agent and the amount of oxide or scale to be removed.

### 7.2 Equipment

A storage or immersion tank, acid-resistant recirculation pump, and associated piping and valving compatible with the acid solution are required.

### 7.3 Cleaning procedure

Common methods of applying acid cleaning agents used for cleaning metals are:

- 1) Large areas may be flushed with an appropriate acid solution
- 2) Small parts may be immersed and scrubbed or agitated in the solution

**CAUTION:** Acid cleaning agents should not be used unless their application and performance are known or are discussed with the cleaning agent manufacturer. The manufacturer's recommendations regarding concentration and temperature should be followed for safe handling and use of the cleaning agent.

### 7.4 Rinsing

Rinse the equipment thoroughly with cold water. Rinsing must begin as soon as practicable after cleaning to prevent excessive attack on the material being cleaned by the acid cleaning solution. If there is a chance of any cleaning solution becoming trapped in the equipment being cleaned, a dilute alkaline neutralizing solution can be applied, followed by water rinsing.

## 7.5 Drying

If drying is not completed with the residual heat in the metal, it can be completed with dry oil-free air or nitrogen. If it is desirable that the equipment be maintained in a dry atmosphere before installation or use, the dew point of the contained atmosphere should not be above  $-30^{\circ}\text{F}$  ( $-34.4^{\circ}\text{C}$ ).

## 8 Solvent washing (including ultrasonic cleaning)

### 8.1 Solvent washing

Solvent washing is the removal of organic contaminants from the surface to be cleaned by the use of chlorinated hydrocarbons or other suitable solvents.

### 8.2 Ultrasonic cleaning

Ultrasonic cleaning is the loosening of oil and grease or other contamination from metal surfaces by the immersion of parts in a solvent or detergent solution in the presence of high frequency vibrational energy.

### 8.3 Materials

The solvents frequently used for solvent washing and ultrasonic cleaning are methylene chloride; refrigerant 11 (trichlorofluoromethane); refrigerant 113 (trichlorotrifluoroethane); perchloroethylene; 1,1,1-trichloroethane (methyl chloroform); or trichloroethylene. Refer to 13.2 for additional precautions concerning these solvents. Suitable corrosion inhibitors and stabilizers should be included in the formulation for the solvents. Carbon tetrachloride shall not be used because of its high toxicity, i.e., its low threshold limit value (TLV). Trichloroethylene should be used only if absolutely necessary since it is more toxic than 1,1,1-trichloroethane (methyl chloroform).

The boiling points, freezing points, threshold limit values, and Kauri-Butanol numbers are listed in Table 1.

### 8.4 Washing equipment

Washing equipment may consist of a recirculating system for the solvent or a closed container for immersing parts. Auxiliary control and test equipment might include the following: space heaters, halogen detectors, thermometers, a utility container, funnel and strainer, an Imhoff cone, dry oil-free air or nitrogen, and siphon pump. For ultrasonic cleaning, a high frequency sound generator and container are substituted for the recirculation system.

**CAUTION:** Some plastic tubing including polyvinylchloride (PVC) may have its plasticizer extracted by the solvent and deposited on the surface being cleaned. For this same reason, rubber, neoprene, and nylon tubing should not be used with these solvents when cleaning oxygen equipment. Polyethylene, polypropylene, and polytetrafluoroethylene (PTFE) tubing are satisfactory with the frequently used solvents.

### 8.5 Control of solvent cleanness

#### 8.5.1 Reference sample

Before a new batch of solvent is used for any cleaning operation, a sample of it should be taken for reference purposes. This sample should be stored in a clean container made of materials that will not contaminate it.

#### 8.5.2 Checking solvent cleanness

The cleanness of the solvent after a period of use can be determined by comparing it to the reference sample in one of several ways: (a) by comparing its color to that of the reference sample, (b) by an analysis, or (c) by an evaporation procedure.

**Table 1—Chemical and physical properties of cleaning solvents**

Solvent	Formula	Molecular weight	Boiling point ° F (° C)		Freezing point ° F (° C)		Density at 68 °F (20 °C) (lb/ft <sup>3</sup> ) (kg/m <sup>3</sup> )		Latent heat of vaporization at boiling point (Btu/lb)	Evaporation rate (Ether=100)	(1) TLV (ppm)	Kauri-Butanol Number <sup>(2)</sup> at 77 °F (25 °C) <sup>(6)</sup>
1,1,1-Trichloroethane <sup>(3)</sup>	C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub>	133.42	165.0	(73.89)	−36.0	(−37.78)	82.10 <sup>(6)</sup>	(1315.12)	102.0	37	350	124
Methylene chloride <sup>(4)</sup>	CH <sub>2</sub> Cl <sub>2</sub>	84.94	103.6	(39.78)	−142.1	(−96.72)	83.37	(1335.46)	141.7	62	100	136
Perchloroethylene	C <sub>2</sub> Cl <sub>4</sub>	165.85	250.2	(121.22)	−8.2	(−22.33)	101.50	(1625.87)	90.0	12	50	92
Refrigerant 11 (Trichlorofluoromethane)	CCl <sub>3</sub> F	137.40	74.8	(23.78)	−168.0	(−111.11)	92.70 <sup>(7)</sup>	(1484.91)	78.31	81	1000	60
Refrigerant 113 (Trichlorotrifluoroethane)	Cl <sub>2</sub> FC <sub>2</sub> ClF <sub>2</sub>	187.40	117.6	(47.56)	−31.0	(−35.00)	94.29 <sup>(8)</sup>	(1510.38)	63.12	126	1000	31
Trichloroethylene <sup>(5)</sup>	C <sub>2</sub> HCl <sub>3</sub>	131.40	188.6	(87.00)	−122.8	(−86.00)	91.42	(1464.41)	103.0	30	50	129

<sup>1)</sup> Threshold Limit Values (time weighted average) adopted by American Conference of Governmental Industrial Hygienists, 1983-1984.

<sup>2)</sup> The higher the Kauri-Butanol Number, the greater the dissolving power for certain gums.

<sup>3)</sup> 1,1,1-Trichloroethane has neither a flash nor fire point. It has flammable limits of 7.5% to 15% in air at 77 °F (25 °C).

<sup>4)</sup> Methylene Chloride has neither a flash nor fire point. It has flammable limits of 12% to 22% in air at 77 °F (25 °C).

<sup>5)</sup> Trichloroethylene has a listed flash point of 90 °F (32.2 °C) and flammable limits of 8% to 10.5% in air at 77 °F (25 °C).

<sup>6)</sup> This value is listed for 77 °F (25 °C).

<sup>7)</sup> This value is listed for 70 °F (21.1 °C).

<sup>8)</sup> This value is listed for 117.6 °F (47.6 °C)

### 8.5.2.1 Color comparison

In the color comparison, it is assumed that the solvent is still sufficiently clean to use if it shows no distinct color change from the reference sample. The color change can be determined visually or by instrument, comparing the simultaneous light transmission through both samples. This should be verified by analytical tests to detect probable contaminants, or by calculation of the amount of residue deposited by evaporation of contaminated solvent. ASTM D-2108-71, *Standard Testing for Color Halogenated Organic Solvents and Admixtures*, [3] may be used if a scale of color changes is to be established for one or more contaminants.

### 8.5.2.2 Analytical tests

Analytical techniques (for example, infrared spectroscopy or chromatography), although somewhat more time consuming, can measure quite exactly the extent of solvent contamination with a known contaminant, e.g., a particular cutting oil used to machine parts. However, if one or several unknown contaminants are present, results might be more difficult to quantify.

### 8.5.2.3 Evaporation test

Contamination can be checked by calculation of the amount of residue deposited by evaporation of contaminated solvent (see 11.2.5). Evaporation of a solvent and measurement of the residue depends on the nonvolatility of any contaminants. However, the vapor pressures of most oils are sufficiently high that significant amounts may evaporate with a large volume of solvent. Therefore, an evaporation determination may give only a lower limit to the amount of dissolved contaminant.

### 8.5.3 Immersion cleaning

A test for contamination should be run periodically on the solvent used for immersion cleaning of components. If a large vessel or piping system is cleaned by circulating solvent through it, the solvent should be tested at the end of the cleaning period. If the solvent is contaminated, as shown by that test, it must be drained from the equipment and replaced with a batch of clean solvent. After further circulation, this solvent shall be similarly tested, and it must either pass or be replaced with clean solvent. A vessel can be considered clean when no distinct color difference exists between the ingoing and drained samples.

#### 8.5.3.1

After a part is removed from or drained of solvent, techniques such as heating and monitoring the exit purge gas for solvent, e.g., by halogen detector, should be used to ensure that all solvent has been removed from the component.

#### 8.5.3.2

Dirty solvent may be reclaimed by appropriate procedures, reused as is for initial cleaning, or it may be discarded. Disposal must comply with applicable federal, state, municipal, and provincial laws and regulations, including environmental and other standards which might apply.

*CAUTION: Use proper solvent transfer containers (precleaned glass or metal) with no seals that can be dissolved by the solvent.*

### 8.6 Removal of solvents

After the oil and grease contaminants have been removed or dissolved and the solvent drained, allow the part to dry, purging any cavity, piping, or closed vessel with dry oil-free air or nitrogen to remove liquid by entrainment. Then circulate the purge gas until the final traces of the solvent have been removed. Purging can be considered complete when the solvent cannot be detected by appropriate methods in the gas venting from the vessel, piping, or component being purged.

#### 8.6.1

If the odor of solvent vapors is detected in the vicinity of the effluent purge gas, the equipment requires additional purging. A halogen leak detector may be used with chlorinated solvents for determining when a vessel, piping, or component is adequately purged. The test method should be agreed upon by the manufacturer and the purchaser.

#### 8.6.2

For equipment being used in oxygen service, it may be desirable to estimate the total quantity of oil or grease removed to justify future extensions of operating periods between washing or omission of washing operations.

## 9 Vapor degreasing

Vapor degreasing is the removal of soluble organic materials from the surfaces of equipment by the continuous condensation of solvent vapors and their subsequent washing action.

### 9.1 Equipment

Commercial degreasers are available for cleaning metals at room temperatures. Vapor degreasing equipment consists essentially of a vaporizer for generating clean vapors from a contaminated solvent and a vessel for holding the parts to be cleaned in the vapor space.

### 9.2 Materials for vapor degreasing

The solvents frequently used for vapor degreasing are methylene chloride; refrigerant 11 (trichlorofluoromethane); refrigerant 113 (trichlorotrifluoroethane); perchloroethylene; 1,1,1-trichloroethane (methyl chloroform); or trichloroethylene. Refer to 13.2 for additional precautions concerning these solvents. Suitable corro-

sion inhibitors and stabilizers should be included in the formulation for the solvents. Some of these solvents are flammable in air under certain conditions and have varying degrees of toxicity. Caution should be exercised in their use. Dry oil-free air or nitrogen should be available for purging.

### **9.3 Vapor degreasing procedure**

The procedure described here is useful for cleaning cold or cryogenic equipment. The temperature of a component must be between the freezing and boiling points of the solvent so that the solvent vapors will condense and wash down by gravity over the equipment surfaces.

#### **9.3.1**

This cleaning procedure requires that the solvent be boiled in a vaporizer and the hot solvent vapors then contact a cooler component on whose surface the vapors condense and over which they wash carrying away soluble contaminants. This action can occur by placing components inside a vapor degreaser chamber into which the solvent vapor rises from a vaporizer chamber. Alternatively, if a vessel is to be cleaned, hot solvent vapor can be piped from a vaporizer into the vessel, on whose inner walls condensation and cleaning will occur. In this case, the equipment should be positioned and connected so that the condensate can be thoroughly drained from the system. Continuous removal of the condensate and its transport back into the vaporizer will carry the dissolved impurities into the vaporizer where they remain, as fresh pure vapors are released to continue the degreasing operation. Cleaning can be considered complete when the returning condensate is as clean as the new solvent.

NOTE: The vapor degreasing action will stop when the temperature of the vessel reaches the boiling point of the solvent.

#### **9.3.2**

The solvent should be removed by following the procedure in 8.6.

## **10 Mechanical cleaning**

This type of cleaning may be accomplished by blast cleaning, wire brushing, grinding, or tumbling.

### **10.1 Blast cleaning**

Blast cleaning may be described as the use of abrasives propelled through nozzles against the surface of pipe, fittings, or containers to remove mill scale, rust, varnish, paint, or other foreign matter. The medium propelling the abrasive shall be oil-free unless the oil is to be removed by subsequent cleaning. The specific abrasive materials used shall be suitable for performing the cleaning without depositing contaminants that cannot be removed by subsequent cleaning. Care is to be taken when blast cleaning so as not to remove an excessive amount of parent metal. The blasting medium and residue shall be removed in a manner that meets the cleanliness levels suggested herein for oxygen service equipment.

### **10.2 Wire brushing or grinding**

Accessible surfaces may be wire brushed. Welds may be ground and wire brushed to remove slag, grit, or excess weld material. Carbon steel wire brushes shall not be used on aluminum or stainless steel surfaces. Any wire brushes previously used on carbon steel shall not be used on aluminum or stainless steel surfaces.

### **10.3 Tumbling**

Tumbling can be described as a cleaning method that uses a quantity of hard abrasive material placed in a container to clean the internal surfaces. The container is rotated to impart relative motion between the abrasive material and the container.

### **10.4 Swabbing, vacuuming**

Equipment, parts, or piping may be vacuum cleaned after mechanical cleaning to remove loose particles of dirt and slag. If vacuum cleaning is not possible, the surfaces may be swabbed with a suitable solvent using a clean, lint-free cloth to remove loose dirt, slag, etc.

## 10.5 Blowing and purging

After the equipment, parts, and piping have been mechanically cleaned and any abrasive material removed, the assembled piping should be blown with dry, oil-free air or nitrogen to remove small particles and any solvent vapors present. If drying is not completed with the residual heat in the metal, it can be completed with dry oil-free air or nitrogen. If it is desirable that the equipment be maintained in a dry atmosphere before installation or use, the dew point of the contained atmosphere should not be above  $-30^{\circ}\text{F}$  ( $-34.4^{\circ}\text{C}$ ).

## 11 Inspection

### 11.1 Approval of quality control procedures and standards

Detailed cleaning and quality control procedures should be agreed upon between the manufacturer and the purchaser. A source inspection by the purchaser's representative at the manufacturer's location is desirable. The purchaser should initially and periodically inspect the manufacturer's facilities and audit the cleaning and quality control procedures.

#### 11.1.1 Recordkeeping

Records of the following information, as applicable, should be prepared for the cleaned equipment or assembly, kept on file, and if requested, a copy forwarded to the purchaser.

- 1) A descriptive name of the item covered
- 2) Its serial number
- 3) Its invoice number or other means of identification
- 4) The cleaning specification and method employed
- 5) The dates of inspection for cleanliness
- 6) The method of inspection
- 7) The results of inspection
- 8) The inspector's signature and date signed

### 11.2 Inspection procedures

When specified by the purchaser, any one or combination of the following tests shall be used to assess the cleanliness of a piece of equipment. Failure to pass any of the specified tests requires recleaning and reinspection and may require reevaluation of the cleaning procedures. In-process inspections to assure the adequacy of cleaning procedures may be desirable.

#### 11.2.1 Direct visual inspection (white light)

This is the most common test used to detect the presence of contaminants such as oils, greases, preservatives, moisture, corrosion products, weld slag, scale, filings, chips, and other foreign matter. The item is observed (20/20 vision without magnification) for the absence of contaminants under strong white light and for the absence of accumulations of lint fibers. This method will detect particulate matter in excess of 50 microns (.002 inch) and moisture, oils, greases, etc. in relatively large amounts. The item being examined must be recleaned if an unacceptable amount of foreign material is detected by this inspection method.

#### 11.2.2 Direct visual inspection (ultraviolet light)

Ultraviolet light causes many common hydrocarbon or organic oils or greases to fluoresce when they may not otherwise be detectable by other visual means. The surface is observed in darkness or subdued light using an ultraviolet light radiating at wavelengths between 2500 and 3700 angstrom units. Ultraviolet (black light) inspection shall indicate that cleaned surfaces are free of any hydrocarbon fluorescence. Accumulations of lint or dust that may be visible under the black light shall be removed by blowing with dry oil-free air or nitrogen, wiping

with a clean lint-free cloth, or vacuuming. Not all organic oils fluoresce, or else fluoresce to different degrees, and for this reason ultraviolet inspection alone cannot be relied on as a test for cleanness. Some materials such as cotton lint that fluoresce are acceptable unless present in excessive amounts. If fluorescence shows up as a blotch, smear, smudge, or film, reclean the fluorescing area.

### 11.2.3 Wipe test

This test is used to detect contaminants on visually inaccessible areas as an aid in the above visual inspections. The surface is rubbed lightly with a clean white paper or lint-free cloth which is then examined under white and ultraviolet light. The area should not be rubbed hard enough to remove any oxide film as this could be confused with any actual surface contamination. The item being examined must be recleaned if an unacceptable amount of foreign material is detected by this inspection method.

### 11.2.4 Water break test

This test may be used to detect oily residues not found by other means. The surface is wetted with a spray of clean water. This should form a thin layer and remain unbroken for at least five seconds. Beading of the water droplets indicates the presence of oil contaminants and that recleaning is required. This method is generally limited to horizontal surfaces.

### 11.2.5 Solvent extraction test

This method may be used to supplement visual techniques or to check inaccessible surfaces by using a solvent to extract contaminants for inspection. The surface is flushed, rinsed, or immersed in a low residue solvent. Solvent extraction is limited by the ability of the procedure to reach and dissolve the contaminants present, and by the loss of contaminant during solvent evaporation (see 8.5.2.3). The equipment tested may also contain materials, such as polymers or elastomers, which would be attacked by the solvent and give erroneous results.

#### 11.2.5.1

The used solvent may be checked to determine the amount of nonvolatile residue by the following procedure. A known quantity of a representative sample of used solvent, which has been filtered, is evaporated almost to dryness, then transferred to a small weighed beaker for final evaporation, with care taken not to overheat the residue. In the same manner, the weight of residue from a similar quantity of clean solvent is determined. The difference in weight of the two residues and the quantity of solvent used should be used to compute the amount of contaminant extracted per square foot (meter) of surface area cleaned.

#### 11.2.5.2

In a similar manner, a one liter representative sample of the unfiltered used solvent can be placed in an Imhoff cone and evaporated to dryness. The volume of residue can be measured directly and used to compute the amount of contaminant extracted per square foot (meter) of surface area cleaned. Greater sensitivity can be achieved by evaporating successive liters of solvent in the same Imhoff cone.

#### 11.2.5.3

Another method is to take a representative sample of known quantity of the used solvent and compare it to a similar sample of new solvent by comparing light transmission through the two samples simultaneously. There should be little, if any, difference in color of the solvents and very few particles.

### 11.2.6 Contamination level

Hydrocarbon or particulate matter residues determined by the inspection procedure shall not exceed the amount specified by the purchaser. An acceptable contamination level for oxygen service equipment is about 47.5 mg per square foot (500 mg/m<sup>2</sup>), but could be more or less depending on the specific application (state of fluid, temperature and pressure).

If the purchaser's requirement includes a particle and fiber count, a representative square foot section of surface shall show no particle larger than 1000 microns and no more than 20 particles per square foot (215 parti-

cles/ M<sup>2</sup>) between 500 and 1000 microns. Isolated fibers of lint shall be no longer than 2000 microns and there shall be no accumulation of lint fibers.

## 12 Packaging and labeling

### 12.1 Protection from recontamination

Once a piece of equipment has been cleaned for oxygen service and the cleaning agent completely removed from the equipment, it should be suitably protected as soon as practicable to prevent recontamination during storage and prior to being placed in service. Following are several ways in which this can be done. The protection provided will depend on a number of factors such as the type of equipment, length of storage, and atmospheric conditions. The type of protection required should be specified by the purchaser.

#### 12.1.1 Protection of openings

Equipment or parts having small openings may be protected by caps or plugs. Small to medium-sized components may be sealed in plastic bags, or protected by other appropriate means. Openings on large equipment may be sealed, preferably with caps, plugs, or blind flanges where appropriate. Taped solid board blanks or other durable covers which cannot introduce contamination into the equipment when removed, can also be used to seal such openings.

#### 12.1.2 Pressurization

Equipment with large internal volumes may be filled with dry oil-free air or nitrogen after all openings have been sealed and valves closed.

Parts in suitable plastic bags may be purged with inert gas or evacuated and sealed.

### 12.2 Labeling

Where the purchaser's requirements include labeling to show oxygen service cleaning of parts or equipment, a statement, "Cleaned for oxygen service" or other suitable wording should appear on the part, or package as applicable. Additional information which may be included is as follows:

- 1) A statement, "This equipment is cleaned in accordance with Oxygen Cleaning Specification No. \_\_\_\_\_"
- 2) Date of inspection and the inspector's stamp or marking
- 3) Description of the part, including part number if available
- 4) Statement, "Do not open until ready for use"

## 13 Personnel safety

Cleaning operations for oxygen service equipment shall be carried out in a manner which provides for the safety of personnel performing the work, and shall conform to the local ordinances and federal, state, and provincial regulations.

### 13.1 Instructions and supervision

Operators shall be instructed in the safe use of the cleaning agents employed, including any hazards associated with the use of these agents. Written instructions shall be issued whenever special safety considerations are involved. A responsible individual shall direct oxygen cleaning operations.

### 13.2 Dangerous chemicals

No highly toxic chemicals shall be used. *Carbon tetrachloride shall not be employed in any cleaning operation.*

### 13.2.1

The health hazards associated with the use of any solvent shall be considered in its selection. The user shall ensure that the time weighed average TLV is not exceeded for a specific solvent and consider that some chlorinated solvents are suspected of being carcinogenic. Breathing of solvent fumes and liquid contact with the skin should be avoided. Material Safety Data Sheets for solvents should be obtained from the solvent manufacturer.

### 13.2.2

Caution must be exercised in using solvents commonly referred to as nonflammable that are flammable in air under certain conditions. The concentrations creating a flammable mixture in air are usually well in excess of the concentrations that cause physiological harm. Therefore, on removing solvents to the extent necessary to protect personnel from respiratory harm, it must not be forgotten that purging with air can create a flammable mixture. Also, failure to purge adequately can leave a flammable mixture which in the presence of heat, flame, or sparks may result in a dangerous energy release.

### 13.2.3

Follow normal industry procedures in the mixing and handling of acids and caustics to eliminate injuries.

### 13.2.4

Special consideration should be given to the safe disposal of waste cleaning solution.

## 13.3 Protective equipment

Face shields or goggles shall be provided for face or eye protection from cleaning solutions. Safety glasses with side protection shall be provided for protection from injuries due to flying particles. Protective clothing shall be provided when required to prevent cleaning solutions from contacting the skin.

Self-contained breathing apparatus (see ANSI Z88.2, *Practices for Respiratory Protection*) [4] shall be provided wherever there is a possibility of a deficiency of oxygen due to the use of an inert gas purge, or if there is any possibility of exceeding allowable TLV values.

## 13.4 Proper ventilation

All areas where cleaning compounds and solvents are used should be adequately ventilated. In outdoor operations, locate cleaning operations so that operators can work upwind of solvent vapor accumulations.

## 13.5 Special situations

### 13.5.1 Entering vessels

#### 13.5.1.1

Work should not be performed inside a vessel or confined area until the vessel or confined area has been properly prepared and work procedures established that will ensure the safety of workers.

#### 13.5.1.2

A Hazardous Work Permit (HWP) is an instrument widely used in industry for ensuring safe working conditions and its use is strongly recommended. The HWP should consider at least the following seven items before anyone enters a vessel or confined space.

- 1) *Isolation*: All lines to a vessel should be suitably isolated to prevent the entry of foreign materials, in particular the atmospheric gases (nitrogen, argon, or the rare gases) that cause asphyxiation by oxygen depletion. Oxygen enrichment is also to be avoided because of the associated fire hazard. Acceptable means of isolating vessels are blanking, double block and bleed valves, or disconnecting all lines from the vessel.

- 2) *Periodic monitoring.* The need for periodic monitoring of the atmosphere in any vessel or confined space shall be considered before any work is performed.
- 3) *Ventilation:* A fresh air supply suitable for breathing is normally supplied to the vessel when personnel are inside.
- 4) *Atmospheric analysis:* The atmosphere in a vessel that has been in service or has been purged with inert gas must always be analyzed before entering to determine that the vessel or confined area has been adequately ventilated with fresh air and is safe for personnel.
- 5) *Rescue procedure:* A reliable procedure for removing personnel from any vessel or confined work space should be available and understood by all workers before any work begins. A portable air breathing supply must be available and used in such a procedure.
- 6) *Work procedure:* When cleaning operations are performed inside oxygen vessels or other such confined spaces, a reliable preplanned procedure for quickly removing or protecting personnel in cases of emergency shall be established and understood by all workers before work begins.
- 7) *Watcher:* When toxic cleaning agents are used, it is recommended that a watcher be stationed immediately outside a vessel or confined space to ensure the safety of those working within. A portable air breathing supply shall be immediately available. If the worker must use a self contained breathing apparatus or a breathing mask, a "watcher" must be present per OSHA requirements at 29 CFR 1910.134(d). [5]

Other considerations may be required depending on the type of work being performed. For example, a vessel should not be entered until its temperature is at or near the ambient temperature. All workers involved with any vessel entry should be fully apprised of the total operation prior to any tank entry.

#### 13.5.1.3

Personnel must not enter any vessel unless its atmosphere has a normal air composition. Normal atmospheric air has 21 percent oxygen by volume. However, it is permissible to work in atmospheres having oxygen concentrations in the range of 19 to 23 percent if the other gases present do not exceed their threshold limit values. In the event that the oxygen concentration deviates from 21 percent, a review of the system is required to assure that oxygen or an asphyxiant is not entering the vessel. (See also CGA P-14, *Accident Prevention in Oxygen-Rich and Oxygen-Deficient Atmospheres.*) [6]

#### 13.5.2 Heating solvents

Chlorinated solvents upon heating can break down into dangerous compounds. A commonly used solvent, trichloroethylene, decomposes at temperatures not far above the boiling point of water. Ventilation must be adequate to prevent breathing excessive amounts of the solvent vapors or their decomposition products. Air respirators must be used in situations where the concentration of solvent vapors or any other foreign material in the atmosphere exceeds their TLV limit.

#### 13.5.3 Welding near solvents

It is important to ensure that parts to be welded shall be free of cleaning solvents. Ultraviolet rays and heat from welding can decompose certain chlorinated solvents to produce phosgene gas. Accordingly, the atmosphere in the vicinity of such operations shall be free from chlorinated solvent vapors.

### 14 References

[1] CGA C-10, *Recommended Procedures for Changes of Gas Service for Compressed Gas Cylinders*, Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

[2] CGA G-4.3, *Commodity Specification for Oxygen*, Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

[3] ASTM D-2108-71, *Standard Testing for Color Halogenated Organic Solvents and Admixtures*, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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[4] ANSI Z88.2, *Practices for Respiratory Protection*, American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

[5] *Code of Federal Regulations*, Title 29 CFR Part 1910 (General Industry), U.S. Department of Labor. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[6] CGA P-14, *Accident Prevention in Oxygen-Rich and Oxygen-Deficient Atmospheres*, Compressed Gas Association, Inc., 1235 Jefferson Davis Highway, Arlington, VA 22202.

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