Handbook of Compressed Gases

Fifth Edition
CHAPTER 11

CLEANING COMPONENTS, EQUIPMENT, AND SYSTEMS FOR OXYGEN SERVICE

INTRODUCTION

The cleaning methods described in this chapter are intended for cleaning components, equipment, and systems used in the production, storage, distribution, and use of liquid and gaseous oxygen. Oxygen equipment and systems include stationary storage tanks, tank trucks, and tank cars; pressure vessels such as heat exchangers and rectification columns; and associated piping, valves, and instrumentation. Oxygen cleaning methods also may be used to clean other oxygen service equipment such as cylinders, cylinder valves, regulators, welding torches, pipelines, vaporizers, compressors, and pumps.

Oxygen equipment and systems including all components and parts thereof must be adequately cleaned to remove harmful contamination before the introduction of oxygen. Harmful contamination includes both organic and inorganic materials such as oils, greases, paper, fiber, rags, wood pieces, coal dust, solvents, weld slag, rust, sand, and dirt, which could cause a violent combustion reaction or even an explosion in an oxygen atmosphere if not removed. At the very least, contamination could have adverse effects on systems and their components in their operation, service life, and reliability, and it would be detrimental to product purity.

This chapter presents methods for cleaning oxygen service equipment. When properly used, these cleaning methods and subsequent inspections will result in the degree of cleanliness required for the safe operation of oxygen service equipment and the necessary product purity required in CGA G-4.3, Commodity Specification for Oxygen [1]. Suggested limits of contamination and ways of determining if a component or system is sufficiently clean to be used in oxygen service are given, along with procedures for keeping such equipment clean before being placed in service. See CGA G-4.1, Cleaning Equipment for Oxygen Service, and ASTM G93, Cleaning Methods and Cleanliness Levels for Material and Equipment Used in Oxygen-Enriched Environments [2, 3].

The cleaning methods and cleaning requirements discussed in this chapter also are applicable to other oxidizers such as ozone and nitrous oxide.
Intermediate Cleaning

Table 11-2. Common alkaline salts and detergents.

<table>
<thead>
<tr>
<th>Alkaline Salts</th>
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<tbody>
<tr>
<td>Sodium hydroxide, NaOH</td>
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<tr>
<td>Sodium metasilicate, ortho, or mica, Na₂SiO₃</td>
<td></td>
</tr>
<tr>
<td>Soda ash, Na₂CO₃</td>
<td></td>
</tr>
<tr>
<td>Sodium tetaborate, Na₈B₄O₁₂</td>
<td></td>
</tr>
<tr>
<td>Trisodium phosphate, Na₈P₆O₁₆</td>
<td></td>
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<tr>
<td>Sodium pyrophosphate, Na₈P₄O₁₆</td>
<td></td>
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<tr>
<td>Sodium tripolyphosphate, Na₈P₃O₁₀</td>
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<table>
<thead>
<tr>
<th>Alkaline Detergents</th>
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<tbody>
<tr>
<td>Saponifiers</td>
<td>Solubilize fats</td>
</tr>
<tr>
<td>Wetting agents</td>
<td>Reduce surface tension</td>
</tr>
<tr>
<td>Defoamers</td>
<td>Prevent pimple</td>
</tr>
<tr>
<td>Agglomerated</td>
<td></td>
</tr>
<tr>
<td>Water softeners</td>
<td>Reduce hardness</td>
</tr>
<tr>
<td>Buffering agents</td>
<td>Maintain pH</td>
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</tbody>
</table>

Intermediate cleaning generally consists of subjecting the part to both caustic and acid cleaning solutions designed to remove solvent residues and residual contaminants that have been conditioned by precleaning. The cleaning environment and handling procedures used for intermediate cleaning operations are more restrictive than those used for precleaning. The cleaning environment must be controlled to minimize introducing contaminants and compromising subsequent precision (final) cleaning operations.

Alkaline cleaning solutions are caustic and can cause personal injury if safety precautions such as protective clothing and ventilation are not rigidly followed. A list of common alkaline salts and detergents is given in Table 11-2.

Precision (Final) Cleaning

Precision (final) cleaning is the final process to meet strict levels of cleanliness. Certain nuclear, space, and other critical applications may require that only very high purity precision cleaning agents be used. Precision cleaning is normally performed by exposing the part to a final cleaning solvent either by vapor degreasing, ultrasonic cleaning, or direct rinsing. (See Fig. 11-2.)

Precision cleaning involves maintaining the most critical level of cleaning environment and handling control. Precautions should be taken to minimize the recontamination of the part by the final cleaning environment or by the handling procedures. (See Fig. 11-3). Certain end-use applications of the part may require strict cleaning environments such as classed clean rooms. (See Fig. 11-4.) Solvents are normally used during the precision cleaning process.

Some equipment components used for vapor degreasing are similar to those used in ultrasonic cleaning. Ultrasonic cleaning equipment consists of an immersion tank, high frequency sound generator, and heater as shown in Fig. 11-5. Vapor degreasing and ultrasonic equipment are commercially available as separate units or combined in one unit, which may include a spray wand.

Fig. 11-2. Examples of ultrasonic aqueous precision cleaners. (Photos courtesy of Shapertek.)

Fig. 11-3. Mobile microenvironment cart for moving piece parts between clean rooms. (Photo courtesy of Astro Pak.)

1 Astro Pak Tel: 848.ASTRO.PAK, Email: info@astropak.com, Website: http://www.astropak.com
Fig. 11-4. Portable clean room. (Photo courtesy of Astro Pak.)

A sample of new wash solvent should be taken for control purposes when required. If solvent monitoring is desired, a representative sample of the used solvent should be taken to determine its contaminant level. Additional solvent should be added to dilute the used solvent to an acceptable contamination level. The basic procedure for precision cleaning parts may include the following steps:

a) Suspension of the part in the vapor of the solvent;
b) Immersion and ultrasonic cleaning in the liquid solvent; and
c) Spray rinsing of the part with filtered solvent.

The solvent must be discarded when the cleaning operation does not yield acceptably cleaned surfaces or the solvent fails to meet the acceptance standards.

Fig. 11-5. Ultrasonic degreasing unit. (Photo courtesy of Astro Pak.)

After the precision cleaning operation, the parts should be dried by purging or blowing with dry, oil-free nitrogen or air to remove entrapped or residual solvents.

CLEANING METHODS

Cleaning methods are grouped by two main divisions—mechanical and chemical. For additional information on cleaning methods, design criteria, and materials compatibility for oxygen service consult ASTM International publications listed in the reference section [3, 14, 15, 16]. Reference [17] is an ASTM Special Technical Publication series of books where numerous symposia papers are published covering a wide range of technical studies on these topics.

Mechanical Cleaning

Mechanical cleaning may be accomplished by methods such as abrasive blast cleaning, wire brushing, grinding, tumbling, steam cleaning, or hot water cleaning. Details are outlined in Metals Handbook, Volume 5, Surface Cleaning, Finishing and Coating [18].

Care needs to be taken when using mechanical cleaning methods so as not to remove an excessive amount of parent metal. The method used must be suitable for performing the cleaning without depositing contaminants that cannot be removed by subsequent cleaning.

Abrasive Blast Cleaning

Abrasive blast cleaning can be described as the use of an abrasive propelled through nozzles against the surface of pipe, fittings, or containers to remove mill scale, rust, varnish, paint, or other foreign matter. The medium propelling the abrasive must be oil free unless the oil is to be removed by subsequent cleaning. The blasting medium and residue shall be removed in a manner that meets the cleanliness level suggested for oxygen service equipment.

Wire Brushing or Grinding

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

Tumbling

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

Vacuuming, Swabbing, Spray, and Dip Cleaning

Equipment, parts, and piping may be vacuum cleaned after mechanical cleaning to remove loose particles of dirt and slag. If vacuum cleaning is not possible, the surfaces can be swabbed with a suitable solvent using a clean, lint-free cloth to remove loose dirt, slag, etc. Swabbing is generally used on parts to clean small, select areas only. Spraying and dipping methods are used when overall cleaning of component surfaces is required. These methods are generally used with alkaline or acid cleaning agents.

Blowing and Purging

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

**Steam Cleaning**

The equipment used for steam cleaning may consist of a steam and water supply, a length of hose, and a steam lance with or without a spray nozzle. A detergent is generally incorporated into the steam spray.

Either plant steam or steam from a portable steam generator can be used. If a steam lance is used, the detergent solution enters the steam gun by venturi action and mixes with the steam. Steam removes oils, greases, and soaps by first “thinning” them at elevated temperatures. Dispersion and emulsification of the oils then occurs, followed by dilution with the condensed steam. The system should provide control over the steam, water, and detergent flows so the full effects of the detergent’s chemical action, the heat of the steam, and the abrasive action of the pressure jet are attained for maximum cleaning efficiency. This is usually followed by a rinsing operation using clean water to remove any detergent residues.

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

**Hot Water Cleaning**

Cleaning with a hot detergent solution may be by using a spray system or a cleaning vat with suitable agitation of either the solution or the parts to be cleaned. Hot water solution cleaning can be used when a temperature of more than 200 °F (93.3 °C) is not necessary to free and fluidize contaminants. Proper consideration must be given to the size, shape, and number of parts to be cleaned to ensure adequate contact between the surfaces to be cleaned and the detergent solution. The solution temperature and strength (dilution value) should be in accordance with the recommendation of the manufacturer of the cleaning agent. Mechanical energy must be applied in the form of ultrasonics or agitation to achieve acceptable results. Soaking helps to soften foreign material, but may not remove it without scrubbing or agitation.

Most detergents are water soluble and are best removed by prompt flushing with sufficient quantities of hot or cold clean water, as appropriate, before the cleaning agents have time to precipitate. Applying mechanical energy increases the effectiveness of soaking or dip rinsing. The equipment is then dried by purging with dry, oil-free air or nitrogen, which may be heated to shorten the drying time. Blowing or purging with dry, oil-free air or nitrogen should be used to remove small particles that may be present as a result of any previous cleaning methods. Purging should also be used as a means to isolate cleaned surfaces to prevent cross-contamination of parts between sequential mechanical cleaning methods or recontamination before packaging.

**Purging**

It is very important to purge the components to ensure that all residuals from previous cleaning operations are removed before subsequent cleaning operations or final packaging. This can be accomplished by rinsing, drying, and blowing. Rinsing depends on the cleaning solutions used, but in general, filtered water may be used. Drying can be accomplished by the application of heat to the component by ovens and infrared lights or by blowing with clean, oil-free, dry air (heated or unheated). A thermal vacuum dryer is shown in Fig. 11-6.

A more critical purging is performed using clean, dry, oil-free nitrogen gas. Factors such as 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 used, and the final application.

**Chemical Cleaning**

**Caustic Cleaning**

Caustic cleaning is cleaning with solutions of high alkalinity to remove heavy or tenacious surface contamination, followed by a rinsing operation. There are many effective materials available for caustic cleaning. They are basically alkalis that are water soluble and nonflammable, but they can be harmful if they come in contact with the skin or are swallowed. The cleaning agents should be chosen so they do not react chemically with the materials being cleaned.

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

The cleaning solution can be applied by spraying, immersion flushing, or hand swabbing as follows:

- Spraying works well, but requires a method whereby the cleaning solution reaches all areas of the surface. It is also desirable to have provisions for draining the solution faster than it is introduced to avoid accumulation.
- Immersion or flushing should be total rather than partial since the solution tends to dry on the surface that is exposed to air.
- Hand-swabbed surfaces should be rinsed before the cleaning solution dries.

Generally, cleaning solutions perform better when warm. Depending upon the particular solution, this temperature will be in the range of 100 °F to 180 °F (37.8 °C to 82.2 °C). The cleaning solution can be re-used until it is too weak or too contaminated as determined by pH or concentration analysis.

Experience will establish when a cleaning solution has become too weak or too contaminated to effectively clean contaminated surfaces.

The cleanliness achieved ultimately depends on the thoroughness of the rinsing procedures. All of the contaminants can be held in suspension in the cleaning solution. However, if the cleaning solution is not completely flushed from the surface being cleaned, the contaminant in any remaining solution will redissolve on the surface during the drying operation. The surface must not be allowed to dry between the cleaning phase and the rinsing phase. If this happens, it is very likely that the film or residue will not be adequately removed during the rinsing phase. Frequently, some type of agitation during rinsing is required. This may be by mechanical brushing, fluid impingement, or agitation of the parts being cleaned.
Acid Cleaning

The acid cleaning procedure removes oxides and other contaminants by immersion in a suitable acid solution, usually at room temperature. The type of cleaning agent selected depends, in most cases, on the material to be cleaned. The following general guidelines can be used:

- Cleaning agents formulated using phosphoric acid can be used for all metals. These agents will remove oxides, light rust, light oils, and fluxes.
- Cleaning agents formulated using hydrochloric acid are recommended for carbon and low-alloy steels only. These agents will remove rust, scale, and oxide coatings and will strip chromium, zinc, and cadmium platings. Certain acid solutions including hydrochloric or nitric acids should contain an inhibitor to prevent harmful attacks on base metals. Hydrochloric acid should not be used on stainless steel since it may contribute to stress corrosion cracking.
- Aluminum, copper, and their alloys can be cleaned using solutions based on chromic or nitric acids. These agents are not true cleaning agents, but are used for deoxidizing, brightening, and removing black smut, which forms during cleaning with an alkaline solution. Some agents are available as liquids, others as powders, and 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.

A storage or immersion tank, acid-resistant recirculation pump, and associated piping and valving compatible with the acid solution are required as shown in Fig. 11-8. Common methods of applying acid cleaning agents for cleaning metals are:

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

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

Solvent Washing

Solvent washing is the removal of organic contaminants from the surface by using suitable solvents acceptable under the Membrane Protocol. This process can be enhanced by ultrasonic cleaning, which involves the loosening or dissolving of oil and grease or other contamination from metal surfaces by the immersion of parts in a solvent solution using high frequency vibrational energy [10].

Production of many of the solvents traditionally used to clean for oxygen service has been phased out. However, replacement solvents are being developed specifically for oxygen cleaning. ASTM G127 may be used to aid in the selection of an appropriate solvent and cleaning process [13]. Suitable corrosion inhibitors and stabilizers should be included in the formulation for the solvents.

Caution: Solvent washing agents should not be used unless their application and performance are known or are discussed with the cleaning agent manufacturer. The manufacturer's recommendations regarding concentration, temperature, and personal protection equipment (PPE) should be followed for safe handling and use of the cleaning agent.

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

Caution: The plasticizer in some plastic tubing including polyvinylchloride (PVC) may be extracted by the solvent and deposited on the surface being cleaned. For this same reason, rubber, Neoprene, and Nylon® tubing should not be used with these solvents when cleaning oxygen equipment. Polyethylene, polypropylene, and polytetrafluoroethylene (PTFE) tubing are satisfactory with the frequently used solvents. Ensure that any plastic tubing is compatible with the solvent you are using. Consult the solvent manufacturer's literature or contact them directly for information on compatible plastics.

Before a new batch of solvent is used for any cleaning operation, a sample of it should be taken for reference purposes. This sample should be stored in a clean container made of materials that will not contaminate it. The cleanliness of the solvent after a period of use can be determined by comparing it to the reference sample in one of several ways—by comparing its color to that of the reference sample, by an analysis, or by an evaporation procedure.

In the color comparison, it is assumed that the solvent is still sufficiently clean to use if it shows no distinct color change from the reference sample. The color change can be determined visually or by instrument, comparing the simultaneous light transmission through both samples. This should be verified by analytical tests to detect probable contaminants or by calculation of the amount of residue deposited by evaporation of contaminated solvents. ASTM D2108, Standard Test Method for Color of Halogenated Organic Solvents and Their Admixtures (Platinum-钴alb Scale) may be used if a scale of color changes is to be established for one or more contaminants [19].

After caustic or acid cleaning, thorough rinsing of the equipment is performed using cold water. Rinsing must begin as soon as practical after cleaning to prevent the acid cleaning solution from excessive attack on the material being cleaned. If there is a chance of any cleaning solution becoming trapped in the equipment being cleaned, a dilute alkaline neutralizing solution can be applied, followed by water rinsing. If drying is not completed with the residual heat in the metal, it can be completed with dry, oil-free air or nitrogen. If it is desirable to complete drying in a dry atmosphere before installation or use, the dew point of the contained atmosphere should not be higher than -30 °F (-34.4 °C).
Analytical techniques such as infrared spectroscopy or chromatography, although somewhat more time consuming, can exactly measure the extent of solvent contamination with a known contaminant, for example, a particular cutting oil used for machine parts. However, if one or several unknown contaminants are present, results might be more difficult to quantify. Contamination can be checked by calculating the amount of residue deposited after a measured amount of contaminated solvent evaporates. Evaporation and measurement of the residue depends on the nonvolatility of any contaminants. The vapor pressures of most oils are high enough that significant amounts of contaminants can evaporate with a large volume of solvent. Therefore, an evaporation determination may give only a lower measurement of dissolved contaminant.

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

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

Dirty solvent may be reclaimed by appropriate procedures, re-used as is for initial cleaning, or discarded. Disposal must comply with applicable federal, state, municipal, territorial, provincial, and local laws and regulations including environmental and other standards that might apply.

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

Removal of solvents is important. After cleaning, crevices and dead zones may still contain solvent. It is vital that all of the solvent be removed from all dead spaces since an explosion could result upon subsequent contact with oxygen. After the oil and grease contaminants have been removed or dissolved and the solvent has been drained, allow the part to dry, purging any cavity, piping, or closed vessel with dry, oil-free air or nitrogen to remove entrained liquid. Then circulate the purge gas until the final traces of the solvent have been removed. Purging can be considered complete when the solvent cannot be detected by appropriate methods in the gas venting from the vessel, piping, or component being purged.

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

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

**Vapor Degreasing**

Vapor degreasing is the removal of soluble organic materials from the surfaces of equipment by the continuous condensation of solvent vapors and their subsequent washing action. Commercial degreasers are available for cleaning metals at room temperatures. Vapor degreasing equipment consists essentially of a vaporizer for generating clean vapors from a contaminated solvent, and a receptacle for holding the parts to be cleaned in the vapor space.

The production of many of the solvents traditionally used to clean for oxygen service has been phased out; however, new solvents are being developed for vapor degreasing operations to replace the chlorinated fluorocarbons used in the past. These include terpenes, aliphatic hydrocarbons, solvents, esters, hydrochlorofluorocarbons, hydrofluorocarbons, and silicone-based solvents. The specific cleaning application must be discussed with the cleaning agent manufacturer to ensure that the solvent selected is compatible with the contaminants, metals, and materials involved. Suitable corrosion inhibitors and stabilizers should be included in the formulation for the solvents. Some of these solvents are flammable in air under certain conditions and have varying degrees of toxicity. Caution should be exercised in their use. Dry, oil-free air or nitrogen should be available for purging.

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

![Fig. 11-9. Solvent vapor degreaser vat. (Photo courtesy of Astro Pak.)](image)

This cleaning procedure requires that the solvent boil in a vaporizer. Then as the hot solvent vapor condenses and washes over a cooler component, the soluble contaminants are carried away. This action can occur by placing components inside a vapor degreaser chamber into which the solvent vapor rises from a vaporizer chamber (see Fig. 11-9). Alternatively, if a vessel is to be cleaned, hot solvent vapor can be piped from a vaporizer into the vessel on whose inner walls condensation and cleaning will occur. In this case, the equipment should be positioned and connected so that the condensate can be thoroughly drained from the system. Continuous removal of the condensate and its transport back into the vaporizer will carry the dissolved impurities into the vaporizer where they remain as fresh pure vapors are released to continue the degreasing operation. Cleaning can be considered complete when the returning condensate is as clean as the new solvent.

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

The solvent should be removed as described in the solvent washing section of this chapter.

**Caution:** Vapor degreasing solvents should not be used unless their application and performance are known or are discussed with the cleaning agent manufacturer. The manufacturer’s recommendations regarding concentration, temperature, and PPE should be followed for safe handling and use of the cleaning agent.
INSPECTION PROCEDURES

The manufacturer and the purchaser should agree upon detailed cleaning and quality control procedures. A source inspection by the purchaser’s representative at the manufacturer’s location is desirable. The purchaser should initially and periodically inspect the manufacturer’s facilities and audit the cleaning and quality control procedures.

Some industries have found a contamination level equal to or below 46.5 mg/l (500 mg/m³) to be the maximum level of hydrocarbon contamination tolerable for components, equipment, and systems in oxygen service. The actual level depends on the specific application (state of fluid, temperature, and pressure). For example, lower contamination levels are recommended for aluminum structured packing used for oxygen distillation. See CGA G-4.8, Safe Use of Aluminum Structured Packing for Oxygen Distillation [20].

Likewise, the requirement for limiting the particle and fiber contamination is necessarily dependent upon actual service. Therefore, the user is urged to review component, equipment, and system requirements. If the purchaser’s requirement does include a particle and fiber count, some industries have found that a representative square-foot section of surface must show no particle larger than 1000 microns and no more than 20 particles per square foot (215 particles/m²) between 500 microns and 1000 microns. Isolated fibers of lint should be no longer than 2000 microns, and there should be no accumulation of lint fibers. In some cases, lower particle size and populations may be necessary depending upon actual service. The seller and the purchaser shall agree to the equipment and procedure used to verify particle and fiber count.

Any one or combination of the following tests can be used to assess the cleanliness of a piece of equipment. The cleanliness assessment is limited to the precision and bias of the verification technique. Failure to pass any of the specified tests requires recleaning and re-inspection, and may require reevaluation of the cleaning procedures. In-process inspections to ensure the adequacy of cleaning procedures may be desirable.

Direct Visual Inspection (White Light)

Direct visual inspection by white light is the most common test used to detect the presence of contaminants such as oils, greases, preservatives, moisture, corrosion products, weld slag, scale, filings, chips, and other foreign matter. The item is observed (20/20 vision without magnification) for the absence of contaminants and accumulation of lint fibers under strong white light. This method will detect particulate matter in excess of 50 microns (0.002 inch) and moisture, oils, greases, etc., in relatively large amounts. The item being examined must be reclassified if an unacceptable amount of foreign material is detected by this inspection method.

Direct Visual Inspection (Ultraviolet Light)

Ultraviolet light causes many common hydrocarbon or organic oils or greases to fluoresce when they may not be detectable by other visual means. The surface is observed in darkness or subdued lighting using an ultraviolet light radiating at wavelengths between 2500 Ångström units and 3700 Ångström units and an intensity of 800nw/cm² or greater at the surface as required by ASTM G93 [3]. Ultraviolet inspection will indicate if cleaned surfaces are free of any hydrocarbon fluorescence providing the hydrocarbons fluoresce visibly. Accumulations of lint or dust that may be visible under the ultraviolet light must be removed by blowing with dry, oil-free air or nitrogen; wiping with a clean lint-free cloth; or vacuuming. Not all organic oils fluoresce to the same degree, and for this reason ultraviolet inspection alone cannot be relied upon as a test for cleanliness. Some materials are acceptable, such as cotton lint that fluoresces unless present in excessive amounts. If fluorescence shows up as a blotch, smear, smudge, or film, the fluorescent area must be reclassified.

Note: In this service, ultraviolet light is occasionally referred to as black light.

Wipe Test

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

Water Break Test

The water break test may be used to detect oily residues not found by other means. The surface is wetted with a spray of clean water. The water should form a thin layer and remain unbroken for at least 5 seconds. Bubbling of the water droplets indicates the presence of oil contaminants, and reclensing is required. This method is generally limited to horizontal surfaces.

Solvent Extraction Test

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

The used solvent may be checked to determine the amount of nonvolatile residue (NVR) by the following procedure. A known quantity of a representative sample of used solvent that has been filtered is evaporated almost to dryness, then transferred to a small weighed beaker for final evaporation with care taken not to overheat the residue. In the same manner, the weight of residue from a similar quantity of clean solvent is determined. The amount of contaminant extracted per square foot (meter) of surface area cleaned can be computed from the difference in weight of the two residues and the quantity of solvent used. Total carbon analyzers may be used to check NVR level in used solvent as shown in Fig. 11-10.

In a similar manner, a 1 liter representative sample of the unfiltered used solvent can be placed in an Imhoff cone and evaporated to dryness. The volume of residue can be measured directly and used to compute the amount of contaminant extracted per square foot (meter) of surface area cleaned. Greater sensitivity can be achieved by evaporating successive liters of solvent in the same Imhoff cone.
Another method is to take a representative sample of the used solvent and compare it to an equivalent volume of new solvent by comparing light transmission through the two samples simultaneously. Nessler tubes are effective for this method. There should be little if any difference in color of the solvents and very few particles. Another technique is to compare using Fourier transfer infrared spectroscopy (FTIR).

PACKAGING AND LABELING

Once a piece of equipment has been cleaned for oxygen service and the cleaning agent completely removed from the equipment, it should be suitably protected as soon as practicable to prevent contamination during storage or before being placed in service. The protection provided will depend on a number of factors such as the type of equipment, length of storage, and atmospheric conditions. The purchaser of the equipment should specify the type of protection required.

Protection of Openings

Caps or plugs may protect equipment or parts having small openings. Small to medium sized components may be sealed in plastic bags or protected by other appropriate means. A typical packaging station is shown in Fig. 11-11. Openings on large equipment may be sealed, preferably with caps, plugs, or blind flanges, where appropriate. Taped solid board blanks or other durable covers that cannot introduce contamination into the equipment when removed can also be used to seal such openings.

Pressurization

Equipment with large internal volumes may be filled to a slight positive pressure with dry, oil-free air or nitrogen after all openings have been sealed and valves closed. Parts in suitable plastic bags may be purged with inert gas or evacuated and sealed. The potential asphyxiation hazard needs to be considered if nitrogen is used.

Where the purchaser’s requirements include labeling to show that oxygen service cleaning of parts or equipment has been performed, a statement such as “cleaned for oxygen service” or other suitable wording should appear on the part or package as applicable. Additional information that may be included is as follows:

- A statement, “This equipment is cleaned in accordance with Oxygen Cleaning Specification No._______”;
- Date of inspection and the inspector’s stamp or marking;
- Description of the part including part number if available;
- A statement, “Do not open until ready for use”; and
- Warning of asphyxiation hazard if applicable.

PERSONNEL SAFETY

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

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

Hazardous Chemicals

No highly toxic chemicals shall be used. Carbon tetrachloride shall not be used in any cleaning operation. The use of carcinogenic or potentially carcinogenic materials is not recommended. The health hazards associated with the use of any solvent must be considered in its selection. The user should ensure that the Threshold Limit Value—Time-Weighted Average (TLV—TWA) is not exceeded for a specific solvent [8], however, they must adhere to Permissible Exposure Limits—Time-Weighted Average (PEL—TWA) in accordance with 29 CFR Part 1910 Subpart Z [21]. Breathing of solvent fumes and liquid contact with the skin should be avoided. Safety Data Sheets (SDS) for solvents should be obtained from the solvent manufacturer in accordance with the requirements of 29 CFR Part 1910.1200(g).

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

Follow normal industry procedures in the mixing and handling of acids and caustics to eliminate injuries. Special consideration should be given to the safe disposal of waste cleaning solutions.

Protective Equipment

A risk assessment should be conducted for cleaning operations, which identifies the necessary safeguards including the selection of appropriate PPE. See CGA P-44, Selection of Personal Protective Equipment [22].

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

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

In accordance with 29 CFR 1910.134, appropriate respiratory protection is required for all areas where the TLV* or PEL may be exceeded. When the potential forIDLH or oxygen-deficient atmosphere exists (e.g., inert gas purge, etc.), then self-contained breathing apparatus (SCBA) must be provided [21].