Designation: G 93 – 03

Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments[1]

This standard is issued under the fixed designation G 93; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the selection of methods and apparatus for cleaning materials and equipment intended for service in oxygen-enriched environments. Contamination problems encountered in the use of enriched air, mixtures of oxygen with other gases, or any other oxidizing gas may be solved by the same cleaning procedures applicable to most metallic and nonmetallic materials and equipment. Cleaning examples for some specific materials, components, and equipment, and the cleaning methods for particular applications, are given in the appendices.

1.2 This practice includes levels of cleanliness used for various applications and the methods used to obtain and verify these levels.

1.3 This practice applies to chemical-, solvent-, and aqueous-based processes.

1.4 This practice describes nonmandatory material for choosing the required levels of cleanliness for systems exposed to oxygen or oxygen-enriched atmospheres.

1.5 This practice proposes a practical range of cleanliness levels that will satisfy most system needs, but it does not deal in quantitative detail with the many conditions that might demand greater cleanliness or that might allow greater contamination levels to exist. Furthermore, it does not propose specific ways to measure or monitor these levels from among the available methods.

1.6 The values stated in both inch-pound and SI units are to be regarded separately as the standard unit. The values given in parentheses are for information only.

1.7 *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.* Federal, state and local safety and disposal regulations concerning the particular hazardous materials, reagents, operations, and equipment being used should be reviewed by the user. The user is encouraged to obtain the Material Safety Data Sheet (MSDS) from the manufacturer for any material incorporated into a cleaning process. Specific cautions are given in Section 8.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
D 1193 Specification for Reagent Water
E 312 Practice for Description and Selection of Conditions for Photographing Specimens
E 1235 Test Method for Gravimetric Determination of Nonvolatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft
E 2042 Practice for Cleaning and Maintaining Controlled Areas and Clean Rooms
F 312 Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters
F 331 Test Method for Nonvolatile Residue of Solvent Extract from Aerospace Components (Using Flash Evaporator)
G 63 Guide for Evaluating Nonmetallic Materials for Oxygen Service
G 88 Guide for Designing Systems for Oxygen Service
G 121 Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents
G 122 Test Method for Evaluating the Effectiveness of Cleaning Agents
G 125 Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants
G 127 Guide for the Selection of Cleaning Agents for Oxygen Systems
G 128 Guide for Control of Hazards and Risks in Oxygen Enriched Systems
G 131 Practice for Cleaning of Materials and Components By Ultrasonic Techniques
G 136 Practice for Determination of Soluble Residual Contaminants in Materials by Ultrasonic Extraction

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[1] This practice is under the jurisdiction of ASTM Committee G04 on Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres and is the direct responsibility of Subcommittee G04.02 on Recommended Practices.

Current edition approved Nov. 1, 2003. Published December 2003. Originally approved in 1987. Last previous edition approved in 1996 as G 93 – 96.

[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.

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G 144 Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High-Temperature Combustion Analyzer

2.2 *CGA Documents:*

CGA Pamphlet G-4.1 Cleaning Equipment for Oxygen Service[3]

CGA Pamphlet G-4.4 Industrial Practices for Gaseous Oxygen Transmission and Distribution Piping Systems[3]

2.3 *SAE Document:*

ARP 598 The Determination of Particulate Contamination in Liquids by the Particle Count Method[4]

2.4 *ISO Document:*

ISO 14644-1 Cleanrooms and Associated Controlled Environments—Part 1: Classification of Air Cleanliness[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *contaminant*, *n*—unwanted molecular or particulate matter that could adversely affect or degrade the operation, life, or reliability of the systems or components upon which it resides.

3.1.2 *contamination*, *n*—*(1)* the amount of unwanted molecular or particulate matter in a system; *(2)* the process or condition of being contaminated.

3.1.2.1 *Discussion*—Contamination and cleanliness are opposing properties; increasing cleanliness implies decreasing contamination.

3.1.3 *direct oxygen service*, *n*—service in contact with oxygen-enriched atmosphere during normal operation.

3.1.3.1 *Discussion*—Examples are oxygen compressor piston rings or control valve seats.

3.1.4 *nonmetal*, *n*—any material other than a metal, nonpolymeric alloy, or any composite in which the metallic component is not the most easily ignited component and for which the individual constituents cannot be evaluated independently, including ceramics (such as glass), synthetic polymers (such as most rubbers, thermoplastics, and thermosets), and natural polymers (such as naturally occurring rubber, wood, and cloth). nonmetallic\adj.

3.1.5 *oxygen compatibility (also oxidant compatibility)*, *n*—the ability of a substance to coexist with both oxygen and a potential source(s) of ignition at an expected pressure and temperature with a magnitude of risk acceptable to the user.

3.1.6 *qualified technical personnel*, *n*—persons such as engineers and chemists who, by virtue of education, training, or experience, know how to apply physical and chemical principles involved in the reactions between oxidants and other metals.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cleanliness*, *n*—the degree to which an oxygen system is free of contaminant.

3.2.2 *fibers*, *n*—particulate matter with a length of 100 µm or greater, and a length-to-width ratio of 10 to 1 or greater.

3.2.3 *particulate*, *n*—a general term used to describe a finely divided solid of organic or inorganic matter.

3.2.3.1 *Discussion*—These solids are usually reported as the amount of contaminant by the population of a specific micrometer size. See methods described in Methods F 312 or ARP 598 for particle size and population determination.

4. Summary of Practice

4.1 General methods, apparatus, and reagents for cleaning materials and equipment used in oxygen-enriched environments are described in this practice. Exact procedures are not given because they depend on the contaminant type and material to be cleaned, cleaning agent used, and degree of cleanliness required. Methods may be used individually, or may be combined or repeated to achieve the desired results. Examples of cleaning procedures that have been successfully used for specific materials, components, and equipment in selected applications are described in the appendices. An index of the specific materials, components, equipment, and applications covered in these examples is given in Table X1.1.

4.2 For the purpose of this practice, both solid and fluid contaminants have been subclassed into three categories: organics, inorganics, and particulates. A list of common contamination levels is given in Table 1.

4.3 Cleanliness specifications that have been used in the past are identified, levels of cleanliness that can be achieved are listed along with factors that suggest potential upper limits for allowable system contamination, and the practical difficulties in adopting and achieving adequately clean systems are reviewed. Cleanliness specifications used by suppliers and manufacturers often differ; it is therefore important to communicate and agree upon which specification is to be used for a given system and to adhere to the most conservative measures.

5. Significance and Use

5.1 The purpose of this practice is to furnish qualified technical personnel with pertinent information for the selection of cleaning methods for cleaning materials and equipment to be used in oxygen-enriched environments. This practice furnishes qualified technical personnel with guidance in the specification of oxygen system cleanliness needs. It does not actually specify cleanliness levels.

TABLE 1 Oil Film Contamination Level Specifications

Concentration, mg/m^2 (mg/ft^2)	Source
0.14 (0.013)	1967 Navy Standard per Presti and DeSimone **(6)**
10.8 (1)	NASA KSC 123 per Report MTB 306-71 **(7)**
16.1 (1.5)	Recommended by Presti and DeSimone **(6)**
43.1 (4)	Air Force 1950s value per LeSuer **(8)**
75.3 (7)	Recommended by Walde **(9)**
108 (10 mg/ft^2 or per item)	Union Carbide Guideline **(10,4)**
50-100 (4.6 to 9.3)	Compressed Gas Association Pamphlet G-4.8 **(3)**
500 (47.5)	Compressed Gas Association Pamphlet G-4.1 **(5)**

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[3] Available from Compressed Gas Association (CGA), 1725 Jefferson Davis Hwy., Suite 1004, Arlington, VA 22202-4102.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

[5] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland.

5.2 Insufficient cleanliness of components used in oxygen systems can result in the ignition of contaminants or components by a variety of mechanisms such as particle, mechanical, or pneumatic impact. These mechanisms are explained in detail in Guide G 88.

5.3 Adequate contamination control in oxygen systems is imperative to minimize hazards and component failures that can result from contamination. Contamination must also be minimized to ensure an acceptable product purity.

5.4 Removal of contaminants from materials and components depends on system configuration, materials of construction, and type and quantity of contaminant.

5.5 Examples of cleaning procedures contained herein may be followed or specified for those materials, components, and equipment indicated. The general cleaning text can be used to establish cleaning procedures for materials, components, equipment, and applications not addressed in detail. See Guide G 127 for discussion of cleaning agent and procedure selection.

6. Interferences

6.1 *Disassembly*:

6.1.1 It is imperative that oxygen systems be cleaned as individual components or piece parts, preferably before assembly. Assembled systems must be disassembled for cleaning if construction permits. Flushing an assembled system can deposit and concentrate contaminants in stagnant areas. Nonvolatile cleaning agents may remain in trapped spaces and later react with oxygen. Cleaning solutions may degrade nonmetals in an assembly. Caustic and acid cleaning solutions may cause crevice corrosion in assemblies.

6.1.2 Manufactured products (that is, valves, regulators, and pumps) should be cleaned preferably by the manufacturer before final assembly and test. All tests should be structured to prevent recontamination. The part must then be packaged in oxygen-compatible materials (see 12.1) and identified to protect it from contamination in transit and storage. The purchaser should approve the cleaning procedure and packaging to assure that they satisfy system requirements. Some purchasers may require the product manufacturer to certify cleanliness level and oxygen compatibility of all component materials.

6.1.3 Manufactured products cleaned by the purchaser must be disassembled for cleaning if construction permits. The purchaser should follow the manufacturer's instructions for disassembly, inspection for damage, reassembly, and testing.

6.2 *Cleaners*:

6.2.1 Mechanical cleaning methods such as abrasive blasting, tumbling, grinding, and wire brushing are very aggressive and should be avoided on finished machined articles. Such methods can damage sealing surfaces, remove protective coatings, and work-harden metals. Sensitive surfaces must be protected before mechanical cleaning methods are applied.

6.2.2 Chemical cleaners, both acid and caustic, can damage metal parts if not neutralized upon completion of cleaning. Corrosion, embrittlement, or other surface modifications are potentially harmful side effects of chemical cleaning agents. Crevice corrosion can occur and sealing surfaces can be etched enough to destroy the finish necessary to seal the part. See Test Method G 122 and Guide G 127 for methods used to evaluate cleaners for use on various materials used in oxygen service.

6.2.3 Solvent cleaning solutions often damage plastics and elastomers. The manufacturer should be consulted or sample parts should be tested to ensure that the solvent is not harmful to the item being cleaned.

6.3 *Lubricants*:

6.3.1 Mechanical components are normally assembled with lubricants on seals, threads, and moving surfaces. The manufacturer should be consulted to determine the kind of lubricant originally used on the article to ensure that the cleaning solutions and methods selected are effective in removing the lubricant and will not damage the component.

6.3.2 Oxygen-compatible lubricants should be selected in accordance with Guide G 63. The component manufacturer should also be consulted to ensure that the selected lubricant provides adequate lubrication for component performance. Oxygen-compatible lubricants often have markedly different lubricating properties from conventional lubricants.

6.4 *Environment and Assembly Requirements*:

6.4.1 Equipment intended for oxygen service must be handled carefully during all phases of a cleaning procedure. The environment should be clean and dust-free. Nearby grinding, welding, and sanding should be prohibited. Parts should not be allowed to stand in the open unprotected after they have been cleaned. Care should be taken to avoid contamination by oil deposits from rotating machinery or oil aerosols in the air. Do not touch part surfaces that will be in direct oxygen service except with clean gloves or handling devices.

6.4.2 In some cases, laminar-flow clean rooms may be necessary in which the entire room is purged with filtered air. In horizontal flow clean rooms, parts are cleaned and verified in a sequence in which successive cleaning operations are at locations progressively closer to the filtered air source so that the part and the environment each become steadily cleaner. In laminar vertical flow clean rooms the layout of the successive cleaning operations is not as critical. See ISO 14664 for further information.

7. Conditioning

7.1 Factors to consider before selecting cleaning methods include:

7.1.1 Type of contaminant, that is, inorganic, organic, particulate, film, or fluid,

7.1.2 Base material or coating of the part to be cleaned,

7.1.3 Initial condition of the part to be cleaned,

7.1.4 Required final cleanliness of the part,

7.1.5 Environmental impact and lawful disposition of hazardous waste products generated by the required cleaning method, solutions, and reagents used,

7.1.6 Cost effectiveness of the required cleaning method,

7.1.7 Effects of the selected cleaning methods on the part to be cleaned, such as mechanical, chemical, and thermal, and

7.1.8 Ease of cleaning (part configuration).

8. Cleaning Methods

8.1 *General*:

8.1.1 A cleaning method is the procedure(s) used to bring a cleaning agent into contact with all component surfaces to be cleaned, with the goal of removing contaminants. Cleaning materials and equipment for use in oxygen-enriched environments should begin with disassembly to the elemental or piece-part level as discussed in 6.1. When the component has been disassembled, parts should be grouped according to cleaning method. While the methods described apply to most metals, special precautions must be taken for nonmetals, which require special attention as discussed in 6.2.1 and 6.2.2.

8.1.2 Cleaning methods can be categorized as mechanical, chemical, or both. Some cleaning operations are enhanced by combining mechanical and chemical methods, such as mechanical agitation of a chemical solution.

NOTE 1—**Caution:** Both caustic and acid cleaning involve the use of hazardous materials and solutions. Full protective clothing, including gloves and face protection, should be worn by cleaning operators. Disposal of spent cleaning solutions should be conducted according to federal, state, and local regulations. The appropriate MSDS for the material must be reviewed and controls implemented before using hazardous materials.

8.2 *Mechanical Cleaning*—These methods use mechanically generated forces to remove contaminants from components. Examples of mechanical cleaning methods are abrasive blasting, grinding, tumbling, swabbing, and ultrasonication. Details of these and other methods are discussed below.

8.2.1 *Abrasive Blast Cleaning:*[6]

8.2.1.1 Abrasive blast cleaning involves the forceful impingement of abrasive particles against surfaces to be cleaned to remove scale, rust, paint, and other foreign matter. The abrasive may be either dry or suspended in liquid. Various systems are used to propel abrasives, including airless abrasive blast blades or vane-type wheels, pressure blast nozzles, and suction (induction) blast nozzles. Propellant gases should be verified as oil-free.

8.2.1.2 Typical abrasive particle materials include metallic grit and shot, natural sands, manufactured oxide grit, carbide grit, walnut shells, and glass beads. The specific abrasive particle material used should be suitable for performing the intended cleaning without depositing contaminants that cannot be removed by additional operations, such as high velocity blowing, vacuuming, and purging.

8.2.1.3 Take care to minimize removal of the component parent material. This cleaning method may not be suitable for components or systems with critical surface finishes or dimensional tolerances.

8.2.1.4 In some cases, abrasive blast cleaning will induce residual compressive stresses in the surfaces of metallic components. Although this induced stress is beneficial in terms of fatigue strength, it may be detrimental to another of these component's material properties, such as magnetic and electrical characteristics.

NOTE 2—**Caution:** Protective gloves, aprons, face shields, and respiratory equipment are recommended unless the blast cleaning is performed inside a glove-box. The immediate health hazards are imbedding of stray abrasive particles in eyes and skin. The long-term hazard could include respiratory disorders caused by inhalation of fine particles.

8.2.2 *Wire Brush or Grinding Cleaning*:

8.2.2.1 Wire brushing or grinding methods generally incorporate a power-driven wire or nonmetallic fiber-filled brush, or an abrasive wheel. These are used to remove excessive scale, weld slag, rust, oxide films, and other surface contaminants. Wire brushes may be used dry or wet. The wet condition results when the brushes are used in conjunction with alkaline cleaning solutions or cold water rinses.

8.2.2.2 These mechanical methods may imbed brush or grinding material particles in the cleaning surface. Cleaning brush selection depends on the component or system parent material. Nonmetallic brushes are suitable for most materials to be cleaned. Carbon steel brushes should not be used on aluminum, copper, and stainless steel alloys. Any wire brushes previously used on carbon steel components or systems should not be subsequently used on aluminum or stainless steel. The user should be aware that wire brushing and grinding can affect dimensions, tolerances, and surface finishes.

8.2.3 *Tumbling*—Sometimes called Barrel or Mass Cleaning, this procedure involves rolling or agitation of parts within a rotating barrel or vibratory tubs containing abrasive or cleaning solution. The container action, rotation, or vibration imparts relative motion between the components to be cleaned and the abrasive medium or cleaning solution. This method may be performed with dry or wet abrasives. The part size may vary from a large casting to a delicate instrument component, but mixing different components in one barrel should be avoided, as damage may occur from one component impacting on another of a different type. Barrel cleaning may be used for descaling, deburring, burnishing, and general washing. Some factors to consider in barrel cleaning are component size and shape, type and size of abrasive, load size, barrel rotational speed, and ease of component/abrasive separation.

8.2.4 *Swab, Spray, and Dip Cleaning*—Each of these methods of applying cleaning solutions to the component surfaces has its particular advantages. Swabbing is generally used on parts or components to clean small select areas only. Spraying and dipping are used for overall cleaning. These methods are generally used with alkaline, acid, or solvent cleaning methods discussed in later sections.

8.2.5 *Vacuuming and Blowing*—These methods remove contaminants from the component by currents of clean, dry, oil-free air or nitrogen. These methods may be used to remove loose dirt, slag, scale, and various particles, but they are not suitable for removing surface oxides, greases, and oils.

8.2.6 *"Pig" Cleaning*—Long continuous pipelines can be cleaned in situ using "pigs," piston-like cylinders with peripheral seals that can be pushed through a pipeline using compressed gas pressure, typically nitrogen. Pigs may be equipped with scrapers or wire brushes, and pairs of pigs may carry slugs of liquid cleaning agents between them. Hence, a train of four pigs can transport three isolated slugs of solution through a pipeline to produce various levels of cleaning and rinsing. The mechanical and chemical suitability of the solvents, scrapers, and wire brushes should be ensured as detailed in 8.2.2 and 8.3.

8.2.7 *Ultrasonic Cleaning*—Ultrasonic energy can be used with a variety of chemical cleaning agents to effect intimate contact between the part and the cleaning agent. Ultrasonic

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[6] For a more detailed discussion of abrasive blast cleaning see Metals Handbook Desk Edition, 2nd Edition, Joseph R. Davis, Editor, American Society for Metals, Metals Park, OH, 1999.

agitation aids removal of lightly adhered or embedded particles from solid surfaces. It is generally used in solvent cleaning of small parts, precious metal parts, and components requiring a very high degree of cleanliness. See Practice G 131 for an ultrasonic cleaning procedure.

8.3 *Aqueous Cleaning*:

8.3.1 The following methods are based on achieving an interaction between the cleaning solution and the contaminant or component surface to effect easy removal of contaminant by subsequent mechanical methods. The interaction may involve surface activation, contaminant breakdown, oxide conversion, and hydrophobic or hydrophilic transformations. Water used for dilution and rinsing of chemical cleaning agents must be as clean or cleaner than the level of cleanliness desired and free of contaminants to prevent reactions with the cleaning agents. Water shall be of a grade equal or better to that specified in Specification D 1193, Type II, without the silica analysis. Water with a higher specific resistance may be required for particular applications or cleaning systems.

8.3.2 *Hot-Water Cleaning*—Hot water cleaning removes gross organic and particulate contamination from parts by using low to moderate heat, detergent, and some mechanical agitation. Equipment used during hot-water cleaning may consist of a spray system or a cleaning vat with or without suitable agitation of the solution. Hot-water cleaning with detergent can be used where steam is not required to free and fluidize contaminants. Consideration should be given to the size, shape, and number of parts to ensure adequate contact between part surfaces and the solution. Solution temperature should be as recommended by the cleaning agent manufacturer. Water-soluble contaminants are best removed by prompt flushing with sufficient quantities of hot or cold clean water before the cleaning agents have time to precipitate. The parts are then dried by blowing with dry oil-free air or nitrogen, which may be heated to shorten the drying time.

8.3.3 *Steam Cleaning*—Steam cleaning removes organic and particulate contaminants from parts by using pressure, heat, and sometimes detergents. Some organics are removed by decreasing their viscosity, or "thinning" them with steam heat. Detergent may be added to disperse and emulsify organics, which allows rinsing of the contaminant by condensed steam. The system should provide control over steam, water, and detergent flows to maximize efficiency of the detergent's chemical action, the steam heat effect, and the steam jet's scrubbing action.

8.3.4 *Caustic and Detergent Cleaning*—This method relates to the cleaning of vessels, piping systems, or components either externally or internally and uses water as the primary solvent. Synthetic detergents and surfactants are combined with additives such as pH buffers, inhibitors, saponifiers, emulsifiers, antifoaming agents, wetting agents, and others for beneficial effects.

8.3.4.1 Caustic cleaning uses highly alkaline solutions to remove organic contamination such as hydrocarbon oils, grease, and waxes. Some common alkaline salts available for caustic cleaning are listed in Table 2. Prepared solutions can be used in static tanks or vessels for component immersion. Alternatively, solutions can be pumped or jetted onto or through components. Depending on the detergent used, solutions may be alkaline, nontoxic, biodegradable, or noncorrosive. Some detergents may be toxic or corrosive, and detergent properties should be verified by the manufacturer or supplier. See Guide G 127 for selection criteria. The cleaning solution can be applied by spraying, immersing, or hand swabbing. Normally, caustic cleaning solutions are applied at temperatures up to 180°F (82.2°C). It is important that the cleaning solution reach all areas of the part to be cleaned. The cleaning solution can be reused until it becomes ineffective as determined by pH or contaminant concentration analysis. Experience may establish a contaminant level of the cleaning solution above which a surface cannot be acceptably cleaned.

TABLE 2 Common Alkaline Salts (see 8.3.4.1 and 9.4)

IUPAC Name[A]	Formula	Common Name
Sodium hydroxide	NaOH	Caustic soda Lye
Sodium metasilicate	Na_2SiO_2	Sodium silicate Water glass
Sodium carbonate	Na_2CO_3	Soda ash
Sodium tetraborate decahydrate	$Na_2B_4O_7 \cdot 10H_2O$	Borax
Sodium orthophosphate	$Na_2PO_4 \cdot 12H_2O$	Trisodium phosphate (TSP) Sodium phosphate tribasic
Sodium pyrophosphate	$Na_4P_2O_7 \cdot 10H_2O$	Tetrasodium pyrophosphate Sodium polyphosphate

[A] According to the International Union of Pure and Applied Chemistry.

NOTE 3—**Caution:** Alkalai cleaners attack aluminum.

8.3.4.2 Aqueous systems have few problems with worker safety compared to most other solvents. They are not flammable or explosive, and toxicity is low for most formulations. Aqueous systems can be designed to remove particulate and film contamination. They are especially good for removing inorganic or polar materials. Aqueous cleaning functions by several mechanisms other than solvency, including saponification, displacement, emulsification, and dispersion. Ultrasonics are especially suited for aqueous solvents.

8.3.4.3 The part must be thoroughly rinsed to prevent the cleaning solution and contaminants from redepositing on the surface. The surface must not be allowed to dry between the cleaning and rinsing phases. Frequently, some type of water rinsing helps to remove the cleaning solution and aids in the drying process. Parts with small crevices and blind channels may be difficult to clean because of the relatively high surface tension and capillary forces of water-based cleaners. Some aqueous cleaner residues can be difficult to rinse from surfaces; nonionic surfactants are especially difficult to rinse. A method of determining when rinsing is complete is to monitor the used rinse water until a pH of ±0.2 of the starting water pH is achieved. Parts with complex geometries may be difficult to dry. Clean, dry, oil-free air or nitrogen, heated if necessary, may be used for drying. Alternatively, vacuum may be used to achieve desired dryness. Table 3 gives general recommendations for alkaline cleaning. This table lists the metallic material, type of contaminant to be removed, and the alkaline solution used.

8.3.4.4 *Drying*:

(1) When aqueous cleaning is used on oxygen system components, rinsing and drying are of critical concern. Drying

TABLE 3 Alkaline Chemical Cleaning Materials (see 8.3.4.3)

Metal	Reason for Cleaning	Cleaning Chemicals[A]	Other Treatment[B,C]
Carbon and low alloy steels	Removal of heavy soil, grease, and oil	Mixtures of sodium hydroxide, carbonates, phosphates and silicates, and synthetic wetting agents	Solutions should not be allowed to dry on the part and must be thoroughly rinsed
Austenitic stainless steel	Removal of heavy soil, grease, light oils, and cutting fluid	Mixtures of sodium hydroxide, carbonates, phosphates and silicates, and synthetic wetting agents	
Copper and alloys	Removal of grease, lubricating oil, drawing compound, oxide, metallic particles, or other contaminants	Mixtures of sodium hydroxide, polyphosphates, silicates, carbonates, and wetting agents	Usually bright dipped in dichromate acid solution
	Removal of brazing flux	Hot water	
Aluminum and alloys	Removal of grease, oil, and oxide	Sodium hydroxide, sodium phosphate, and sodium carbonate for etching Sodium carbonate, sodium silicate, sodium pyrophosphate, and sodium metasilicate for nonetching	Dilute nitric acid dip to remove smut

[A] The manufacturer's specification for application of the cleaning agent shall be strictly enforced.

[B] *Postchemical Cleaning Treatment*—After cleaning using alkaline chemicals, all components shall be thoroughly rinsed, preferably using hot flowing water to aid drying, unless otherwise specified by the cleaning material supplier. Some components require treatment by using neutralizing solutions after certain cleaning treatments.

[C] Thorough rinsing is necessary to avoid stress corrosion risk.

is the removal of water or other solvents from critical surfaces. The actual process of drying involves a change of state and requires energy. The amount of energy depends on many factors such as the solvent to be evaporated, the configuration of the hardware, the temperature of the operation, and the conductivity of the liquid and the hardware. The heat of vaporization for water is an order of magnitude higher than that for some common chlorofluorocarbon solvents. The removal of vapor is also critical in drying, and a means for removal of vapor must be provided. This is usually accomplished with a moving dry gas purge.

(2) In selection of a drying process, consideration must be given to the level of dryness required. The user should evaluate each method for the specific application intended. There are three basic water removal methods commonly used:

(a) Physical—actual removal of liquid such as scraping, wiping, centrifuging, or blowing.

(b) Solvent—wetting the part with a higher vapor pressure liquid to displace the water, such as with alcohol or hydrofluorocarbons.

(c) Evaporation—adding energy and physically removing the vapor such as drying by oven, air, or purge.

(3) Small- and medium-size hardware drying is often done in filtered gas-purged ovens. System and tank drying may be achieved by purging with a clean, flowing, dry gas, usually nitrogen or air. Care must be taken in measuring the dew point of a flowing gas. It is possible to inadvertently measure the dryness of the purge gas only. To sample correctly, a lock-up and pressurization procedure, with a time allowance interval, is necessary. Items dried with a flowing, heated, dry gas purge are usually considered dry when the dew point of the exit gas is within 5°F (3°C) of the purge gas.

(4) Dryness is measured in many ways:

(a) Relative humidity,

(b) Dew point,

(c) Unit mass of water per unit mass of gas (ppm),

(d) Unit volume of water per unit volume of gas (v/v), and

(e) Moles of water per moles of air.

(5) Oxygen systems are typically considered dry at equilibrium exit gas dew points of from 0°F (-18°C) to as low as -70°F (-57°C) depending on the specific application. The choice depends on many variables such as cost, time, use temperature, and effects of moisture on components. Industrial gases are easily obtained with dew points of -40°F (-40°C), a common specification level for oxygen system dryness.

8.3.5 *Semiaqueous Cleaning*:

8.3.5.1 Semiaqueous cleaning uses hydrocarbon-water emulsions to remove heavy contaminants from part surfaces with organic solvents dispersed in an aqueous medium by an emulsifying agent. The cleaning action of emulsion cleaners combines the advantages of both the aqueous and organic phases.

(1) Many emulsion cleaners are commercially available and are composed of petroleum-derived solvents and surfactants that render them emulsifiable. Some emulsion cleaners tend to separate into individual solutions if left standing for extended periods, and it may be necessary to periodically agitate them so that they remain emulsified. It is important that two-part mixtures are not allowed to separate, to preclude only part of the mixture being removed from the system. Emulsion cleaners are normally applied to parts by soaking, spraying, or swabbing. Emulsion cleaners must be removed by rinsing and subsequent cleaning operations.

8.3.5.2 One type of semiaqueous material is a water emulsion with natural citrus and pine-based terpenes. Semiaqueous cleaners are either emulsified in water and applied in a manner similar to standard aqueous cleaners or they are applied in concentrated form and then rinsed with water. Semiaqueous formulations are compatible with most metals and plastics. They have good cleaning ability, especially for heavy grease, tar, wax, and hard to remove soils. The semiaqueous formulations are considered nonflammable in bulk but can be flammable as a mist. Proper equipment design is essential to minimize risk from flammable mists. Some formulations can auto-oxidize into an undesirable condition. Material must be verified with the supplier.

8.3.5.3 The cleaning solution must be thoroughly rinsed from the part to prevent contaminants from redepositing on the surface. The surface must not be allowed to dry between the cleaning and rinsing phases. Semiaqueous residues are especially difficult to rinse from surfaces. A more thorough analysis than rinse water pH may be required to determine rinse phase completion. Parts with complex geometries may be difficult to dry. Clean, dry, oil-free air or nitrogen, heated if necessary, may be used for drying. Alternatively, vacuum may be combined with purging to achieve desired level of dryness. Care must be used to prevent buckling from external pressure when vacuum is applied.

8.3.6 *Acid Cleaning*:

8.3.6.1 Acid cleaning is a process in which a solution of mineral acid, organic acid, or acid salt (often in combination with a wetting agent and detergent) is used to remove oxides, oils, and other contaminants from parts, with or without the application of heat. Acid cleaning must be carefully controlled to avoid damage to the part surfaces, such as undesired etching or pickling. The type of cleaning agent selected will depend on the material or part to be cleaned. The following is a general guide for the use of acid cleaning.

8.3.6.2 Phosphoric acid cleaning agents can be used for most metals. These agents will remove oxides, light rust, light soils, and fluxes.

8.3.6.3 Hydrochloric acid cleaning agents are recommended only for carbon and low alloy steels. These agents will remove rust, scale, and oxide coatings and will strip chromium, zinc, and cadmium platings. Certain acidic 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 or stress corrosion cracking.

8.3.6.4 Chromic and nitric acid cleaning compounds are recommended for aluminum and copper and their alloys. These compounds are not true cleaning agents, but are used for deoxidizing, brightening, and for removing black residue that forms during cleaning with an alkaline solution. Some compounds are available as liquids, and others as powders. They 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.

8.3.6.5 Acid cleaning requires a storage or an immersion tank, recirculation pump, associated piping, and valving compatible with the cleaning solution. Common techniques for acid cleaning are immersion, swabbing, and spraying. Acid cleaning compounds should not be used unless their application and performance are known or are discussed with the cleaning compound manufacturer. The manufacturer's recommendations regarding concentration and temperature should be followed for safe handling of the cleaning agent. After acid cleaning, surfaces must be thoroughly rinsed with water equal to that described in 8.3.1 to remove all traces of acid and then thoroughly dried after the final water rinse. To minimize staining, do not allow surfaces to dry between successive steps of the acid cleaning and rinsing procedure. A neutralizing treatment may be required under some conditions. Neutralization must be followed by repeated water rinsing to remove all traces of the neutralizing agent. If drying is required, it can be completed with heated or unheated, dry, oil-free air or nitrogen. Table 4 gives typical acid solutions for cleaning various types of metallic materials.

8.3.7 *Solvent Cleaning*—This cleaning or degreasing method was once considered to be the principal procedure for removal of soluble organic contaminants from components to be used in oxygen service and was suitable for use with most metals. The use and attractiveness of chlorinated solvents as cleaning solutions, however, have been limited by environmental concerns and legislative restrictions. Chlorinated solvents are being replaced by aqueous or semiaqueous detergents or emulsion solutions, often in conjunction with deionized water as part of the process. Alcohols, ethers, and other specialized solvents are used in unique cleaning applications where their hazards are warranted due to process restrictions. A list of common solvents appears in 11.4.2. (**LORI — SHOULD THIS TABLE REFERENCE BE HERE?**Table 5). This method is limited by the ability of the solvent to reach and dissolve any contaminants present. Before starting any cleaning operation, a reference sample of fresh clean solvent should be set aside to use as a base reference. At intervals throughout the procedure, samples of used solvent can be compared with the reference sample to determine the level of contamination. Methods of determining contamination can be by comparison to the color of the reference sample, by fluorescence under ultraviolet light, by analysis, or by evaporation. Clean glass bottles must be used to hold samples.

8.3.7.1 After completion of any solvent cleaning method, all gross residual cleaning fluid must be drained from the component to prevent drying in pools. The component shall then be

TABLE 4 Acid Chemical Cleaning Materials (see 8.3.6.5)

Metal	Reason for Cleaning	Cleaning Chemicals[A]	Other Treatment[B]
Carbon and low alloy steels	Removal of scale and oxide films (pickling)	Hydrochloric or sulfuric acid and wetting agents	Dilute alkali dip to neutralize acid or treatment with inhibitor
	Removal of light rust	Citric, sulfuric, and phosphoric acids	Light scrubbing action helpful
	Removal of grease, oil, or drawing compound	Phosphoric acid and synthetic detergents mixture	
Cast iron	Removal of oxide	Chromic and sulfuric acid	
Austenitic stainless steels	Removal of oxide, tarnish and scale and metallic deposits/contaminants	Chromic, sulfuric, and hydrofluoric acid, or nitric, hydrofluoric, and phosphoric acids	Nitric acid solution used to brighten
Copper and alloys	Removal of scale and oxide (pickling)	Hydrochloric or sulfuric acid	
	Brightening	Sulfuric, nitric, and hydrochloric acids	
Aluminum and alloys	Removal of oxide (etch cleaning)	Nitric acid solution used to brighten	Hydroxide solutions

[A] The manufacturer's specification for application of the cleaning agent should be strictly observed or the properties of the metals can be impaired. Time, temperature, and concentrations are very important.

[B] *Postchemical Cleaning Treatment*—After acid cleaning, all components should be thoroughly rinsed preferably using flowing hot water to aid drying, unless otherwise specified by the cleaning material supplier. Some components require treatment with neutralizing solutions after certain cleaning treatments.

TABLE 5 Common Solvents (see 8.3.7)

Chemical Class	Common Examples
Hydrochlorofluorocarbons	Asahiklin AK 225
Hydrofluorocarbon	DuPont Vertrel XF DuPont Vertrel MCA
Hydrofluoroether	3M HFE 7100 3M HFE 71DE

purged and dried with heated dry, oil-free air or nitrogen. Small components may be air dried if appropriate, so long as they do not become recontaminated.

8.3.7.2 Solvent cleaning may be performed using any of the methods previously discussed such as swabbing and spraying. Components and disassembled parts can also be cleaned by immersion in a solvent tank and applying agitation. The process can be improved by the use of ultrasonic cleaning techniques. Cleaning by forced circulation of a liquid solvent flow through the component can also be carried out. The duration of cleaning by circulation shall be continued using clean solvent until the used solvent emerges from the component as clean as the reference sample.

8.3.7.3 Solvents frequently require inhibitors to control corrosion reactions. The addition of inhibitors may require monitoring to ensure continued effectiveness. This method is often applied to assemblies that cannot be disassembled, to large size components, to prefabricated circuits, and pipeworks.

8.3.8 *Solvent Cleaning Hazards*:

8.3.8.1 Take care that generous ventilation is provided in solvent cleaning areas to prevent workers from breathing excessive amounts of solvent vapor or decomposition products. Vapor from any halogenated solvents is a powerful anesthetic. Inhaled in small quantities, it will cause drowsiness. In large quantities, the vapor can cause unconsciousness and ultimately death.

8.3.8.2 Chlorinated or fluorinated solvents may decompose in the presence of heat sources greater than 392°F (200°C), ultraviolet rays, and atmospheric humidity to form toxic gases, such as phosgene.

8.3.8.3 It is important to ensure that parts to be welded or heated are totally free of solvent. Smoking and the performance of any operation involving the use of flame, arc, or other heat source higher than 392°F (200°C) should be prohibited in the vicinity of solvent vapor. Exposure of the solvent to daylight over a prolonged period may cause decomposition.

8.3.8.4 Solvent containers should not be left in working areas without suitable securely fitted lids or caps. Skin contact should be avoided by wearing protective clothing. Solvents should be carried only if contained unsuitable properly labeled containers.

8.3.8.5 Federal, state, local, or insurance regulations may require that precautions such as electrically grounding containers, remote storage, and spill containment structures be provided. Some solvents are flammable, toxic, or carcinogenic, and. manufacturers recommended safety precautions should be followed. Also, compliance to federal, state, and local regulations may be required. Manufacturers of ultrasonic cleaning tanks and associated equipment issue recommendations on their safe operation. Operators shall comply with the manufacturer's recommendations. A material Safety Data Sheet is required for each chemical used.

NOTE 4—**Caution:** Aluminum and its alloys have been known to react vigorously with chlorinated hydrocarbon solvents to produce hydrochloric acid vapor, which is both toxic and corrosive. The conditions under which these reactions occur are not well known. This particularly occurs on aluminum particles such as swarf or chips from machining or cutting processes.

8.3.8.6 When using solvents to clean aluminum, the following should be observed:

(1) Ensure that only inhibited commercial grade solvents, specifically designated as degreasing solvents, are used for aluminum and its alloys. These solvents should be periodically checked to monitor the inhibitor level.

(2) If a degreasing tank is used, gently place components into the degreasing tank to avoid rupturing the protective oxide film.

(3) Ensure that the material being cleaned is free from particles such as swarf or dust. Aluminum fines, chips, or powders should never be allowed to contact the solvent.

(4) Aluminum parts should never be left in contact with degreasing solvents for extended periods of time since the solvent can react with the metal under such conditions.

8.4 *Vapor Degreasing*—Vapor degreasing is the removal of soluble organic materials from part surfaces by the continuous condensation of solvent vapors on the cold part and their subsequent washing action. However, the use and attractiveness of chlorinated solvents as cleaning agents has been limited by environmental concerns and legislative restrictions. Chlorinated solvents are being replaced with nonrestricted replacements; selection of replacement agents is discussed in Guide G 127. Vapor degreasing equipment consists of a vaporizer for generating clean vapors from a contaminated solvent and a container for holding the parts in the vapor phase. DO NOT use refrigerant grade solvents, as they have been known to contain oils. Some of these solvents used are flammable in air under certain conditions and have varying degrees of toxicity; therefore, caution should be exercised in their use. Part temperature must be below the boiling point of the solvent so that solvent vapors will condense and wash down by gravity over part surfaces. The component should be positioned and connected so that the condensate will drain from the ports. Continuous circulation of the condensate and its transport back into the vaporizer will carry the dissolved contaminants into the vaporizer where they will remain. No further cleaning will occur after the part temperature reaches the vapor temperature.

NOTE 5—**Caution:** Highly flammable materials such as gasoline, kerosene, naphtha, or paint thinners should not be used for any chemical cleaning or rinsing. Some plastic tubing or seals used in cleaning equipment may undergo chemical extraction by the solvent, and which would be deposited on the surface intended to be cleaned. Nylon and polytetrafluoroethylene (PTFE) tubing are satisfactory with many frequently used solvents. The precautions stated in 8.3.8.6 should be observed in cleaning aluminum and its alloys.

8.5 *Purging*:

8.5.1 It is very important to purge the component to ensure that all residuals from previous cleaning operation(s) are removed before subsequent cleaning operations or final packaging occur. This can be accomplished by rinsing, drying, and blowing. Rinsing may be dependent upon the cleaning solutions used, but in general filtered water may be used. Drying may be done by the application of heat to the component by ovens and infrared lights, or by blowing with clean, oil-free, dry air. Removal of solvent at elevated temperatures requires additional attention because solvents are more likely to attack the component surfaces or to decompose and deposit undesirable films on the component under such conditions. Environmental law may require passing exhaust gases through a charcoal or absorbant bed to remove solvent atmospheres before release to atmospheric exhaust. It is important that the purging medium have a cleanliness level greater than the desired cleanliness level of the component.

8.5.2 A more critical purging is performed using clean, dry, oil-free nitrogen gas. This may require dryness verification by measuring the dew point of the effluent drying gas. Final duration and the type and number of purging operations depend on the component to be cleaned, the cleaning methods used, and the final application.

9. Cleaning Procedures

9.1 A cleaning program should be selected that results in an increase in the degree of cleanliness of the component after each cleaning operation. It, therefore, becomes a matter of processing the component through a series of cleaning methods, or cycles within a single method, or both, in order to achieve the desired final degree of cleanliness.

9.2 It may be possible to obtain the desired degree of cleanliness in a single operation, but many cleaning operations are required to progress in several stages, such as a precleaning or initial cleaning stage, an intermediate cleaning stage, and a final cleaning stage. Each cleaning stage must be isolated from previous stages by appropriate rinsing, drying, and purging operations.

9.3 *Precleaning*:

9.3.1 Precleaning should be used to remove gross contaminants, such as excessive oxide or scale buildup, large quantities of oils and greases, and inorganic particulates.

9.3.2 Precleaning reduces the quantity of contaminants, thereby increasing the useful life and effectiveness of the cleaning solutions used in subsequent cleaning operations. The cleaning environment and handling procedure used for all precleaning operations are not critical, but users are encouraged to be aware of, and follow, all related safety practices.

9.4 *Intermediate Cleaning*—The intermediate cleaning stage generally consists of subjecting the part to caustic or acid cleaning solutions designed to remove solvent residues and residual contaminants. The cleaning environment and handling procedures used for intermediate cleaning operations are more restrictive than those used for precleaning. The cleaning environment and solutions must be appropriately controlled in order to maximize solution efficiency and to minimize introducing contaminants, compromising subsequent final or precision cleaning operations. A list of common alkaline salts and detergents is given in Table 2.

9.5 *Final Cleaning*:

9.5.1 When components are required to meet very high degrees of cleanliness, such as in nuclear, space, and electronic applications, they are subjected to a final cleaning stage. This final stage involves the removal of minute contaminants and is generally performed with chemical cleaning methods. At this stage of cleaning, protection from recontamination of the component by the cleaning solutions or the environment becomes critical. In order to obtain very high degrees of cleanliness, the cleaning environments may require strict controls, such as those found in classified clean-rooms.

9.5.2 The final cleaning stage incorporates expanded drying and purging operations with a packaging program to protect the component from re-contamination.

10. Cleanliness Requirements

10.1 *The Need for Cleanliness*:

10.1.1 Scrupulous cleaning is the most fundamental fire-safety measure applied to oxygen-handling systems. One may not have to alter polymers or metals in some systems of low severity, but any system that is exposed to oxygen or oxygen-enriched service will require scrupulous cleaning. Various cleanliness requirements have been followed by different organizations over the years. These levels have treated liquid contaminants (basically oils and greases) and solid contaminants (basically particulates) separately.

10.1.2 *Fluids and Greases*—Table 1 lists several oil-film specifications that have been published through the years, ranging from 0.013 to 100 mg/ft^2 (0.14 to 1080 mg/m^2). Today, the extremes of this range do not appear to be in use.

10.1.2.1 Among the factors involved in choosing the degree of cleanliness required for surface films are such things as: film flammability, film ignitability, film sensitization of other materials, film migration, and accumulation (including tendencies to flow, to evaporate and condense at elevated temperature, and to chip at low temperatures) **(1)**.[7]

10.1.2.2 When assessing contaminant type (see 7.1) and final cleanliness level (see 7.1.4), it is important to consider potential ignition hazards that could be active in a system. Adiabatic compression is the primary ignition mechanism of oils and greases, having produced ignition experimentally **(2)** at approximately 6 mg/ft^2 (65 mg/m^2); also, migration and collection of nonviscous oils appears to occur above ~20 mg/ft^2 (~220 mg/m^2) **(1)**. This suggests 6 mg/ft^2 (65 mg/m^2) may be the highest conservative limit that may be applicable for incompatible oils in severe service. In a system that does not experience rapid compression, this conservative limit might be extended to 20 mg/ft^2 (220 mg/m^2) on small components or regions that are difficult to clean whether they are part of larger systems or not. However, where surfaces are large, lower levels of maximum fluid contamination are usually needed. A recent CGA pamphlet **(3)** recommends that oil film contamination on structured distillation column packing (that is a very high surface area application) be limited to 4.6 to 9.3 mg/ft^2 (50 to 100 mg/m^2) with the upper limit applied to local regions and the lower limit taken as a system overall average.

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[7] The boldface numbers in parentheses refer to the list of references at the end of this standard.

This level takes into account the high surface area (resulting in a limit less than 20 mg/ft^2 [220 mg/m^2]), but also factors in material compatibility considerations, knowledge of the specific contamination that might be present, and migration factors that allow a higher oil film limit than otherwise be acceptable.

10.1.3 *Solids and Particulates*—Solids and particulates should be controlled in order to reduce the particle impact ignition hazard and to better ensure component reliability and functionality. Bankaitis and Schueller **(4)** list several limits which have been applied in government and industry to control solids and particulate contamination.

10.1.3.1 Factors involved in choosing the degree of cleanliness required for particles are such things as particle flammability, ignitability, size, shape, and migration tendency (including fluidization) **(5)**, critical sealing surfaces, and tolerances within the equipment that can be affected by particles.

10.1.4 *Fluids Versus Solids*—Through the years, more attention has been focused on fluid oil films than on solid contaminants. This is due to several reasons. Oil films tend to be more easily ignited. They migrate. They vaporize. They are more likely to be present in greater total amounts. Also, when an oil film is scrupulously removed, it is likely that there will be little if any unacceptable particulate contaminant remaining. Further, many solid particulates are inert and present more of a mechanical problem than a fire risk.

10.2 *Technical Practicalities*:

10.2.1 *Cleaning Capabilities*—When the present-day cleaning methods described in this practice are carefully used, it is realistic to achieve oil film residues that are no more than a very few mg/ft^2 (for example, one to three), and typically, cleanliness levels of less than 1 mg/ft^2 (11 mg/m^2) or less will result. Very few systems will demand cleanliness better than this level. Further, for most systems, the time or economic saving that can be had with less scrupulous use of these conventional methods is often not great. Therefore, there are only a few systems with a practical or economic incentive to establish target thresholds above or below this level, and they are very few.

10.2.2 *Cleanliness Verification*—Traditionally verification of cleanliness of oxygen systems has relied on spot and sometimes general inspection of surfaces after they are cleaned. However, one can also "verify" cleanliness by establishing the suitability of the cleaning procedure and the diligence of its use, as well. Common inspection techniques that are practical in the field have always been limited in their ability to conveniently detect oils to the levels that are achievable with scrupulous cleaning and that are often needed for safety. Indeed, such common inspection methods as "black" (ultraviolet) light examination may not detect some oils that are far in excess of safe levels. In general, this type of verification cannot employ the awkward or cumbersome high-tech laboratory methods such as solvent extraction/evaporation, or loss on ignition methods. Such post-cleaning inspections are nonetheless beneficial, because they establish an atmosphere of diligence and can detect when serious breaches of good cleaning practice occur. Doubtless, however, a greater margin of the safety that has resulted in oxygen systems in the past has been due to diligent cleaning practices with effective cleaning agents than due to inspection. Because of the change in cleaning process resulting from the loss of cleaning materials due to environmental and toxicological regulations, it is much more difficult to be confident that systems are adequately clean despite verification of cleanliness through visual inspection of equipment after it has been cleaned. Hence, in the future, there will be increasing need to practice the world-wide quality principle of prevention: focusing on qualifying appropriate cleaning procedures (perhaps with high technology laboratory verification methods not suited to general inspection use) and using these procedures for careful cleaning of the system rather than focusing on final inspection with common instruments such as ultraviolet light. However, in many cases, the use of final spot- or random-sample inspections (statistical process control) to detect when the cleaning system has broken down will continue to have value.

10.3 *Suggested Surface-Film Cleanliness Limits*:

10.3.1 *General Conservative Target*—For the majority of systems, a target cleanliness goal of about 1 to 5 mg/ft^2 (11 to 55 mg/m^2) or less of nonapproved oil or grease film is suggested. This appears to be conservative for even the more undesirable contaminants.

10.3.2 *General Upper-Limit Target*—A more liberal target allowance up to perhaps, 20 mg/ft^2 (220 mg/m^2) may be acceptable and conservative, especially in systems not susceptible to rapid pressurization or in small components that are particularly difficult to clean and inspect. This level appears to control the migration hazard of even fairly light oils.

10.3.3 *Exceptional Cases*—To exceed a 20 mg/ft^2 (220 mg/m^2) level, one must consider both the severity of the system and the nature of the contaminant. The adoption of a more liberal allowance should be justified by a review of the hazards, risks, and consequences involved, especially the prospect of rapid compression of the oxygen. Those portions of a system of primary concern for cleaning are always the high-risk areas of high velocity regions (such as valve seats), sumps (where debris may collect or solvent may evaporate and concentrate solutes), and dead ends (where heat of compression is most likely). One strategy can be to allow those areas that may not be quite as clean and that cannot be inspected reasonably with current techniques to be offset somewhat by those more critical areas that achieve or exceed the target cleanliness. In evaluating higher target cleanliness, the property of any contamination to consider first is its viscosity and whether migration is less likely than for thin oils. If it is less migratory, then the amount of contamination that can be tolerated may be significantly higher. Indeed, if the contamination is a varnish or paint residue that is neither volatile nor migratory, then one could consider such things as the tendency to chip or to burn in place in setting a practical cleanliness limit. In those cases where greater cleanliness (lower levels of contamination) is demanded, the factors important to the evaluation should include the presence of high pressures, high oxygen concentrations, high temperatures, high gas velocities, high surface areas, low compatibility of structural materials, high exposures to people (primarily) or capital, and high pressurization rates. In the past, equipment has been successfully used in low severity systems with contamination present up to at least 100 mg/ft^2 (1080 mg/m^2), and indeed, there is industry experience in some systems containing oil contamination at the basic cleanliness level cited in CGA 4.1 of 47.5 mg/ft^2 (500 mg/m^2).

10.4 *Suggested Particulate Cleanliness Limits*:

10.4.1 In most instances, suitable oil film cleaning and proper and prompt protection of the cleaned surface will reduce particulate contamination to acceptable levels and maintain them. Particulate contamination is somewhat easier to inspect for than are oil films. Clearly, any obvious particulate contamination is undesirable. In cases where particulates are known to be inert materials (metal oxides or ceramics), their presence in a fire regard is much less serious than if they are flammable materials such as metals fines, carbon, or polymers.

10.4.2 In considering particle cleanliness allowances, the principal focus should be on the nature of the particles (if known), the presence of regions where particles might collect if they should migrate through the system, and the nature of regions where they might impact (as well as their velocities at impact).

11. Inspection

11.1 Presently available inspection methods range from simple to complex. Typically, the simple methods do not have sensitivities capable of effectively detecting contamination at the levels acceptable for oxygen system use. Similarly, the complex methods are often impractical for general use. As a result, the range of application of existing methods is limited, and better inspection methods are constantly being sought. Table 6 is a list with brief descriptions of some available tests that are recognized as having some application.

11.2 *Simple Inspection Method*—Simple inspection methods are not quantitative and are used to detect gross exceptions, such as parts which may have bypassed the cleaning procedures or parts that may have been recontaminated subsequent to cleaning. These methods should not be used to test for adequate cleanliness of components unless the component is known to have undergone a special cleaning process and efforts have been made to preserve its cleanliness, the nature of contaminants on the component prior to cleaning are known, and adequate sensitivity of the inspection method relative to those specific contaminants has been established. Simple inspection methods should not be used to infer the cleanliness of components of unknown origin.

11.3 *Complex Inspection Methods*—Complex inspection methods are usually quantitative and have sensitivities adequate to detect low levels of contamination. In many cases, complex methods are impractical for use on each component. As a result, cleanliness is sometimes inferred. In some cases, complex inspection may be applied to randomly selected

TABLE 6 Surface Cleanliness Tests

Name of Test	Test Method	Characteristics or Limitations
Visual	Examination with the unaided eye or with a microscope.	Subjective but widely used; most effective with particulate matter, least effective with invisible films; use of a highly trained microscopist increases the validity of test results.
Tissue paper or white cloth	Surface is rubbed with a piece of white tissue paper or a white cloth. Grease or soot is observable.	Limited to visible soils, insensitive qualitative test.
Water break	Normally applied after last clean water rinse. Any break in continuity or receding water film is observed as water drains off the part.	A qualitative test for hydrophobic soils; contaminants in the water lessen sensitivity; use of deionized water and a trained inspector may increase sensitivity to one-molecular thickness of contaminant.
Gravimetric	A test piece is weighed before and after cleaning, or the soil remaining from the evaporated cleaning solvent is weighed.	Results show good sensitivity (5×10^{-5} gm/cm^2), but are more indicative of cleaning method effectiveness than surface cleanliness.
Ferrocyanide paper	Paper is immersed in a solution of NaCl, $K_3Fe(CN)_6$ and $K_4Fe(CN)_6$ in water and dried. Paper is moistened and placed on metal surface, then removed and rinsed in clear water. Clear areas on the paper are caused by soil on the metal.	Limited to ferrous metals and laboratory tests.
Copper dip	Cleaned metal panels are dipped in an acid copper sulfate (copper flash) solution.	Continuous and adherent copper flash indicates surface was clean; areas with no or poor copper flash indicate surface contamination. Limited to ferrous metals; requires an experienced operator.
Solvent ring	A drop of solvent is repeatedly deposited and picked up from the test surface. It is finally deposited on a quartz or glass slide and dried. If contamination is present, a ring will be formed on the slide.	Enables subsequent identification of soil by infrared spectrophotometry, assumes use of a high purity solvent.
Solvent	After each cleaning step, used solvent is filtered through membrane filters and examined for levels of particulate contamination. NVR is also monitored. Deionized water rinses are monitored for resistivity if ionic cleaners are used.	Commonly used indirect method that assumes acceptable cleanliness if the solvent no longer removes contamination.
Atomizer	Surface is cleaned and dried. Water is applied as a spray with an atomizer. The droplet pattern with the advancing contact angle is observed to determine surface cleanliness.	Sensitive but only for hydrophobic soils; results affected by spray time, nozzle-to-part distance, atomizer air pressure and ambient temperature; applicable to small cross-sectional areas with stainless steel or gold. Surface must be smooth and free of wettable detergent films.
Contact angle	A light beam is directed into a water droplet on the test surface. The angle of the reflected beam indicates the contact angle or angle of incidence. Greater contact angles indicate larger amounts of contamination.	Effective only on nonwetting hydrophobic contaminants.
Ring test	A droplet of water on a surface tension ring tester is repeatedly lowered to contact the test surface. The number of contacts, or B-number, indicates surface cleanliness.	Must be performed by a trained operator to be repeatable; a measure of surface wettability.

representative components, or it may be used to qualify a cleaning procedure after which inferred-cleanliness of the components is assumed. Industry quality control methods may be used to ensure confidence in these inferred-cleanliness approaches.

11.4 *Available Inspection Methods*—Two types of inspection techniques are presented for use. Type I tests are qualitative and are intended as "pass-fail" criteria. Type II tests are quantitative and several levels are provided to represent increasing control over measured contaminants and to represent levels used in various organizations.

11.4.1 *Type I—Qualitative Tests*:

11.4.1.1 *Test 1—Direct Visual Inspection (White Light)*—This is the most common test used to detect the presence of contaminants such as oil, greases, preservatives, moisture, corrosion products, weld slag, filings, chips, and other foreign matter. The item is inspected for the presence of contaminants under strong white light and for the absence of accumulations of lint fibers. This method will detect particulate matter larger than 50 µm and moisture, oils, greases, etc., in relatively large amounts. Any visual contaminate is cause for recleaning.

11.4.1.2 *Test 2—Direct Visual Inspection (Ultraviolet Light)*—Ultraviolet (UV) light (black light) causes many, but not all, common organic oils or greases to fluoresce when they may not be detectable in white light. The surface is observed in darkness or subdued light, using an ultraviolet light radiating at wave lengths between 250 and 370 nm and an intensity of 800m W/cm^2 at the surface. During ultraviolet inspection, fluorocarbon oils do not fluoresce and therefore can not be detected by this method. Some materials such as cotton lint that do fluoresce may be acceptable unless present in excessive amounts. 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. If fluorescence shows up as a blotch, smear, smudge, or film, reclean the entire component.

NOTE 6—UV light can show fluorescence when no contamination is present. If this occurs, reclean the area and re-examine with UV light. If the fluorescence persists, it should be assumed a false positive and ignored. It should also be noted that in many cases visual inspection with white light and UV light can be used to fail a component; however, they cannot be used to pass a component.

11.4.1.3 *Test 3—Wipe Test*—This test is used to detect contaminants on visually inaccessible areas. It is often used as an aid in the above visual inspection. Rub the surface lightly with a clean white lint-free paper or lint-free cloth, either dry or soaked in water or solvent, then examine under white or ultraviolet light. The area should not be rubbed hard enough to remove any oxide film as this could be confused with surface contamination. Discoloration of the wiping medium is cause for recleaning.

11.4.1.4 *Test 4—Water Break Test*—This test may be used to detect some oily residues not found by other means. Wet 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. This method is generally limited to horizontal surfaces, and its ability to identify water-soluble oils is not determined. Beading of water is cause for recleaning.

11.4.1.5 *Test 5—Gas Extraction*—In gas-extraction tests, a clean particle free gas stream is used to entrain contaminants and transport them to a detection device. As with the solvent-extraction methods, this method is limited by its ability to remove all of the contamination present. Since real physical entrainment is not possible, the approach is more effective at demonstrating inadequate cleanliness than it is at quantifying the amount of contamination present. It is principally useful for inspection for particles, oil being more effectively addressed with solvent extraction. The presence of detectable particles is cause for recleaning.

11.4.2 *Type II—Quantitative Tests*—This verification method uses primarily solvents as the verification agent because of their solvent properties and fast evaporation rate. When choosing solvent alternatives, consideration should be given to a solvent's toxicity, flammability, and material compatibility, as well as its cleaning ability. Terpenes and citrus-based solvents generally are not compatible with oxygen service. Deionized water can be used in quantitative verification methods. Examples of solvents currently used in this application include, but are not limited to:

(a) Hydrofluorochlorocarbons, such as Asahiklin AK 225

(b) Hydrofluorocarbons, such as DuPont Vertrel XF or Vertrel MCA

(c) Hydrofluoroethers, such as 3M HFE 7100 or 71DE

(d) Water/water based solvents

11.4.2.1 *Test 1—Solvent Extraction Test*—This method may be used to supplement visual techniques or to check inaccessible surfaces by using a solvent to extract and quantify contaminants for inspection. See Test Method F 331 and Practice G 136 for methods of performing this test. The solvent extraction test is limited by the ability of the solvent to reach and dissolve the contaminants present. Components of the equipment being tested may also contain materials that would be attacked by the solvent and thereby produce erroneous results. The used solvent is examined by one of the following methods to determine the amount of nonvolatile residue. Flush, rinse, or immerse the surface of the item being tested in a low residue solvent with the amount of solvent being proportional to the surface area of the item being cleaned. A typical value is 100 mL/ft^2 (1100 mL/m^2). This may be adjusted to 100 mL for parts smaller than 1 ft^2 (0.1 m^2). For very large components a statistical sampling procedure may be used, rinsing several smaller areas in a random fashion to find the cleanliness of the entire component. Filter a representative sample of this used solvent. A known quantity is evaporated almost to dryness and then transferred to a small weighed beaker for final evaporation and weighing. Take care not to overheat the residue. In the same manner, the weight of residue from a similar quantity of clean solvent is determined. Use the difference in weight of the two residues to compute the amount of the contaminant extracted per square meter of surface area cleaned. Place a measured quantity of sample of the unfiltered used solvent in an Imhoff cone and evaporate it to dryness. The volume of residue can be measured directly and used to compute the amount of contaminant extracted per square meter of surface area cleaned. Greater sensitivity can be achieved by evaporating successive quantities of the solvent in the same Imhoff cone. Compare a sample of known quantity of the used solvent and a similar sample of new solvent by light transmission through the two samples. There should be little difference in color of the solvents and very few particles. Hydrocarbon or particulate matter residues determined by the inspection procedure shall not exceed the amount specified by the user of the equipment. A comparative chemical analysis may indicate the nature of the contaminants.

11.4.2.2 *Total Organic Carbon*—When water is used as a quantitative verification solvent, aqueous ultrasonic extraction has been used to release organics and particulates from surfaces of fittings and piece parts for total organic carbon analysis. In this method, high-density ultrasonic energy is used to cause resident organics to be broken into micelles, which persist in solution for a limited time. The total carbon content is determined using a total combustion carbon analyzer. For this to be a true representation of the contaminant, water with low organic and particulate content is required. The ultrasonic extraction degasses the water to eliminate any contribution of carbon dioxide to the total carbon. Testing is done to establish the efficiency of organic removal and dilution factor for a particular configuration. See Test Method G 144 for further details.

11.4.2.3 *Cleanliness Levels*—The following levels of cleanliness are representative of those used by various industries. This test has an extensive practical history, but the results represent only an indication of the potential level of contamination.

11.4.3 The nonvolatile residue remaining shall be as follows:

11.4.3.1 *Level A*—Less than 1 mg/ft^2 (11 mg/m^2),

11.4.3.2 *Level B*—Less than 3 mg/ft^2 (33 mg/m^2),

11.4.3.3 *Level C*—Less than 6 mg/ft^2 (66 mg/m^2),

11.4.3.4 *Level D*—Less than 20 mg/ft^2 (220 mg/m^2),

11.4.3.5 *Level E*—Less than 50 mg/ft^2 (550 mg/m^2), and

11.4.3.6 *Level F*—Specified by the user or supplier of the components in question.

11.4.3.7 *Test 2*—A nonaqueous solvent extraction test used to find the particulate population of a sample of solvent obtained as in Test 1 except instead of being vaporized immediately the sample is passed over a filter paper to capture the representative particles. Test Methods F 312 and SAE ARP 598 are two methods used to find particle populations in aerospace fluids. This cleaning verification method has extensive practical history but represents only an indication of the potential level of cleanliness. Following the total carbon determination, the rinse is filtered and the particulate population is determined by methods such as Test Methods F 312 or SAE ARP 598. The following particle population levels are representative of those used in industry, with "x" being the size of the particles counted:

Test Levels	Particles Allowed (#)	Size Range (μm/100 mL)
Level 175	0	X > 175
	1	100 < X < 175
	5	50 ≤ X < 100
	20	X < 50
	5	Fibers
Level 300	0	X > 300
	5	175 < X< 300
	20	100 ≤ X < 175
	no limit	X < 100
	25	Fibers
Level 500	0	X > 500
	5	300 < X < 500
	20	175 ≤ X < 300
	100	100 < x < 175
	no limit	X < 100
	100	Fibers
User-specified		

11.4.4 *Gas Blowdown*—This test is based on the entrapment of contaminants onto a minimum size filter paper. Inspection of the paper then reveals the lack of cleanliness, but not the level of cleanliness present. This test is qualitative but yields a quantifiable data.

11.4.4.1 Use a blowhorn or similar device to hold a microfine filter disk. The disk diameter, pore size, and size of grid, are dependent on the maximum amount of contaminant allowable for the process being cleaned. A gas purge over the test surface and through the filter paper will cause entrapment of contaminants. A particle inspection by optical techniques as in Practice E 312 or ARP 598 will show the size and population of the particles, while fluorescent stains will indicate hydrocarbon contamination.

11.5 *Optional Tests*—The following optional tests may be required depending on the particular contaminant expected or the type of component being cleaned.

11.5.1 *Instrumental Analysis*—There are many instrument systems available to determine particle size and distribution. Light scattering and light interruption methods of instrumented particle analysis are the most versatile since these techniques can be automated to give real time data of production processes.

11.5.2 *Light Scattering*—As the name implies, this method uses the variations in intensity of light scattered (reflection and refraction) by the particle in the direction of a sensor. The size of the particles that can be measured is 0.5 μm and below depending on the equipment. The disadvantages of this method are that the sensing angle is critical; changes in color and density of the fluid medium affect detection; and the system cannot detect particles when the refractive index of the fluid and particle are identical.

11.5.3 *Light Interruption*—The particle size is determined by the change in the light intensity produced by the particle as it passes between the light source and light sensor. This system has several advantages, which are the ability to measure particles in a gas or liquid; lack of dependence upon particle characteristics; and close discrimination of particle size. A disadvantage is the inability to detect particles when the refractive index of the particle and fluid are identical. Particles 0.5 μm and larger can be detected.

11.5.4 Another solvent extraction method utilizes the infrared absorption technique. Since most crude oils and refined petroleum products contain hydrocarbon bonds with a strong absorption band in the 3.4 to 3.5 μm range an instrument that will measure this infrared absorption will accurately measure the oil contamination. This can then be reported as parts per million (sample volume) of the extracted solvent and related to the rinsed area.

11.5.5 Due to the unattractiveness of chlorofluorocarbons as solvents, many alternative solvents are being evaluated for use as cleanliness verification fluid. Many alternate tests are being evaluated in addition to those listed above. These methods include turbidimetry, surface tension methods, total organic carbon analysis, and modification or enhancements to the tests listed above.

12. Packaging and Package Marking

12.1 *Packaging*:

12.1.1 After oxygen components and equipment have been cleaned and verified as meeting the established cleanliness criteria it is essential that measures be taken immediately to prevent recontamination. This becomes especially important if the oxygen component or equipment is to be shipped or stored. It should be noted that packaging or sealing materials that come in contact with the clean component or equipment must have an equal or greater degree of cleanliness than the oxygen units to be packaged or sealed.

12.1.2 Component or equipment openings should be sealed with caps, plugs, blind flanges, or other means to prevent contamination. Durable covers such as sheet metal may be taped over large component openings to prevent recontamination as long as these covers do not become the source of contamination. Very small components or equipment may be packaged in suitable plastic bags.

12.1.3 Caps, plugs, or bags made of polyethylene are commonly used to seal and protect oxygen-clean components. The user may require that PCTFE caps, plugs, bags, or other types of seals and protective coverings must be used on oxygen-cleaned components and equipment.

12.1.4 Hot dip coating compounds should not be used for any purpose, as it will be difficult to completely remove all material on assembly. Rubber or cork stoppers, paper and cloth are not suitable for use on process fluid wetted surfaces, as they will leave organic deposits which could later initiate an explosion or fire when the oxygen system is assembled and in service. Only material preservatives compatible with oxygen should be applied to oxygen equipment.

12.2 *Package Marking*:

12.2.1 Each oxygen cleaned and packaged article shall be clearly labeled to include the following information:

12.2.1.1 The manufacturer, component identification, date cleaned, responsible department or agent,

12.2.1.2 Notification that it has been specially cleaned for oxygen service, such as oxygen cleaned, cleaned for oxygen service or specially cleaned,

12.2.1.3 Identification of cleaning method used, such as "Cleaned in accordance with ASTM G 93, Verification Type I, Test 1 through 4, Type II, Test 1, Level A, and Test 2, Level 175" or "Cleaned in accordance with ASTM G-XXX" (the manufacturer's or purchaser's specification), and

12.2.1.4 A warning to not unwrap the article prematurely, such as "Do not open until ready for installation" or "Do not open except in a controlled clean environment."

13. Maintaining Cleanliness During Assembly

13.1 Follow clean habits during assembly of cleaned components to maintain their cleanliness. Good practices include but are not limited to the following:

13.1.1 Before assembly, gather all fittings, tubing, and components and assemble them in a linear fashion.

13.1.2 Unbag an item only when it is ready to be installed.

13.1.3 Minimize the quantity of lubricant used, and ensure the lubricant is compatible for oxygen service.

13.1.4 Limit assembly and disassembly generated contaminant by avoiding galling on threaded fittings.

13.1.5 Use PTFE tape on NPT fittings and oxygen compatible lubricants on threads. Ensure that the tape is applied so that it does not extend into the flow path. Minimize the use of oxygen compatible lubricants.

NOTE 7—Refer to A-A-58092, Commercial Item Description, Tape, Antiseize, Polytetrafluoroethylene, United States Department of Defense, Washington, DC.

13.1.6 Use the correct fittings so as to avoid mixing straight and pipe threads.

13.1.7 Before assembling the system, purge cylinder valves, make seals before engaging threads on fittings, properly deburr tubing, and remove any weld slag from the interior of lines.

13.1.8 After assembly and before wetting the system with oxygen, purge the system using clean, dry gaseous nitrogen to remove assembly generated contaminants through the system or to a benign location.

14. Ordering Information

14.1 This practice may be used to develop cleaning procedures for oxygen systems and components.

14.2 Specification of this practice should include the following:

14.2.1 List of materials and specifications of items to be cleaned,

14.2.2 Cleaning solution specifications required (see 8.4),

14.2.3 Dryness requirements in degrees of dew point or parts per million by volume of water,

14.2.4 Type of cleanliness verification required (see Sections 10 and 11),

14.2.5 Level of cleanliness verification required (see Sections 10 and 11),

14.2.6 Packaging requirements (see Section 12),

14.2.7 Inspection witnessing requirements,

14.2.8 End use of component or system (not mandatory), and

14.2.9 Purge gas specifications required (if any).

15. Keywords

15.1 cleaning; contamination control; oxygen; oxygen-enriched environments; oxygen service; oxygen systems

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE NUMBER 1—CLEANING OF CARBON STEEL PIPING

NOTE X1.1—This section describes detailed cleaning procedures typical of those encountered in industry and government. These were chosen to illustrate specifically how individual cleaning operations are combined to yield a component or system acceptable for various oxygen applications. These examples list specific hardware items and an appropriate sequence of cleaning operations to clean components for oxygen service. References to particular procedures are for information purposes only and do not constitute an endorsement or recommendation by ASTM of a particular procedure. Furthermore, the omission of a procedure does not imply unsuitability. Table X1.1 indexes and summarizes the hardware, applications, and general categories of cleaning procedures reviewed in the following examples.

X1.1 Cleaning before welding of carbon steel piping (including elbows, spool pieces, and tees) to be used for dry, gaseous oxygen up to 1000 psig service and at oxygen velocities in accordance with CGA Pamphlet G-4.4. Welded valves, orifices, instruments, etc. are separately cleaned by other methods.

X1.1.1 Cut piping to proper sizes for prefabrication.

X1.1.2 Grit-blast the interior pipe surface to acceptance level B Sa2 ½ using clean, dry, inert, oil-free grit (sand, crushed slag, glass beads, or equivalent) in accordance with Test Method D 2200.

X1.1.3 Blow out residual grit with dry oil-free air or nitrogen.

X1.1.4 *Optional*—In climates where rusting before installation or fabrication is likely, dip individual components into an alkaline passivating fluid such as aqueous sodium hydroxide[8] and allow the liquid to dry on the pipe surface, but do not allow puddling.

X1.1.5 Weld the piping while maintaining its cleanliness by avoiding contact with dirty surfaces, wearing clean gloves, not introducing foreign materials, and observing general clean assembly practices; use of a GTAW root-pass weld is recommended; use of internal alignment clamps is discouraged. It is advisable to configure the joint and weld schedule to preclude particles from forming on the pipe inside diameter during welding. Inspection and removal of loose debris is essential for all applications.

X1.1.6 Cap the pipe opening if piping will not be used immediately. In climates where rusting before to use is likely, a desiccant may be mounted on the closure cap.

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[8] Oakite 444 has been found suitable for this purpose.

X2. EXAMPLE NUMBER 2—CLEANING COPPER, BRASS, OR STAINLESS STEEL

X2.1 Small, new and unused copper, brass, or stainless steel parts for 0 to 3000 psig gaseous or liquid oxygen service or aluminum parts for 0 to 150 psig gaseous or liquid oxygen service; valves and tubing are included provided the gas-wetted surfaces are generally smooth and there are no porous or deeply recessed regions.

X2.1.1 Clean only in fully disassembled form.

X2.1.2 Preclean any gross contamination (see Section 8).

X2.1.3 Fully immerse the component in cleaning solution to wet all internal surfaces for at least 30 s. Use only glass or metal in contact with the component or solvent.

X2.1.3.1 Use Practice G 131 for ultrasonic cleaning.

X2.1.4 Remove component and drain all gross liquid.

X2.1.5 Air dry or blow dry with clean dry air or nitrogen (see 8.2.5) and.

X2.1.6 Package or install (see 13.1) using clean handling methods.

TABLE X1.1 Index of Specific Cleaning Examples

Application	Cleaning Example Number
Carbon steel pipeline, all welded construction, no flanges or polymers	1
Copper tubing, brass or stainless steel parts, 0 to 3000 psig, small aluminum parts, 0 to 150 psig	2
Brass, copper valves, fittings, or multipiece components	2
Removing silicone compounds and greases from glass, porcelain, and other ceramics	3
Removing silicone compounds and greases from tin, aluminum, and zinc alloys	4
Removing silicone compounds and greases from steel, iron, iron-alloys, copper, and copper alloys	5
Cleaning of machined brass bar stock regulator body (free cutting brass CDA-360) for 4500 psig gaseous oxygen service	6
Cleaning of austenitic, ferritic, martensitic, and precipitation hardened stainless steels	7
Removal of Aerocoat AR-7 coating using a high-pressure water blast system	8
Cleaning of unlined gas storage vessels	9
Cleaning of stainless steel	10
Cleaning of convoluted stainless steel hose	11

X3. EXAMPLE NUMBER 3—REMOVING SILICONE COMPOUNDS AND GREASES FROM GLASS, PORCELAIN, AND OTHER CERAMICS

X3.1 Remove as much of the silicone compound or grease as possible with a dry cloth or disposable tissue.

X3.2 Make up a solution of 100 parts of denatured ethanol and 10 to 15 parts of 50 % potassium hydroxide. Warm the solution to about 150°F (65°C). Immerse the piece in this solution for 5 to 10 min.

NOTE X3.1—Do not leave glassware or porcelain in the solution longer than 10 min to preclude etching.

X3.3 Rinse the part with mineral spirits.

X3.4 Clean with a warm chromic acid solution.

X3.5 Rinse with fresh chromic acid solution.

X3.6 Rinse with water.

X4. EXAMPLE NUMBER 4—REMOVING SILICONE COMPOUNDS AND GREASE FROM TIN, ALUMINUM, AND ZINC ALLOYS

X4.1 Remove as much of the silicone compound or grease as possible with a dry cloth or disposable tissue.

X4.2 Make up solution of 50 parts of Dowanol DPM or EB, 50 parts of mineral spirits having a flash point of over 140°F (60°C) (SSC-Solvent 140), one part sodium hydroxide and one part cresylic acid.

X4.3 Warm solution to 150°F (65°C).

X4.4 Immerse part to be cleaned in this hot solution for 5 to 10 min.

X4.5 Rinse with solvent (such as the DPM or EB listed above) and then rinse thoroughly with water.

X4.6 Remove excess water and permit to dry.

X5. EXAMPLE NUMBER 5—REMOVING SILICONE COMPOUNDS AND GREASES FROM STEEL, IRON, IRON ALLOYS, COPPER, AND COPPER ALLOYS

X5.1 Remove as much silicone compound or grease as possible with a dry cloth or disposable tissue.

X5.2 Make up a solution of 100 parts Dowanol DPM or EB, 100 parts of mineral spirits having a flash point of 140°F (60°C), (SSC-Solvent 140) and one part of sodium hydroxide.

X5.3 Heat the solution to 150°F (65°C).

X5.4 Immerse part in hot solution for 5 to 10 min.

X5.5 Rinse with solvents (such as DPM or EB listed above) and then rinse thoroughly with water.

X5.6 Remove excess water and permit it to dry.

X6. EXAMPLE NUMBER 6—CLEANING OF MACHINED BRASS BAR STOCK REGULATOR BODY (FREE CUTTING BRASS CDA-360) FOR 4500 PSIG GASEOUS OXYGEN SERVICE

X6.1 The parts are thermally deburred and then degreased in hot alkaline cleaner. However, the thermal deburr operation leaves a light oxide coating on the brass. But degreasing in hot alkaline cleaner also removes this oxide with minimal dimensional change or etching.

X7. EXAMPLE NUMBER 7—CLEANING OF AUSTENITIC, FERRITIC, MARTENSITIC AND PRECIPITATION HARDENED STAINLESS STEELS

X7.1 A final cleaning of all stainless steel series for critical applications.

X7.1.1 Remove all gross contamination such as oils, greases, rust, and paint using one of the methods discussed in Section 8.

X7.1.2 Immerse all components in sodium hydroxide in a tank at the conditions described below. Assist cleaning action by brushing the components with stainless steel or nylon brushes as necessary. The immersion time is 5 to 15 min, the ultrasonic time is 5 to 10 min (during the above immersion time), the bath temperature is 170 to 190°F (76 to 87°C), and the concentration 0.5 lb of NaOH to 1 gal of water.

X7.1.3 Rinse or soak the components in hot tap water until all surfaces have been thoroughly rinsed.

X7.1.4 Immerse the parts in a tank containing phosphoric acid cleaning solution, and allow them to soak at the conditions shown as follows: Assist cleaning action by brushing the components with stainless steel or nylon brushes as necessary. The immersion time is 5 to 10 min, the ultrasonic time is 3 to 6 min, bath temperature is 130 to 150°F (54 to 65°C), and the concentration is 0.134 gal of phosphoric acid in 1 gal of water.

X7.1.5 Rinse or soak the components in hot tap water until all surfaces have been thoroughly rinsed.

X7.1.6 Spray, rinse, or soak the components with isopropyl alcohol until all surfaces have been thoroughly flushed.

X7.1.7 Blow dry the components with gaseous nitrogen.

X7.1.8 Ultrasonically clean for 2 to 5 min (see G SONC), and spray rinse and take particulate and NVR sample (see 11.1).

X8. EXAMPLE NUMBER 8—FIELD REMOVAL OF AEROCOAT AR-7 COATING USING A HIGH-PRESSURE WATER BLAST SYSTEM

X8.1 Conditions

X8.1.1 This example pertains to removal of Aerocoat AR-7 coating from pipe fittings and related hardware.

X8.1.2 This procedure should be performed when the ambient temperature is above 32°F (0°C). Operation of the equipment in subfreezing temperatures will cause ice to form in the surrounding areas and may cause a hazard to personnel working in the area.

X8.1.3 Before attempting to loosen and remove any fitting, be sure to establish an internal inert gas purge or static pressure above atmospheric pressure on all piping and fittings that are being cleaned. Pressurizing the system will prevent contamination from migrating into the piping when the fitting is loosened.

X8.2 Cleaning Procedure

X8.2.1 Place a welder's curtain adjacent to the area to be cleaned.

X8.2.2 Put on all protective clothing as recommended in X8.3.2.

X8.2.3 Fill the water blast reservoir with cold tap water or connect a water supply to the water blast unit.

X8.2.4 Connect the water blast drive unit to a 220 volt, 30 amp, three-phase power outlet.

X8.2.5 Remove the water blast gun from its storage location and turn on the water blast unit.

X8.2.6 Carry the water blast gun to the cleaning area. Do not point the water stream at anyone. The work area should be at least 10 ft (3.04 m) from the motor drive unit to avoid splashing water on the motor and creating a shock hazard.

X8.2.7 Hold the water blast gun about 1 in. (25.4 mm) from the coated area and blast off all areas that need stripping. Use even strokes and follow an orderly pattern to avoid missing any areas. It is not necessary to hold the nozzle at a 90° angle to the pipe or fitting; in some cases angling the nozzle may increase the cleaning action.

X8.2.8 Carry the water blast gun back to the drive unit and turn off the water blast unit, and do not point the water blast gun toward any people or the motor drive unit. Secure the water blast gun.

X8.2.9 Disconnect the power to the water blast unit.

X8.2.10 Inspect the cleaned area and repeat X8.2.7-X8.2.9 as necessary.

X8.2.11 Allow the cleaned area to air dry or blow dry the area with filtered gaseous nitrogen.

X8.2.12 Verify that the system is slightly pressurized with an inert gas.

X8.2.13 Loosen the fittings and remove all piping components that are to be replaced.

X8.2.14 Turn off the system purge.

X8.2.15 Immediately place an approved clean room bag over the open ends of the remaining piping system, and secure this bag with acceptable clean room tape so that contamination cannot enter the piping.

X8.2.16 Place a polypropylene bag over the first bag and tape this bag into place.

X8.2.17 Allow all of the water left from the cleaning operation to evaporate and then sweep up the solid waste as necessary.

X8.2.18 Dispose of solid waste in accordance with all federal, state, and local regulations.

X8.3 Safety Precautions

X8.3.1 This high-pressure water blast machine operates at outlet pressures exceeding 20 000 psi; therefore it must be treated like a cutting tool. The cutting-tool action is evident within about 3 in. (76 mm) of the outlet head, and parts that are not to be stripped must be kept at least 3 in. (76 mm) from the operating outlet nozzle.

X8.3.2 Personnel operating the system should wear rain-type splash suit, steel-toed boots, insulated neoprene gloves,[9] full coverage face shield, and ear plugs or muffs.

X8.3.3 Safety personnel should review this cleaning system operation and establish specific requirements for its use. Safety regulations may require that this system be operated by two people, one to operate the high pressure gun, and another to stand at the drive motor and shut the system in case of an accident or equipment malfunction.

X8.3.4 Additional splash protection for areas adjacent to the work area may be afforded by placing a welder's curtain around the working area. The welder's curtain will prevent water splash from wetting areas near the operation. This splash curtain should be transparent so that safety personnel may observe the operation.

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[9] Best Corporation Style No. 725R have been found suitable for this purpose.

X9. EXAMPLE NUMBER 9—CLEANING OF HIGH PRESSURE GASEOUS STORAGE VESSELS (UNLINED VESSELS)

X9.1 Scope

X9.1.1 This example pertains to the methods, procedures, examinations, and acceptance criteria for cleaning high-pressure gaseous storage vessels. Whenever possible vessels should be furnished with access means for drawing, inspection, and recleaning.

X9.1.2 This appendix shall apply when vessels must be oil-free and free of particles and fibers with sizes greater than those given in the acceptance criteria.

X9.2 Mechanical Cleaning

X9.2.1 Just before final closure weld, clean all interior surfaces to white metal by grinding, brushing and grit blasting using fine sand, as required, to remove all oxide, scale, grease, paint, and weld spatter.

X9.2.2 After cleaning per X9.2.1, sweep and vacuum all interior surfaces to remove visible particulate and fibrous contamination.

X9.2.3 Visually inspect for cleanliness and release.

X9.3 Final Closure Weld

X9.3.1 Back purge the final closure weld with inert gas during the application of the stringer bead to preclude the formation of oxides.

X9.3.2 After application of the stringer bead, examine the internal surface of the closure weld by means of borescopes or fiber optics to determine if there are any visible weld defects or contamination. Visually inspect and release.

X9.3.2.1 If there are visible weld defects or contamination, repair the closure weld or cut apart, clean, and reweld in accordance with X9.3.1, then re-examine in accordance with X9.3.2.

X9.4 Preliminary Sealing

X9.4.1 After examination per X9.3.2, purge the vessel with clean, dry, oil-free nitrogen and seal the vessel openings to preclude contaminating the interior. Vessel shall remain sealed unless operation being performed requires opening. If opening is required, repurge and reseal vessel immediately after the operation requiring opening.

X9.4.1.1 Preferred purge method is to vacuum evacuate to a pressure of 0.5 in. of mercury absolute (maximum) for a minimum of 5 min at a temperature of 60°F (15.6°C) or higher (or at such lower pressure that is 96 % of the vapor pressure of water at the vessel temperature), and filling with dry nitrogen.

X9.4.1.2 Vessel may be purged using multiple pressurizations to higher pressure with dry nitrogen. Dew point should be -40°F (-40°C), maximum.

X9.5 Post-Weld Heat Treatment (PWHT)

X9.5.1 During PWHT the vessel shall remain purged or pressurized with nitrogen to prevent oxidation of vessel interior.

X9.6 Hydrostatic Testing

X9.6.1 Perform hydrostatic testing using Type II water or equivalent solution filtered through a 10 µm nominal rated stainless steel filter with rust inhibitor added.

X9.7 General

X9.7.1 Clean the vessel with one end of the vessel elevated to facilitate drainage. In general, cleaning is a continuous process and should not be interrupted once started. If necessary the cleaning cycle can be interrupted after preliminary rinse or during final rinse if vessel is dried (per X9.17) and purged (per X9.18.1) before to interruption.

X9.8 Degreasing

X9.8.1 Accomplish degreasing after hydrostatic testing is complete.

X9.8.2 Make up the degreasing solution up by adding to demineralized water (per X9.6.1) the following compounds at the rates given:

Compound	Rates
Trisodium phosphate	2 to 4 oz/gal
Wetting agent	1 to 2 pints/1000 gal

X9.8.3 Degrease the vessel by circulating hot (140°F (60°C) minimum) degreasing solution for approximately 30 min through a pressure spray nozzle over all interior surfaces.

X9.9 Preliminary Rinse

X9.9.1 Rinse the vessel immediately after degreasing by spraying demineralized water through a pressure spray nozzle over all interior surfaces of the vessel until all traces of the detergent have been removed and pH is 6 to 8.

X9.10 Pickling

X9.10.1 Pickling is preferred immediately after the preliminary rinse. The pickling solution shall be made up of two parts 20° Baumé hydrochloric acid (~32% by weight) to ten parts demineralized water, filtered through a 40 µm nominal rated filter.

X9.10.2 Pickle the vessel by circulating and spraying the pickling solution through a pressure spray nozzle over all interior surfaces of the vessel immediately after rinsing.

X9.10.3 Pickling time shall be from 1 to 24 h depending on the requirements of the particular vessel being cleaned.

X9.11 Intermediate Rinse

X9.11.1 Rinse the vessel by spraying demineralized water per X9.6.1 through a pressure spray nozzle over all interior surfaces of the vessel immediately after pickling.

X9.11.2 Rinsing time shall be approximately 30 min and until pH is 6 minimum.

X9.12 Citric Acid Flush

X9.12.1 The citric acid solution shall be made up of 8 lb and 5 oz of citric acid to each 100 gal of demineralized water, filtered through a 40 µm nominal rated filter.

X9.12.2 Flush the vessel immediately after the intermediate rinse by spraying the citric acid solution through a pressure spray nozzle over all interior surfaces of the vessel.

X9.12.3 The flushing time shall be approximately 30 min.

X9.13 Final Rinse and Passivation Surface Treatment

X9.13.1 Immediately following the flushing (before internal surface dry), rinse all internal surfaces with a solution of demineralized water (per X9.6.1) for approximately 60 min. Filter this solution through a 10 µm nominal rated stainless steel filter.

X9.14 Examination Number 1

X9.14.1 During the final rinse and prior to the drying operation, collect and examine a 100 mL sample of the effluent in accordance with IAW Test Methods F 312 or ARP 598. During the time the sample is being collected, perform the rinse using a pressure spray nozzle on the upper interior surface to ensure the dislodgement of particles.

X9.14.2 Effluents containing contamination exceeding permissible limits given in the acceptance criteria shall be cause for recleaning and reexamination. Perform inspection and release.

X9.14.3 *Acceptance Criteria*

X9.14.3.1 Total filterable solids 2.0 mg maximum per square foot of significant surface area.

X9.14.3.2 Maximum allowable particle distribution per square foot of significant area:

Particle Size, µm	Quantity, max
0 to 300	Unlimited
301 to 500	10
501 to 1000	2
over 1000	0

X9.14.3.3 Maximum allowable fiber distribution per square foot of significant area:

Fiber Size, µm	Quantity, max
0 to 750 × 25	Unlimited
751 to 2000 × 25	20
2001 to 6000 × 40	2
over 6000	0

X9.15 Examination Number 2

X9.15.1 Visually examine vessel interior for evidence of corrosion products including rust, metal chips, scale, weld scale, oil, grease, paints, preservatives, decals, or other foreign matter. Perform inspection and release.

X9.15.2 Use inspection mirrors, borescopes, and flexible fiber optics to visually examine the interior surfaces of the vessel.

X9.15.2.1 Clean inspection tools before use to preclude the introduction of foreign material into vessel interior.

X9.16 Sealing

X9.16.1 Seal the vessel immediately after it is determined that it meets the acceptance criteria of the two examinations.

X9.16.2 Seals shall be tight enough to prevent contamination and shall be protected so that they will not be broken or warped.

X9.16.3 Any tape used for sealing purposes shall not leave any residue on connections when removed.

X9.17 Drying

X9.17.1 Dry the vessel by vacuum evacuation if analysis precludes the possibility of buckling from external pressure.

X9.17.2 Consider the vessel dry when the pressure is maintained at 0.5 in. of mercury absolute (maximum) for a minimum of 5 min at a temperature of 60°F (16.6°C) or higher, or at such lower pressure that is 96 % of the vapor pressure of water for vessel temperature.

X9.18 Pressurizing

X9.18.1 After drying pressurize the vessel to 10 psig with clean, dry, oil-free nitrogen.

X9.18.1.1 Filter the nitrogen used through a 40 µm absolute rated filter with an element constructed of stainless steel.

X9.18.1.2 Perform a dew point determination on purge gas from vessel and release. Dew point should be -40°F (-40°C) maximum.

X9.18.2 Maintain the vessel at a positive pressure up to and during the time of acceptance by the customer.

X9.18.3 All vessels should be equipped with a shut-off valve and gage for pressurizing. The gage should be capable of reading from 0 to 15 psig in one-pound increments. A protective metal cover should be provided around the gage and valving.

X9.18.4 Complete loss of pressure should be cause for reexamination and recleaning as necessary to meet the permissible contamination limits.

X10. EXAMPLE NUMBER 10—CLEANING OF HIGH PRESSURE GASEOUS STORAGE VESSELS (STAINLESS STEEL LINED VESSELS)

X10.1 Scope

X10.1.1 This appendix establishes the methods, procedures, examinations, and acceptance criteria for the cleaning of high pressure gaseous storage vessels. Whenever possible vessels should be furnished with access means to allow for draining, inspection, and recleaning.

X10.1.2 This appendix should apply when vessels must be oil-free and free of particles and fibers with sizes greater than those given in the acceptance criteria.

X10.2 Mechanical Cleaning

X10.2.1 Vessel lining components should be blast cleaned just prior to placing inside the vessel for assembly, to remove oxide, scale, grease, paint, and other contaminates.

X10.2.2 Just prior to welding the last head on to the vessel, the liner should be inspected for cleanliness and cleaned by blasting, grinding, brushing, and vacuum cleaning to remove visible particulate and fibrous contamination.

X10.2.3 Visually inspect for cleanliness and release.

X10.3 Preliminary Sealing

X10.3.1 After performance of the examination in X10.2.3, purge the vessel with clean, dry, oil-free nitrogen and seal the vessel openings to preclude contaminating the interior. Vessel should remain sealed until post weld heat treatment is complete.

X10.3.1.1 Preferred method of purging is to vacuum evacuate to a pressure of 0.5 in. of mercury absolute (maximum) for a minimum of 5 min at a temperature of 60°F (15.6°C) or higher, (or at such lower pressure that is 96 % of the vapor pressure of water at the vessel temperature), and filling with dry nitrogen. Perform vacuum and purging only after analysis has precluded the potential for buckling from external pressure. Vessel may be purged using multiple pressurizations to higher pressure with dry nitrogen, with permission and specific instructions from engineering.

X10.3.1.2 Dew point should be -40°F (-40°C) maximum.

X10.4 Postweld Heat Treatment

X10.4.1 During postweld heat treatment, the vessel should remain purged or pressurized with helium conforming to prevent oxidation of vessel interior.

X10.5 Liner Completion

X10.5.1 After PWHT, make the final liner welds.

X10.5.2 After liner completion, clean the balance of the liner by grinding, brushing, and vacuum cleaning to remove visible particulate and fibrous contamination. Blasting is allowed.

X10.5.3 Visually inspect for cleanliness and release.

X10.6 Hydrostatic Testing

X10.6.1 Perform hydrostatic testing using Specification D 1193, Type reagent grade water with a suitable dewetting additive.

X10.7 Penetrant Inspection

X10.7.1 Perform penetrant inspection of liner welds using water washable penetrant.

X10.7.2 Following penetrant inspection, thoroughly remove the penetrant with clean tap water.

X10.8 General

X10.8.1 Clean the vessel with one end of the vessel elevated to facilitate drainage. In general, the cleaning is a continuous process and should not be interrupted once started. If necessary, the cleaning cycle can be interrupted after preliminary rinse or during final rinse if vessel is dried (per Section 18) and purged (per section 19.1) prior to interruption.

X10.9 Preliminary Rinse

X10.9.1 Rinse the vessel by spraying Specification D 1193, Type II demineralized water through a pressure spray nozzle over all interior surfaces of the vessel until all traces of penetrant have been removed.

X10.10 Passivation

X10.10.1 Make up the passivation solution of 20 % by volume of 42°. Be nitric acid, 2 to 4 % by volume of 30° Baumé hydrofluoric acid, balance demineralized water, filtered through a 40 µm nominal rated filter.

X10.10.2 Passivate the vessel by circulating and spraying the passivating solution through a pressure spray nozzle over all interior surfaces of the vessel immediately after rinsing.

X10.10.3 Passivating time should be from 1 to 24 h depending on the requirements of the particular vessel being cleaned.

X10.11 Intermediate Rinse

X10.11.1 Rinse the vessel by spraying demineralized water through a pressure spray nozzle over all interior surfaces of the vessel immediately after passivating.

X10.11.2 Rinsing time should be approximately 30 min and until pH is 6 to 8 and no traces of passivating solution remains.

X10.12 Degreasing

X10.12.1 Accomplish degreasing after rinsing is complete.

X10.12.2 Make up the degreasing solution by adding to demineralized water the following compounds at the rates given:

Compound	Rates
Trisodium phosphate	2 to 4 oz/gal
Wetting agent	1 to 2 pints/1000 gal as specified by the supplier

X10.12.3 Degrease the vessel by circulating hot (140°F (60°C) minimum) degreasing solution for approximately 30 min through a pressure spray nozzle over all interior surfaces.

X10.13 Intermediate Rinse

X10.13.1 Rinse the vessel immediately after degreasing by spraying demineralized water through a pressure spray nozzle over all interior surfaces until all traces of detergent have been removed and pH is 6 to 8.

X10.14 Final Rinse

X10.14.1 Following preliminary rinse, rinse all internal surfaces with Specification D 1193, Type II demineralized water for approximately 60 min. Filter this solution through a 10 µm absolute rated stainless steel filter.

X10.15 Examination Number 1

X10.15.1 During the final rinse and prior to the drying operation, collect a 100 mL sample of the effluent and examine it by using Test Methods F 312 or ARP 598. During the time the sample is being collected, perform the rinse using a pressure spray nozzle on the upper interior surface, to ensure the dislodgement of particles.

X10.15.2 Effluents containing contamination in excess of the permissible contamination limits given in the acceptance criteria should be cause for recleaning and re-examination. Perform inspection and release.

X10.15.3 *Acceptance Criteria*:

X10.15.3.1 Total filterable solids 1.0 mg maximum per square foot of significant surface area.

X10.15.3.2 Maximum allowable particle distribution per square foot of significant area:

Particle Size, µm	Quantity, max
0 to 300	Unlimited
301 to 500	10
501 to 1000	2

over 1000	0

X10.15.3.3 Maximum allowable fiber distribution per square foot of significant area:

Fiber Size, µm	Quantity, max
0 to 750 × 25	Unlimited
751 to 2000 × 25	20
2001 to 6000 × 40	2
over 6000	0

X10.16 Examination Number 2

X10.16.1 Visually examine the vessel interior for evidence of corrosion products including rust, metal chips, scale, weld scale, oil, grease, paints, preservatives, decals, or other foreign matter. Perform inspection and release.

X10.16.2 Use special devices such as inspection mirrors, borescopes, and flexible fiber optics to visually examine the interior surfaces of the vessel.

X10.16.2.1 Clean the special devices before use to preclude the introduction of foreign material into vessel interior.

X10.17 Sealing

X10.17.1 Seal the vessel immediately after it is determined that it meets the acceptance criteria of the two examinations.

X10.17.2 Seals should be tight enough to prevent contamination and should be protected so that they will not be broken or warped.

X10.17.3 Any tape used for sealing purposes should not leave any residue on connections when removed.

X10.18 Drying

X10.18.1 Dry the vessel by vacuum evacuation after analysis has precluded the potential for buckling.

X10.18.2 The vessel should be considered dry when the pressure is maintained at 0.5 in. of mercury absolute (maximum) for a minimum of 5 min at a temperature of 60°F (15.6°C) or higher, or at such lower pressure that is 96 % of the vapor pressure of water for vessel temperature.

X10.19 Pressurizing

X10.19.1 After drying pressurize the vessel to 10 psig with clean, dry, oil-free nitrogen.

X10.19.1.1 The nitrogen used should have been filtered through a 40-µm absolute rated filter with an element constructed of stainless steel.

X10.19.1.2 Perform a dew point determination on purge gas from vessel and release. Dew point should be 0°F (-17.8°C) maximum.

X10.19.2 Maintain the vessel at a positive pressure up to and during the time of acceptance by the customer.

X10.19.3 All vessels should be equipped with a shut-off valve and gage for pressurizing. The gage should be capable of reading from 0 to 15 psig in 1 lb increments. A protective metal cover should be provided around the gage and valving.

X10.19.4 Complete loss of pressure should be cause for reexamination and recleaning as necessary to meet the permissible contamination limits.

X11. CLEANING OF CONVOLUTED STAINLESS STEEL HOSES

X11.1 Hoses 1 in. or smaller in diameter may be cleaned in any position that will facilitate exercise. Manual exercise during the pump-through procedure should include all sections of the hose being flexed to its designed bend radius on all axes, working from one end of the hose to the other for three complete cycles minimum.

X11.2 Clean hoses over 1 in. in diameter in the vertical position. Exercise the hose.

X11.3 When hoses (over 1 in. diameter) are cleaned vertically to a final clean condition in a noncontrolled environment, the following handling instructions are mandatory:

X11.3.1 After hose is dry and while a light purge is continuing through the assembly, cover all openings with a polyethylene tent. Continuously purge the tent with GN_2.

X11.3.2 While tent purge continues disconnect GN_2 from hose and package ends.

TABLE X11.1 Cleaning of Convoluted Stainless Steel Hoses

Item	Operation	Solution	Temperature	Time, min	Remarks
1	Degrease	Trisodium phosphate 10 ± 2 %	Ambient	As required	Spray, immerse, pump through
2	Clean	25 ± 5 %: nonionic detergent phosphoric: nonionic detergent	150 ± 15°F (65.6 ± 9.4°C)	15/20	Spray/pump through
3	Rinse	Water	Ambient	As required	To pH of 6.0 to 8.0
4	Dry	GN2	Ambient	As required	Visually dry

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