



Designation: G 93 – 96

## Standard Practice for Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments<sup>1</sup>

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This practice covers the selection of methods and apparatus for the cleaning of 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 described in detail in the appendix.

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 discourages the use of chlorinated fluorocarbon solvents in cleaning operations and encourages the use of alternate methods. A substitute method for the use of solvents in the verification methods is in development and will be issued as a separate standard.

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 levels of contamination to be present. Furthermore, it does not propose specific ways to measure or monitor these levels from among the available methods.

NOTE 1—Although this practice has been found applicable for assisting qualified technical personnel to establish necessary cleanliness levels, each system is unique and departures from these suggestions may be warranted.

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

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee G-4 on Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres and is the direct responsibility of Subcommittee G04.02 on Recommended Practices.

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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 Sheets (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:

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems<sup>2</sup>

D 1193 Specification for Reagent Water<sup>3</sup>

E 312 Practice for Description and Selection of Conditions for Photographing Specimens<sup>4</sup>

E 1235 Test Method for Gravimetric Determination of Non-volatile Residue (NVR) in Environmentally Controlled Areas for Spacecraft<sup>5</sup>

F 312 Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters<sup>6</sup>

F 331 Test Method for Nonvolatile Residue of Halogenated Solvent Extract from Aerospace Components (Using Rotary Flash Evaporator)<sup>5</sup>

G 63 Guide for Evaluating Nonmetallic Materials for Oxygen Service<sup>6</sup>

G 88 Guide for Designing Systems for Oxygen Service<sup>6</sup>

G 121 Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents<sup>6</sup>

G 122 Test Method for Evaluating the Effectiveness of Cleaning Agents<sup>6</sup>

G 125 Test Method for Measuring Liquid and Solid Material Fire Limits in Gaseous Oxidants<sup>6</sup>

<sup>2</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>3</sup> Annual Book of ASTM Standards, Vol 11.01.

<sup>4</sup> Annual Book of ASTM Standards, Vol 06.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 15.03.

<sup>6</sup> Annual Book of ASTM Standards, Vol 14.02.

G 127 Guide for the Selection of Cleaning Agents for Oxygen Systems<sup>6</sup>

G 128 Guide for the Control of Hazards and Risks in Oxygen Systems<sup>6</sup>

G 131 Practice for Cleaning of Materials and Components By Ultrasonic Techniques<sup>6</sup>

G 136 Practice for Determination of Soluble Residual Contaminants In Materials By Ultrasonic Extraction<sup>6</sup>

2.2 CGA Documents:

CGA Pamphlet G-4.4 Industrial Practices for Gaseous Oxygen Transmission and Distribution<sup>7</sup>

CGA Pamphlet G-4.1 Cleaning Equipment for Oxygen Service<sup>7</sup>

2.3 SAE Document:

ARP 598 The Determination of Particulate Contamination in Liquids by the Particle Count Method<sup>8</sup>

2.4 Federal Standard:

FED-STD-209 Clean Room and Work Station Requirements, Controlled Environments<sup>9</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *oxygen compatibility, n*—the ability of a substance to coexist with both oxygen and a potential source(s) of ignition within the acceptable risk parameter of the user (at an expected pressure and temperature) (Guide G 128G 128).

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *cleanliness, n*—the degree of success in preventing contamination from being present in an oxygen system. Cleanliness and contamination are inverse properties: increasing cleanliness implies decreasing contamination.

3.2.2 *contaminant, n*—a foreign or unwanted substance that can have deleterious effects on system operation, life, or reliability.

3.2.3 *contamination, n*—the amount of material (that typically is not oxygen compatible) in a system that is not intended to be there. Contamination and cleanliness are inverse properties: increasing cleanliness implies decreasing contamination.

3.2.4 *emulsion, n*—a liquid consisting of two or more immiscible liquids, at least one of which, as minute globules, is dispersed uniformly throughout the other.

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

3.2.6 *nonmetallics, n*—organic and inorganic materials such as ceramics, glasses, polymers, rubber, cloth, wood, and paper products.

3.2.7 *particulate, n*—a general term used to describe a finely divided solid of organic or inorganic matter, including metals. These solids are usually reported as the amount of contaminant by the population of a specific micrometer size. See methods described in Methods F 312F 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 since they are dependent upon the type of contaminants and materials to be cleaned, cleaning agents used, and the 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 used successfully for specific materials, components, and equipment in selected applications are described in detail as a supplement to the general text. An index of the specific materials, components, equipment, and applications covered in these examples is given in Table 1.

4.2 For the purpose of this practice, both solid and fluid contaminants have been subclassified into three categories: organics, inorganics, and particulates. The definition of each category is given in Section 3. A list of common contaminants is given in Table 2, and their approximate size is shown graphically in Fig. 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 the factors that suggest what the upper limits of contamination in these systems might be, and the practical difficulties in adopting and achieving adequately clean systems are reviewed.

### 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 the cleaning of 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 purport to actually specify a cleanliness.

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 impact, mechanical or pneumatic impact. These mechanisms are explained in detail in Guide G 63G 63.

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

5.4 Removal of contamination from materials and components is dependent 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 127G 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 articles, preferably prior to assembly. Assembled

<sup>7</sup> Available from Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

<sup>8</sup> Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

<sup>9</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 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; contaminates 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 ( $5 \times 10^{-5}$ gm/cm <sup>2</sup> ), but are more indicative of the effectiveness of the cleaning method than surface cleanliness.
Ferrocyanide paper	Paper is immersed in a solution of NaCl, K <sub>3</sub> Fe(CN) <sub>6</sub> and K <sub>4</sub> Fe(CN) <sub>6</sub> 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 surface (copper flash) solution.	Adherence, continuity, and appearance of copper flash indicate part cleanliness before the test. 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 which assumes part 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.

**TABLE 2 Examples of Oil Film Specifications**

Concentration, mg/m <sup>2</sup> (mg/ft <sup>2</sup> )	Source
0.14 (0.013)	1967 Navy Standard per Presti and DiSimone (6)
10.8 (1)	NASA KSC 123 per Report MTB 306-71 (7)
16.1 (1.5)	Recommended by Presti and DiSimone (6)
43.1 (4)	Air Force 1950s value per LeSuer (8)
75.3 (7)	Recommended by Walde (9)
108 (10 mg/ft <sup>2</sup> 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)
1080 (100)	Compressed Gas Association Pamphlet G-4.1 (5) and Kehat (11)

systems must be disassembled for cleaning if construction permits. Flushing an assembled system can deposit and concentrate contaminants in stagnant areas. Non-volatile cleaning agents may remain in trapped spaces and later react with the oxygen. Cleaning solutions may degrade nonmetallics in an assembly. Caustic and acid cleaning solutions may cause crevice corrosion in assemblies.

6.1.2 Manufactured products (for example, valves, regulators, and pumps) should preferably be cleaned by the manu-

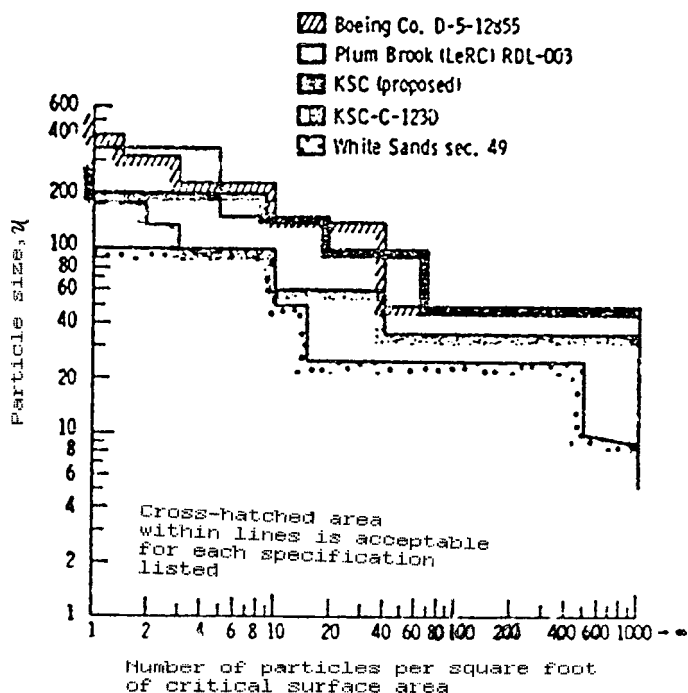
facturer prior to final assembly and test. All tests should be structured to prevent recontamination. The part must then be packaged in oxygen-compatible materials (see 12.1) and identified to protect it from contamination in transit and storage. The purchaser should approve the cleaning procedure and packaging to assure that they satisfy the system requirements. Some purchasers may require certification by the product manufacturer of cleanliness level and oxygen compatibility of all component material.

6.1.3 Manufactured products that are 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



**FIG. 1 Particulate Matter—Cleanliness Requirements for Ground Based Components and Systems That May Interface With Flight Systems**

potentially harmful side effects of chemical cleaning agents. Crevice corrosion can occur, particularly in welded assemblies. Sealing surfaces may be etched enough to destroy the finish necessary to seal the part. See Test Method G 122G 122 and Guide G 127G 127 for methods used to evaluate cleaners for use on various materials used in oxygen service.

6.2.3 Solvent cleaning solutions are often damaging to 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 63G 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 the 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 that employs successive cleaning operations 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 FED-STD-209 for information on clean room requirements and the levels of cleanliness available.

## 7. Conditioning

7.1 Factors to be considered before selecting cleaning methods are as follows:

- 7.1.1 The types of contaminants, for example, inorganic, organic, particulate, film, or fluid,
- 7.1.2 The base material or coating of the part to be cleaned,
- 7.1.3 Initial condition of the part to be cleaned,
- 7.1.4 The 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 in bringing the cleaning agent into contact with all of the surfaces of the component to be cleaned with the goal of removing contaminants. The cleaning of material 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, the parts should be grouped according to the method of cleaning. While the methods described are applicable to most metallic materials, special precautions must be taken for nonmetallic products. Special attention must be directed to the cleaning of component nonmetallic products 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.

8.2 *Mechanical Cleaning*—These methods use mechanically generated forces to remove contaminants from the components. Examples of mechanical cleaning methods are rinsing, abrasive blasting, tumbling, and blowing. Details of these and other methods are discussed as follows:

### 8.2.1 Abrasive Blast Cleaning:<sup>10</sup>

8.2.1.1 Abrasive blast cleaning entails the forceful impingement of abrasive particles against the surfaces to be cleaned to

<sup>10</sup> For a more detailed discussion of abrasive blast cleaning see ASME Metals Handbook "Surface Cleaning, Finishing and Coating," Volume 5, Ninth edition.

remove scale, rust, paint, and other foreign matter. The abrasive particles may be either dry or suspended in a liquid. A variety of systems are used to propel the abrasive, some of which are airless abrasive blast blades or vane-type wheels, pressure blast nozzles, and suction (induction) blast nozzles. Propellant gases shall 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 the 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 clothing, including gloves, aprons, face shields, and respiration equipment are recommended unless the blast cleaning is performed inside a glove-box. The immediate health hazards are imbedment 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 surface that is being cleaned. The selection of cleaning brushes is dependent upon the component or system parent material. Nonmetallic brushes are suitable for most materials to be cleaned. Carbon steel brushes shall not be used on aluminum, copper and stainless steel alloys. Any wire brushes previously used on carbon steel components or systems shall 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.

**NOTE 3—Caution:** Protective gloves, aprons, face shield, and goggle-type eye protection are recommended.

8.2.3 *Barrel or Mass Cleaning*—Sometimes called tumbling, this procedure involves rolling or agitation of parts within a rotating barrel or vibratory tubs. An abrasive or cleaning solution is added to the container. 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. 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 be considered in barrel cleaning are the component size, shape, type of abrasive, abrasive size, load size, barrel rotational speed, and ease of component/abrasive separation.

8.2.4 *Swab, Spray, and Dip Cleaning*—These are three methods of applying cleaning solutions to the component surfaces. Each method 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 employed with alkaline, acid, or solvent cleaning methods, that are discussed in later sections.

**NOTE 4—Caution:** Protective gloves, aprons, face shield, and goggle-type eye protection are recommended.

8.2.5 *Vacuuming and Blowing*—These methods incorporate removing the contaminant from the component by air 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 the removal of surface oxides, greases, and oils.

**NOTE 5—Caution:** Eye protection is recommended when using these cleaning methods.

8.2.6 *“Pig” Cleaning*—Long continuous pipelines can be cleaned in situ using “pigs.” A pig is a piston-like cylinder with peripheral seals that can be pushed through a pipeline using compressed gas pressure, typically nitrogen. The pigs may be equipped with scrapers, 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 solutions 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. The ultrasonic agitation aids the removal of lightly adhered or embedded particles from solid surfaces. It is generally employed in solvent cleaning of small parts, precious metal parts, and components requiring a very high degree of cleanliness. See Practice G 131G 131 for practices related to ultrasonic cleaning.

#### 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 the easy removal of the 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 contamination to prevent reactions with the cleaning agents. Water shall be of a grade equal or better to that specified in Specification D 1193D 1193, Type II, without the

silica analysis. Water with a higher specific resistance may be required for particular applications or cleaning systems. Water used for rinsing must be free of particulate contamination to at least the same level as that required of the item being cleaned.

**8.3.2 Hot Water Cleaning**—Hot water cleaning is used to remove gross organic and particulate contamination from parts by the use of 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 necessary to free and fluidize contaminants. Consideration should be given to the size, shape and the number of parts to ensure adequate contact between the surfaces of the parts and the solution. The solution temperature should be as recommended by the manufacturer of the cleaning agent. 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, that may be heated to shorten the drying time.

**8.3.3 Steam Cleaning**—Steam cleaning is used to remove organic and particulate contaminants from parts by the use of pressure, heat, and sometimes detergents. Some organics are removed by decreasing their viscosity, or “thinning” them with steam heat. A detergent may be added that disperses and emulsifies the organics, which allows the rinsing of the contaminant by the condensed steam. The system should provide control over the flows of the steam, water, and detergent flow to maximize the efficiency of the detergent’s chemical action, the heat effect of the steam, and the scrubbing action of the steam jet.

**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 solutions of high alkalinity for the removal of organic contamination such as hydrocarbon oils, grease, and waxes. There are many effective cleaning materials available for caustic cleaning. Some common compounds are listed in **Table 3**. Detergents are supplied in powder,

crystal, or concentrated liquid form. They are prepared for use by mixing with hot water to form aqueous solutions. Prepared solutions can be utilized in static tanks or vessels for the immersion of components. Alternatively, the solution can be pumped or jetted onto or through the component. Depending on the detergent used, the solutions produced may be alkaline, non-toxic, biodegradable, or non-corrosive. Some types of detergent may be toxic or corrosive. Properties of detergent materials must be checked with the manufacturer or supplier. See Guide G 127G 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 could not be acceptably cleaned.

**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 just solvency, including saponification (chemical reaction), 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 contamination from redepositing on the surface. The surface must not be allowed to dry between the cleaning and the 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 the rinsing is complete is to monitor the used rinse water until a pH of + or – 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 4** 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:**

**8.3.4.4.1** When aqueous cleaning is used on oxygen system components, rinsing and drying are of critical concern. Drying 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 of water is an order of magnitude higher than that

**TABLE 3 Common Alkaline Salts (See 9.4)**

Iupac Name <sup>A</sup>	Formula	Common Name
Sodium hydroxide	NaOH	Caustic soda Lye
Sodium metasilicate	Na <sub>2</sub> SiO <sub>2</sub>	Sodium silicate Water glass
Sodium carbonate	Na <sub>2</sub> CO <sub>2</sub>	Soda ash
Sodium tetraborate decahydrate	Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub> ·10H <sub>2</sub> O	Borax
Sodium orthophosphate	Na <sub>2</sub> PO <sub>4</sub> ·12H <sub>2</sub> O	Trisodium phosphate (TSP)
Sodium pyrophosphate	Na <sub>4</sub> P <sub>2</sub> O <sub>7</sub> ·10H <sub>2</sub> O	Sodium phosphate tribasic Tetrasodium pyrophosphate Sodium polyphosphate

<sup>A</sup> According to International Union of Pure and Applied Chemistry.

**TABLE 4 Alkaline Chemical Cleaning Materials (see 8.3.4.3)**

Metal	Reason for Cleaning	Cleaning Chemicals <sup>A</sup>	Other Treatment <sup>B, C</sup>
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 fluids	Mixtures of sodium hydroxide, carbonates, phosphates and silicates, and synthetic wetting agents	
Copper and alloys	Removal of greases, lubricating oils, drawing compounds, oxides, metallic particles, or other contaminants	Mixtures of sodium hydroxide, polyphosphates, silicates, carbonates, and wetting agents	Usually bright dipped in dichromate acid solution
Aluminum and alloys	Removal of brazing flux Removal of greases, oils, and oxides	Hot water Sodium hydroxide, sodium phosphate, and sodium carbonate for etching Sodium carbonate, sodium silicate, sodium pyrophosphate, and sodium metasilicate for non-etching	Dilute nitric acid dip to remove smut

<sup>A</sup> The manufacturer's specification for application of the cleaning agent shall be strictly enforced.

<sup>B</sup> *Post Chemical 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 supplier of the cleaning materials. Some components require to be treated by using neutralizing solutions after certain cleaning treatments.

<sup>C</sup> Thorough rinsing is necessary to avoid stress corrosion risk.

for some common chlorofluorocarbon solvents. The removal of vapor is also critical in drying. A means for removal of vapor must be provided. This is usually accomplished with a moving dry gas purge.

8.3.4.4.2 There are three basic water removal methods commonly used:

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

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

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

In selection of drying processes, consideration must be given to the level of dryness required. The user should evaluate each method for the specific application intended.

8.3.4.4.3 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 degrees of the purge gas.

8.3.4.4.4 Dryness is measured in many ways:

(a) (a) Relative Humidity

(b) (b) Dew Point

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

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

(e) (e) Moles of water per moles of air

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, effects of moisture on components, etc. Industrial gases are easily obtained with dew points of −40 degrees F (−40 C). A dew point of −40 degrees F (−40 C) is a common specification level for oxygen system dryness.

### 8.3.5 Semi-Aqueous Cleaning:

8.3.5.1 Semi-aqueous cleaning uses hydrocarbon-water emulsions. Emulsion cleaning is a process for removing heavy contaminants from the surface of parts by using 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.

8.3.5.1.1 By definition, an emulsion is a mixture of liquids that do not dissolve in each other. In an emulsion, one of the liquids contains minute droplets of the other which are evenly distributed throughout. Cohesion forces which hold oil film to a surface are extremely strong. It is practically impossible to remove an oily film from a surface by rubbing, wiping, or scrubbing alone. Applying the water break test to a metal object that has been visibly cleaned of oil film by scrubbing will clearly demonstrate that visible cleanliness is not also chemical cleanliness. Water when applied to such a surface will break up and refuse to wet the surface. Until water refuses to break up on the surface of the object, the object will not be considered chemically clean. When water and detergent (one with an emulsifying agent) are used for a cleaning agent for oil, the process of emulsification enables cleaning. Thorough wetting results in the formation of globules of oil on the surface of the detergent film. Here the process of emulsification comes into play. The oil globules will be detached from the surface and will be dispersed throughout the cleaning solution, the adhesion of the oil to the surface will be permanently disrupted. Once so scattered the portion of the oil removed will not be redeposited as a film. When part of an oily film has been removed in this manner another layer of the film is exposed to the wetting action of the detergent. Emulsifying action then comes into play again then disperses an additional portion of the oily mass. Emulsification is contingent upon wetting, and further wetting is contingent on emulsification, and the combined effect of the two action is the loosening, breaking up, and the dispersion of the oily film.

8.3.5.1.2 A variety of emulsion cleaners are commercially available and are composed of petroleum derived solvents and surfactants that render them emulsifiable. Some emulsion cleaners may tend to separate into individual solution if left

standing for extended lengths of time. It may be necessary to agitate periodically. Emulsion cleaners are normally applied to parts by methods such as soaking, spraying, or swabbing. Emulsion cleaners must be removed by rinsing and subsequent cleaning operations.

8.3.5.2 One such type of semi-aqueous material is a water emulsion with citrus and pine-based terpenes that are natural products. The semi-aqueous cleaners are used in two ways. They 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. Semi-aqueous 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 semi-aqueous formulations are considered non-flammable in bulk form but can be flammable in an aspirated or mist condition. Proper equipment design is essential to minimize risk from flammable mists. Some formulations can auto-oxidize into an undesirable condition. Properties of the materials must be verified with the supplier.

8.3.5.3 The cleaning solution must be thoroughly rinsed from the part to prevent contamination from redepositing on the surface. The surface must not be allowed to dry between the cleaning and rinsing phase. The semi-aqueous residues are especially difficult to rinse from surfaces. A more thorough analysis than pH of rinse water may be required to determine completion of the rinse phase. 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 a 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 surface of parts, such as undesired etching or pickling. The type of cleaning agent selected will depend, in most cases, 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 for carbon and low alloy steels only. These agents will remove rust, scale, and oxide coatings and will strip chromium, zinc, and cadmium platings. Certain 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 acid 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 which 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 A storage or immersion tank, recirculation pump, associated piping, and valving compatible with the cleaning solution are required. 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, the surfaces must be thoroughly rinsed with water equal to that described in 8.3.4 to remove all traces of the acid and thoroughly dried after the final water rinse. To minimize staining, surfaces must not be permitted 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 5 gives typical acid solutions for cleaning various types of metallic materials.

NOTE 6—**Caution:** Both caustic and acid cleaning involve the use of

**TABLE 5 Acid Chemical Cleaning Materials (see 8.3.6.5)**

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

<sup>A</sup> The manufacturer's specification for application of the cleaning agent shall be strictly observed or the properties of the metals can be impaired. Time, temperature, and concentrations are very important.

<sup>B</sup>Post Chemical Cleaning Treatment—After cleaning using acid, all components shall be thoroughly rinsed preferably using flowing hot water to aid drying, unless otherwise specified by the supplier of the cleaning materials. Some components require to be treated using neutralizing solutions after certain cleaning treatments.



hazardous materials and solutions. Full protective clothing to include gloves and face protection should be worn by the cleaning operators. The disposal of spent cleaning solutions should be conducted according to federal, state, and local regulations.

**8.3.7 Solvent Cleaning**—This cleaning or degreasing method was considered to be the principal procedure for the 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 is limited by environmental concerns and legislative restrictions. Chlorinated solvents are being replaced by aqueous or semi-aqueous detergents or emulsion solutions, often in conjunction with deionized water as part of the process. Alcohols, ethers, and other specialized solvents are used on unique cleaning applications where their hazards are warranted due to process restrictions. A list of solvents appears as **Table 6**. 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. This sample will be used 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, fluorescence under ultraviolet light, by analysis, or by evaporation. Clean glass bottles must be used to hold samples.

**8.3.7.1** After the completion of any method of solvent cleaning, all gross residual cleaning fluid must be drained from the component to prevent drying in pools. The component shall then be purged, and dried with warm, dry, oil-free compressed air or nitrogen. Small components may be air dried if appropriate.

**8.3.7.2** Solvent cleaning may be performed using any of the methods previously discussed such as swabbing and spraying. Cleaning can also be effected by immersing the component in a tank of solvent and applying a means of agitation. Disassembled parts can be cleaned by this method. The process can be improved by the use of ultrasonic cleaning techniques. Cleaning by forced circulation of a flow of the solvent liquid 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, pipeworks, etc.

**8.3.8 Solvent Cleaning Hazards:**

**8.3.8.1** Take care that generous ventilation is provided in areas utilized for solvent cleaning 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 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 shall be totally free from solvent. Smoking and the performance of any operations involving the use of flame, arc, or other source of heat higher than 200°C shall be prohibited in the vicinity of solvent vapor. Exposure of the solvent to daylight over a prolonged period may cause decomposition of the material.

**8.3.8.4** Containers for the solvent shall not be left in working areas without suitable lids or caps securely fitted. Skin contact should be avoided by wearing protective clothing. Solvents shall only be carried using suitable enclosed containers with proper labeling.

**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. Manufacturers' recommended safety precautions should be followed. Also, compliance to some federal, state, and local regulations may be required. Manufacturers of ultrasonic cleaning tanks and associated equipment issue recommendations on safe operation of the unit. Operators shall comply with the manufacturer's recommendations. A material Safety Data Sheet is required for each chemical used.

**NOTE 7—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. When using solvents to clean aluminum, the following should be observed:

**8.3.8.6** 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.

**8.3.8.7** If a degreasing tank is used, place components gently into the degreasing tank to avoid rupturing the protective oxide film.

**8.3.8.8** 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.

**8.3.8.9** 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.

**TABLE 6 Solvents (see 8.3.7)**

lupac <sup>4</sup>	Formula	Common Name
Dichloromethane	CCl <sub>2</sub> H <sub>2</sub>	Methylene chloride Methylene dichloride Alpha-trichloroethane
1,1,2,2-tetrachloroethene	CCl <sub>2</sub> CCl <sub>2</sub>	Perchloroethylene Tetrachloroethylene
1,1,2-trichloroethene	CCl <sub>2</sub> CHCl	Trichloroethylene Trichlene Ethylene trichloride

<sup>4</sup> According to International Union of Pure and Applied Chemistry.

8.4 *Vapor Degreasing*—Vapor degreasing is the removal of soluble organic materials from the surfaces of parts by the continuous condensation of solvent vapors on the cold part and their subsequent washing action. The use and attractiveness of chlorinated solvents as cleaning agents is limited by environmental concerns and legislative restrictions. Chlorinated solvents are being replaced with nonrestricted replacements; selection of replacement agents is discussed in Guide G 127G 127. Several vapor degreasing solvents are listed in Table 7. Vapor degreasing equipment consists essentially 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. They have been known to contain oils. Some of these solvents are flammable in air under certain conditions and have varying degrees of toxicity; therefore, caution shall be exercised in their use. The temperature of the part must be below the boiling point of the solvent so that the solvent vapors will condense and wash down by gravity over the surfaces of the part. The component should be positioned and connected so that the condensate will drain freely 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 temperature of the part reaches the temperature of the vapors.

NOTE 8—**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 have the chemicals extracted by the solvent and 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 solvents at elevated temperatures requires additional attention because the solvents are more likely to attack the component surfaces or to decompose and deposit undesirable films on the component. New environmental legislation may require passing the exhaust gases through a charcoal or absorbant bed to remove solvent atmospheres prior 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. Factors as to the duration of the purge, the number of purging operations, and the type of purging operations are dependent upon the component to be cleaned, the cleaning methods employed, and the final application.

NOTE 9—**Caution:** Appropriate protective equipment should be used to protect operators from coming in contact with cleaning solutions or airborne particles.

### 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. Examples of gross contamination include: 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 the handling procedure used for all precleaning operations are not critical, but users are encouraged to be cognizant 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 3. 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.

#### 9.5 *Final Cleaning:*

9.5.1 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

**TABLE 7 Vapor Degreasing Solvents (see 8.4)**

Iupac Name <sup>A</sup>	Formula	Common Names
Dichloromethane	CCl <sub>2</sub> H <sub>2</sub>	Methylene chloride Methylene dichloride
1,1,2,2-tetrachloroethene	CCl <sub>2</sub> CCl <sub>2</sub>	Perchloroethylene Tetrachloroethylene
1,1,2-trichloroethene	CCl <sub>2</sub> CHCl	Trichloroethylene Trichlene Ethylene trichloride

<sup>A</sup> According to International Union of Pure and Applied Chemistry.