AEROSPACE RECOMMENDED PRACTICE

ARP1176™ REV. B

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Superseding ARP1176A

(R) Oxygen System and Component Cleaning

RATIONALE

This document has been revised to reflect current industry recommended practices regarding the cleaning of components and systems for oxygen service.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides recommended practices for the cleaning of aircraft oxygen equipment, both metallic and non-metallic articles, such as oxygen lines (tubes, hoses, etc.), components (including regulator and valve parts), cylinders, and ground-based equipment that may be used to support aircraft oxygen systems. This document also specifies work area details, methods for selecting suitable cleaning agents, cleaning methods, and test methods for verifying levels of cleanliness. The cleanliness coding scheme specified in this document provides a method for documenting minimum cleanliness level requirements and for identifying compliance.

1.1 Purpose

The purpose of this document is to provide recommended methods for the cleaning of both aircraft and ground-based oxygen equipment that support aircraft oxygen systems and to outline the minimum accepted practices for articles that are cleaned for oxygen service . Oxygen equipment cleaning operations must perform to a minimum level of safety suitable for precluding toxic and fire hazards for the application and conditions for which the equipment is intended.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR5742 Packaging and Transportation of Oxygen Equipment

ARP598 Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems

AS9138 Aerospace Series - Quality Management Systems Statistical Product Acceptance Requirements

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM G93 Standard Practice for Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments

ASTM G120 Standard Practice for Determination of Soluble Residual Contamination in Materials and Components by Soxhlet Extraction

ASTM G121 Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents for Use in Oxygen-Enriched Systems and Components

ASTM G122 Standard Test Method for Evaluating the Cleaning Effectiveness of Cleaning Agents

ASTM G127 Standard Guide for the Selection of Cleaning Agents for Oxygen Systems

ASTM G128 Standard Guide for the Control of Hazards and Risks in Oxygen Systems

ASTM G131 Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques

ASTM G136 Standard Practice for the Determination of Soluble Residual Contaminants of Materials and Components by Ultrasonic Extraction

ASTM G144 Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer

2.1.3 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil/.

BB-A-1034 Compressed Air, Breathing

CGA-G4 Oxygen

A-A-59503 Nitrogen, Technical

MIL-STD-1330 Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems

MIL-STD-1916 DOD Preferred Methods for Acceptance of Product

MIL-HDBK-407 Contamination Control Technology Precision Cleaning Methods and Procedures

2.1.4 NASA Publications

NASA Technical Services, NASA STI Program STI Support Services, Mail Stop 148, NASA Langley Research Center, Hampton, VA 23681-2199, 757-864-9658, Fax: 757-864-6500, http://ntrs.nasa.gov/.

NASA JSC/WSTF Specification No. 022 Chemical and Cleanliness Requirements for WSTF Test Hardware and Facility Equipment, 17 Feb 1987

2.1.5 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 14644-1 Cleanrooms and Associated Controlled Environments - Part 1: Classification of Air Cleanliness

ISO 14644-2 Cleanrooms and Associated Controlled Environments - Part 2: Specifications for Testing and Monitoring to Prove Continued Compliance with ISO 14644-1

2.1.6 ASQ Publications

Available from American Society for Quality, 600 North Plankinton Avenue, Milwaukee, WI 53203, Tel: 800-248-1946 (United States or Canada), 001-800-514-1564 (Mexico), or +1-414-272-8575 (all other locations), www.asq.org.

ANSI/ASQ Z1.4 Sampling Procedures and Tables For Inspection By Attributes

2.1.7 CGA Publications (Compressed Gas Association

Available from CGA, 14501 George Carter Way, Suite 103, Chantilly, VA 20151, Tel: 703-788-2700, www.cganet.com.

CGA-G4 Oxygen

2.1.8 Other Publications

“Evaluation of Solvent Alternatives for Cleaning of Oxygen Systems,” by Harold Beeson, NASA Johnson Space Center, White Sands Test Facility, Las Cruces, New Mexico; Paul Biesinger and Rafaol Delgado, Allied-Signal Technical Services Corp. Team, White Sands Test Facility, Las Cruces, New Mexico, and Neil Antin, Naval Sea Systems Command, CO3L, Arlington, Virginia; 1997, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19990075880.pdf.

IATA Resolution 618, International Air Transport Association, 800 Place Victoria, Montreal, QC H4Z1M1.

ADR European Agreement, United Nations Economic Commission for Europe, CH-1211 Geneva 10, Switzerland.

2.2 Definitions

AQUEOUS CLEANING: A cleaning process using clean non-ionic water to clean equipment. A cleaning agent may be added to the water to increase the capability of the water to clean as mentioned in the aqueous cleaning solution definition.

AQUEOUS CLEANING SOLUTION: An aqueous cleaning solution is a water based cleaner whose constituents are soluble inorganic compounds such as silicates or phosphates or soluble organic compounds such as non-ionic surfactant or combinations thereof. Examples of aqueous cleaning solutions include commercial detergents which generally contain both soluble inorganic and organic compounds and navy oxygen cleaner (NOC) which contains only soluble inorganic compounds.

ARTICLE: A material, part, component, or appliance.

CLEAN: Cleaned to a specified cleanliness level by the removal of contaminants. Clean refers to the absence of scale, particulate, oil, and grease contaminants to a level below that which adversely affects the operation or reliability of the component or system. The process of cleaning should not affect the form, fit, or function of the item being cleaned.

CLEANING AGENT: Any compound or substance, which promotes the removal of contaminants through mechanical or chemical action, may be called a cleaning agent.

CLEANING METHOD: A procedure for bringing a suitable cleaning agent in contact with all surfaces to be cleaned under the proper conditions and for a sufficient length of time to remove contaminants and loose particles to the required cleanliness level.

CLEAN ROOM: A clean room is a permanent area where a high degree of cleanliness is continuously achieved by employing varying degrees of control and monitoring of environmental conditions such as ventilation, filtration, temperature, humidity, pressure, personnel, clothing, and room maintenance. See Section 4 for clean room requirements.

CLEANING SOLVENT: A cleaning solvent is any material that exhibits the capability to dissolve other substances through chemical action and, for the purposes of this document, is 100% volatile. An example is a hydrocarbon solvent such as isopropyl alcohol (IPA), which is very flammable.

CLEANLINESS: The degree of success in preventing contamination from being present in an oxygen system is cleanliness. Cleanliness and contamination are inverse properties in that increasing cleanliness implies decreasing contamination.

CLEANLINESS LEVEL: An established maximum allowable distribution of contamination of a non-volatile residue of a specified threshold per area or particles of a given size, quantity and distribution per specified volume or area.

COMPONENT: An integral unit part of an assembly or system is a component. Examples include tubes, ducts, tanks, valves, actuators, reservoirs, and accumulators.

CONTAMINANT: A foreign or unwanted substance that can have deleterious effects on system operation, life, reliability or safety.

CONTAMINATION: 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 in that increasing cleanliness implies decreasing contamination.

CONTROLLED CLEAN AREA: A controlled clean area is an area where a high degree of cleanliness is temporarily achieved and maintained by the use of boundaries, air filtration, and the enforcement of controls on personnel access, operations, and area maintenance. Controlled clean areas are most often used for cleaning oxygen equipment where a high degree of cleanliness is necessary, but the requirements are not as stringent as an ISO Class 8 clean room. See Section 4 for controlled clean area requirements.

FIBERS: Particulate matter with a length of 100 µm or greater, and a length-to-width ratio of 10 to 1 or greater.

FILTRATION: The process of removing contaminants from a gas or liquid by passing them through porous media.

GASEOUS OXYGEN: Gaseous oxygen is a colorless, odorless, tasteless gas slightly heavier than air. Oxygen strongly supports and rapidly accelerates the combustion of many materials. If the correct oxygen pressure and temperature are present most materials react with oxygen.

GENERAL CLEAN ROOM: A room setup specifically to clean, assemble, and package oxygen equipment. There should be some control exercised to maintain room cleanliness to levels needed to clean oxygen system components/articles effectively and safely. General clean rooms are the most commonly used areas or rooms to clean aircraft oxygen equipment. See Section 4 for general clean room requirements.

GROSS CLEANING: Preliminary or rough cleaning to remove scale, rust, metal chips, dirt, etc. This cleaning is performed in a normal work area to visual inspection standards. It is inappropriate to perform gross cleaning in a controlled clean area or room.

LIQUID OXYGEN (LOX): An extremely cold, -297 °F (-183 °C), pale blue, clear liquid, slightly more dense than water and strongly paramagnetic. It strongly supports and rapidly accelerates the combustion of all flammable materials. Note that a hydrocarbon in contact with LOX will ignite explosively under the influence of pressure.

NON-VOLATILE RESIDUE (NVR): The organic and inorganic material remaining on the surface after evaporation of the solvent or volatile liquid.

NON-METALLICS: Organic and inorganic materials such as ceramics, glasses, polymer, rubber, cloth, wood and paper products.

OXYGEN COMPATIBILITY: 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).

OXYGEN SERVICE: Surface or part of the equipment that comes in direct contact with oxygen is referred to as the part that sees oxygen service. Also referred to as the wetted surface.

PARTICULATE: A general term used to describe a finely divided solid of organic or inorganic matter, including metals. The amount of contamination for an item is usually reported as the population of a specific micrometer size. Refer to ARP598 for particle size and count determination.

PRECISION CLEANING: Final or fine cleaning accomplished in a controlled environment to remove minute quantities of contaminants to achieve the specified levels of cleanliness.

PURGE: To flow a gas through a system or line, tank, etc., for the purpose of eliminating cleaning fluid left as a residue or water and moisture as left from a cleaning operation or use of the equipment. The purging gas must be clean and free of contamination or organic material that may be included or added during a pumping operation.

PURITY: The percentage by volume of gases or by weight of liquids of the major constituent such as oxygen or liquid oxygen and the remainder is other gases such as inert gases and undesired materials or contamination. If the purity standard is met, the contamination included is within acceptable standards or purity limits.

ULTRASONIC CLEANING: A process where high frequency vibrations are used to produce a cleaning action. This requires a medium such as a solution of water and a cleaning agent to transmit the vibrations.

VISUALLY CLEAN: No contaminants or particulates are found when examined with the naked eye. This clean level should only be used for equipment operating at a pressure equal to or less than 10 psig (68.9 kPa).

3. CLEANLINESS LEVELS

3.1 General Requirements

All oxygen systems and components are required to meet an acceptable level of cleanliness established by the organization responsible for the installation of such equipment. The selection of the cleanliness level should consider the need to remove contaminants such as the following:

- Incompatible oils, grease, or any other combustible fluid or compound
- Organic particles that can oxidize or react with oxygen, such as:
  - Lint
  - Shredded paper
  - Any other combustible material
- Shreds of easily oxidizable metals, such as:
  - Aluminum
  - Magnesium
  - Iron
- Non-combustible particles that could become entrained and cause ignition due to impact with vulnerable components.

3.2 Cleaning Process Consideration Factors

Many oxygen system components, including supply plumbing and cylinders, can most effectively be cleaned when not installed in the system. Components containing plastic or elastomeric parts are subject to damage when exposed to some cleaning agents, and their resulting odors are difficult to satisfactorily remove. Contaminants such as oils, dust, metal chips, etc., cannot be easily removed by gas purging or liquid flushing within the installed system. Such contaminants can eventually become trapped in some narrow orifice causing either partial or complete failure of the system. In addition, if the contaminant is of a combustible type, the fire hazard is increased. Such contaminants can only be removed by complete disassembly of the affected components, followed by proper cleaning procedures and controlled handling of the clean components until reinstallation into the using system.

NVR (Non-Volatile Residue) testing must be used to verify that the cleaning process meets the required NVR level or better. The cleaning process verification and/or individual part cleanliness verification are necessary based upon individual components and their applications for use.

3.3 Recommended Cleaning for Articles

Appropriate cleanliness levels need to be determined and established based on the type of article and the application and conditions for which it is intended. Cleanliness levels should be specified within the technical documentation that controls the article's design requirements.

Cleanliness levels for articles being cleaned for oxygen service may also be referenced in the contract for the cleaning.

Minimum recommended cleanliness levels, based on the maximum operating pressure of the article being cleaned, are shown in Table 1.

Table 1 - Minimum recommended cleanliness levels

Pressure Level	NVR Level	Particulate Level	Cleanliness Level Code
<10 psig (68.9 kPa)	Visually Clean	Visually Clean	ARP1176-V
10 to 450 psig (68.9 kPa to 3.1 MPa)	≤3 mg/ft^2 (0.032 g/m^2)		ARP1176-3
>450 psig (3.1 MPa)	≤3 mg/ft^2 (0.032 g/m^2)	300	ARP1176-3-300

3.4 Coding

The coding scheme specified in this section is used to identify the level of cleaniness required for an article. See Figure 1 for details on how this coding scheme is defined.

The cleanliness level code requires that the maximum level of NVR (see Note 2) must be specified. The possible minimum and maximum levels of NVR that can be specified are Visually Clean and 1 mg/ft^2, respectively.

A Particulate Level is not required to be specified in the cleanliness level code unless a Particulate Level is required for the article being cleaned. The application and conditions for which the article is intended determines whether a Particulate Level is needed, and should be specified in the design requirements for the article.

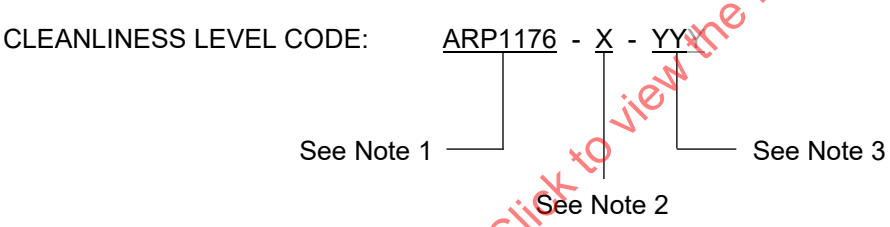

Figure 1 - Cleanliness level code

Note 1: These characters reference the specification that define the cleanliness requirements.

Note 2: This single character references the maximum allowed level of NVR. See Table 2 for the defined levels of NVR, and see 5.3.1 for NVR test methods.

Note 3: These characters reference the maximum allowed Particulate Level. Either two or three characters will be used and is dependent on the Particulate Level required. See Table 3 for the defined Particulate Levels, and see 5.3.2 for particulate test methods.

NOTE: The original release of this Aerospace Recommended Practice referenced categories as the method for determining the minimum levels of cleanliness for an article. See Appendix C for the conversions between this historical method and the current cleanliness level coding scheme.

Table 2 - NVR levels

Character	NVR Level
V	Visually Clean
1	≤ 1 mg/ft^2 (0.011 g/m^2)
2	≤ 2 mg/ft^2 (0.022 g/m^2)
3	≤ 3 mg/ft^2 (0.032 g/m^2)

Table 3 - Particulate levels

Particulate Level	Particulate Size (micrometers)	Maximum Particle Count
50	<15 15 thru 25 >25 thru 50 >50	Unlimited* 17 8 0
100	<25 25 thru 50 >50 thru 100 >100	Unlimited* 68 11 0
150	<50 50 thru 100 >100 thru 150 >150	Unlimited* 47 5 0
200	<50 50 thru 100 >100 thru 200 >200	Unlimited* 154 16 0
300	<100 100 thru 250 >250 thru 300 >300	Unlimited* 93 3 0

* “Unlimited” means particulate in this size range is not counted; however, if the accumulation of this particulate from the unlimited size range is sufficient to interfere with the analysis, the sample should be rejected (refer to MIL-STD-1330). Large amounts of “allowable particulate” can still cause a particle impact hazard. NASA has been able to ignite targets and components using collections of small particles in place of one large particle. An accumulation of the counted particulate can interfere with the proper operation of a component; therefore, there could be a limit on “unlimited.”

4. CLEANING METHODS AND PROCEDURES

Oxygen equipment and parts require a cleaning procedure and work areas that will achieve an adequate level of cleanliness consistent with its use and operating pressure. To establish an adequate cleaning procedure, the following should be considered:

a. Controlled clean area or clean room.

b. Selecting suitable cleaning agents and mixture ratios.

c. Selecting the proper cleaning methods for the cleaning agents used.

d. Inspection of either the articles that have been cleaned, or the cleaning process, for verification that the required cleanliness level has been met.

e. Drying and purging the articles so that all cleaning agents and media (such as water that carries the cleaning agent if aqueous cleaning methods are used) are removed.

f. Verify that the cleaning agents are also removed. This is especially critical after the use of a pre-cleaner if the substance is combustible in oxygen.

g. Packaging and marking the package containing the articles until removal or shipment to another area for reassembly, installation, or storage.

h. Assurances that precaution instructions are established for safety and operations. For information regarding hazards with cleaning substances refer to the manufacturer for information on hazard and proper handling. Other production information may be available.

4.1 Clean Room and Controlled Clean Area

Articles used in oxygen systems should be properly cleaned and kept clean until assembled, reassembled, or packaged. It is essential to maintain a controlled environment to prevent any contamination during cleaning, drying, assembly, testing and packaging. Therefore, the cleaning of oxygen system articles and assembling, testing, and packaging of these articles should be done in a controlled clean area or a clean room. The cleaning and handling environment needs to be controlled at a minimum level to prevent the clean article, when exposed for the expected handling period, from picking up contamination that could take the article out of its required level of cleanliness. In general the clean room or controlled clean area should be of adequate size, isolated from oil, grease, paper and lint particles, and other airborne contaminants. The walls, ceiling, and floors should be designed with a surface that is non-dusting and also minimizes the collection of dust. Clean room and controlled clean area characteristics discussed in this ARP are very similar to those listed in MIL-STD-1330 and are summarized in Table 4. These clean room characteristics will be consistent with standard clean rooms used worldwide. An ISO Class 8 or better clean room, in accordance with ISO 14644, should be used for critical applications.

Table 4 - Clean Room and Controlled Area Requirements

Attribute	ISO Class 8 Clean Room	General Clean Room	Controlled Clean Area
Structure	Class A	Class B	Class C
Maintenance	Class A	Class B	Class B
Average air temperature	72 °F ± 5 °F (22 °C ± 3 °C)	72 °F ± 10 °F (22 °C ± 6 °C)	Uncontrolled
Average relative humidity	30 to 50%	70% maximum	Uncontrolled
Air filtration	Class A	Class B	Class B
Ventilation and air pressure	Class A	Class B	Class C
Personnel clothing	Class A	Class B	Class B

Care needs to be exercised, when establishing the clean room requirements, that the room level does not exceed that which is required to maintain the level of cleanliness by such a margin that efficiencies are lost and resources wasted (unless future expansion to higher levels of cleaning is planned). It should be noted that the use of such a clean room means that the articles must be assembled in a clean room of the same class. Any articles with surfaces that see oxygen service, and that have been opened, must be cleaned to the same level. Otherwise, the purpose of cleaning to this level may be negated. For many other applications, a general clean room should be used. A controlled clean area may be used for general-purpose cleaning, pre-cleaning and, in some cases, packaging. It should also be noted that for extremely sensitive articles, an ISO Class 7 (or better) clean room may be required to achieve the desired level of cleanliness.

4.1.1 Structure

Class A:

All Class B requirements apply for Class A plus additional requirements. These additional requirements are more stringent than the requirements given for Class B. Best commercial practices should be employed in the use of materials, construction, filtration, clothing, personnel, and temperature, pressure, and humidity control to achieve an airborne particulate cleanliness level equivalent to ISO 14644 Class 8 or better. Refer to MIL-HDBK-407 for additional guidance.

NOTE: Where critical fits, such as metal to metal seats are involved, the assembly should be done on a laminar flow clean surface.

Class B:

a. A permanent enclosure comprised of a rigid frame with clearly defined walls, ceilings, and floor, all adequate to prevent the entry of contamination from the surrounding environment.

b. The surface of the walls, ceiling, and floor should be fabricated or coated with a material that minimizes attraction of dirt and is easily cleaned. Refer to MIL-HDBK-407 for additional guidance.

c. Where dirt may be brought into the clean area, preventative measures such as anterooms, shoe covers, or tack mats should be employed. Anterooms should provide for changing and stowing of clothing, examination of tools and equipment, and personnel access to the clean area. Washing, toilet facilities, and storage facilities for maintenance of equipment should be provided in the immediate area where desirable.

d. Furnishings and equipment such as work benches, chairs, and racks should be constructed and finished with materials that will not produce dust or particulate as a result of chipping, flaking, or rusting. Paint should be hard and non-flaking or non-chalking. Furnishings likely to be abraded or bumped should be constructed of either stainless steel or non-fracture type plastic. Storage areas should have easily cleaned surfaces. Refer to MIL-HDBK-407 for additional guidance.

e. Work Benches: Workbenches should be covered with easily cleaned surfaces, such as synthetic rubber, vinyl, linoleum, laminate, or stainless steel.

f. Walls and Ceiling: Walls and ceiling should be covered with a non-dusting and non-gassing surface such as washable vinyl or painted with epoxy, latex paint, polyurethane-based paints, or equivalent.

g. Floors: Floors should be non-dusting and easily cleaned. Covering may be vinyl linoleum or polyurethane paint.

h. Work that produces airborne dust, dirt, or particulate should not be performed in a clean room. Welding and brazing should not be performed in a clean room.

Class C:

Airborne debris or contamination resulting from work accomplished in the controlled clean area should be eliminated before redesignation as a controlled clean area. Depending on the time and work involved for a particular operation, a controlled clean area should be one of the following:

a. A clean space should not be located or set up adjacent to areas where contaminates are produced.

b. A clean tent or partitioned and covered area. The clean-tent should be established by taping clean, unused, polyethylene plastic sheets on the deck, overhead, and vertical areas for a distance of 3 to 4 feet (0.91 to 1.22 m) around the area concerned. The outside surfaces of exposed materials within the confined area should be cleaned to remove dust, oil, dirt, and other foreign material. Inward air movement within the confined area should be held to minimum.

c. A clean glove box or isolation box with a clean atmosphere. The glove box is a temporary enclosure surrounding the work area and sealed from the outside atmosphere. Work is accomplished through plastic gloves sealed to the box walls.

d. A sleeve, with a clean, dry, nitrogen supply or equally clean, dry, air supply.

When cleaning aircraft oxygen equipment other special considerations apply for effective cleaning structures and work practices. The room should be of adequate size, isolated from oil, grease, paper and lint particles, and other airborne contaminants. Work areas should be illuminated to at least 100 lm (lumens) on the work surface. Special lighting may be required to inspect for cleanliness.

4.1.2 Maintenance

Class A:

Class B requirements apply. Additionally, when specified, a particle count of the laminar flow benches and each clean area should be accomplished daily.

Work area, benches, floors, and storage areas should be vacuum cleaned with adequate filtration daily. Airborne particle size should be checked with standard test equipment often enough to prove the airborne particle size in the general work area is less than that desired (e.g., 100 µm).

Class B:

a. Complete cleaning and wipe-down of equipment, tools, workbenches, counters, tabletops, and fixtures with detergent solution, as well as vacuuming and mopping of the floor, should be accomplished as deemed necessary after inspection of the work area.

b. Complete cleaning and wipe-down of the walls, floors, and ceiling with a detergent solution monthly, if conditions necessitate.

c. The average air temperature and average humidity in a clean room should be measured daily.

d. Air filters should be cleaned or replaced at regular intervals.

e. Oil, grease, residue, spilled chemicals, and any foreign material, which develops in the area, should be cleaned immediately. Chips, particles, and dust generated during any operation should be removed during the operation by vacuum.

f. No eating, drinking, smoking, or personal grooming is allowed. Drinking fountains are permissible.

g. Only oxygen approved lubricants should be stored and used in general clean rooms or clean areas. Items incompatible with oxygen such as oils and greases containing hydrocarbons should not be stored or used in general clean rooms or clean areas.

4.1.3 Temperature and Humidity

The temperature and humidity ranges indicated are recommendations only. Exceeding the recommended ranges may result in personnel discomfort, build-up of static charge if the humidity drops below 30%, or rusting of equipment and the enclosure if the humidity exceeds 50%. More stringent requirements may apply if other work, such as calibration, is being performed.

4.1.4 Ventilation and Air Filtration

Class A:

The best commercial practice employing items such as high efficiency particulate air (HEPA) filters should be used to achieve and maintain an ISO Class 8 airborne particulate cleanliness level.

Class B:

Outside and recirculated air should be filtered to remove dust particles. Filter nominal rating should be less than 10 µm. The concentration of airborne particles should be held to the minimum possible.

NOTE: A high concentration of 10 µm airborne particles can cause more problems to components than a low concentration of 100 µm particles.

Laminar flow benches may be a cost-effective method to clean and assemble smaller articles in a structure that does not meet the requirement for cleaning. A laminar flow bench achieves cleanliness levels one-step better than the structure in which it is included. For example, ISO Class 8 clean levels may be achieved in a general clean room and general clean room levels may be achieved in a controlled clean area. That is, of course, dependent on the work area. If high levels of dust or particles are in the controlled clean area, these can penetrate the laminar flow on the workbench.

4.1.5 Ventilation and Air Pressure

Class A:

The clean room should have a positive pressure above ambient pressure. A slight positive differential pressure should exist between any enclosure within the clean room and any adjacent area of lesser clean requirements.

Class B:

The ventilation air supply should maintain a slight positive pressure so that the airflow will always be outward from the clean area.

Class C:

The ventilation air supply should maintain a slight positive pressure so that the airflow will always be outward from any inhabited area. This includes work being performed on location in a non-fixed structure.

Fully contained uninhabited areas, such as a glove bag or glove box, should employ ventilation to prevent the introduction of contaminants.

4.1.6 Personnel Requirements

Oxygen system and article cleaning should only be performed by properly trained and qualified personnel using appropriate equipment, facilities, procedures, and safety practices.

Class A:

Strict control of personnel and their clothing is required to achieve and maintain an ISO Class 8 clean room. At a minimum, Class B requirements should apply. Additional items such as full coveralls with hoods and booties, anti-static gloves, lint-free paper, and limitations on personnel with skin ailments and colds are generally employed. Refer to MIL-HDBK-407 for guidance in establishing the requirement for additional personnel and clothing requirements.

Class B:

a. All personnel including visitors and observers should wear clean, undamaged, non-shredding, nylon (or equivalent) coveralls or smocks, without exposed buttons or zippers, keys, and similar articles. Protective clothing should not be worn open or worn outside of the clean room or controlled area.

b. Where contaminants could be brought in from the outside, shoe covers should be worn.

c. Clean items should only be handled with clean gloves such as latex, vinyl, nitrile, or polyethylene, which are free of lint and powder. Gloves in contact with cleaning solvents or solutions should be chemically resistant for personnel safety and to prevent spread of contamination to oxygen clean surfaces. If the cleanliness of a glove is compromised, or suspected of being compromised, it should be replaced immediately with a new, clean glove. Oxygen clean surfaces touched with bare hands should be considered contaminated.

d. Special precautions should be taken in the case of opened piping and components to prevent the introduction of loose articles such as buttons, jewelry, pens, coins, glasses, contact lenses, and hearing aids. Badges, where required to be worn, should be securely fastened to the clothing.

e. There should be no smoking, eating, or drinking in the work area.

f. Lint producing cloths, wipes, and dunnage should be prohibited in the work area.

g. Articles should be transported and cleaned in lint-free containers.

h. Hands must be clean and free of hand creams and other combustible products, and hair should be free of flammable hair sprays.

i. Outside personnel traffic through the area should be prohibited.

4.1.7 Tools and Equipment

Tools and equipment brought into a clean room or controlled area should be free of visible soil and particulate. Tools and equipment used in direct contact with oxygen clean surfaces should be cleaned to the same level as the oxygen clean surfaces. Tools used on oxygen equipment should be dedicated to that purpose and not used for any other purpose. Where tool configuration or equipment prevents cleaning in accordance with this standard, such as micrometers and dial indicators, all exposed surfaces should be wiped clean with an acceptable cleaning solvent or solution and inspected for visual cleanliness. Pencils or erasers should not be used in the clean area as this adds particulate to the air. Solvents, cleaners, or other equipment not related to the immediate work effort should be kept away from the work area.

4.2 Selecting Suitable Cleaning Agents

The function of a cleaning agent is to assist in the removal of contaminants (organic and inorganic material) without degrading the articles being cleaned. The selection and use of cleaning agents should ensure no hazards are posed to the articles being cleaned and to personnel performing the cleaning operations. Many cleaning substances have been banned from use because of the hazards they posed to personnel or the environment. The broad categories of cleaning chemicals are solvent types and aqueous types. The cleaning methods, personnel, and equipment required should be considered during the selection process, as handling and processing could differ for solvent based agents than for aqueous based agents. Regulatory agencies impose rules and regulations for chemicals used within their respective jurisdictions. Use of ozone depleting substances (ODS) should be avoided; however, if their use is required, it should be limited and all rules and regulations for their use should be followed. Many ODSs have been and are being phased out for use due to the hazards they pose. Disposal of cleaning agents should be considered during the selection process, as waste products from the cleaning operations could adversely impact the environment in which they are disposed. It is the responsibility of the organization intending to establish a cleaning operation to follow all rules and regulations for the use and disposal of any chemicals used.

A good cleaning agent should:

a. Effectively remove all expected contaminants to the cleanliness level desired.

b. Effectively remove particulates, inorganic and organic residues, and solids to the level desired.

c. Have a low risk of being flammable in the liquid oxygen or pressurized gaseous oxygen environment intended for its use.

d. Not adversely affect the metals and non-metals being cleaned.

e. Not alter the physical dimensions or properties of the articles being cleaned.

f. Have a level of toxicity that is low enough to be easily controlled by procedure and satisfy medical toxicology experts that it is generally recognized as safe for use within the procedures established.

ASTM G127 provides further details on the methodology for solvent selection.

4.2.1 Cleaning Agents

Many cleaning substances are under consideration for use to clean oxygen equipment. Only a few are mentioned herein. It is the organization's responsibility in setting up their cleaning facility to determine what cleaning substance(s) best suit their purposes. The entity purchasing the oxygen equipment or requesting the cleaning may have special needs or requirements that also need to be satisfied. Currently, aviation regulatory agencies do not certify cleaning chemicals or operations for commercial oxygen equipment, but military organizations and the Compressed Gas Association (CGA) do on a limited basis. The cleaning agent, if a solvent or aqueous solution, must remove contaminants to a non-volatile residue of less than the cleanliness level desired.

The following ASTM standards can assist in selecting a suitable cleaning substance: ASTM G93, ASTM G120, ASTM G121, ASTM G122, ASTM G127, ASTM G128, ASTM G131, ASTM G136, ASTM G144.

4.3 Selecting the Proper Cleaning Method

No single method of cleaning will completely remove all types of contaminants. Also, unless a satisfactory cleaning method is selected and properly carried out, more harm than good may result. Usually the best cleaning method is strongly dependent on the type of cleaning agent. Aqueous cleaning is much different than solvent cleaning. Refer to the cleaning agent manufacturer's recommended practices before establishing the cleaning method. The selected cleaning method should bring a reliable cleaning agent in contact with all surfaces to be cleaned for a sufficient length of time and in such manner as to remove contaminants to the cleanliness level desired. If possible, some means of agitating the cleaning agent or scrubbing of the surface with the cleaning agent should be used in the process. Hard to reach places should be given special attention. In order to select the proper cleaning method, the following factors should be considered:

a. Composition of the article to be cleaned.

b. Complexity of construction.

c. Properties of the cleaning agent.

d. Availability of cleaning materials and equipment.

e. Limitations of the cleaning agents such as its potential to damage articles and finishes.

f. Facilities available for cleaning and level of cleanliness desired.

g. Rinsing requirements, if any, and drying requirements.

h. Properties of contaminants.

4.3.1 Composition of the Article to be Cleaned

The function of a cleaning agent is to assist in the removal of contaminants without attacking the material of the article being cleaned or leaving non-removable residues. Cleaning agents should not be used haphazardly for cleaning. There should be a full understanding of what effect, if any, the cleaning agent may have on the article being cleaned. Cleaners suitable for use on one material may react with another material. For example, when cleaning metal articles with a water-soluble cleaning agent, an acceptable cleaning compound should be used that does not contain an unacceptable pH level that will damage the surface of the metal cleaned. Details about cleaning agents and acceptable concentrations in water should be determined. Refer to MIL-STD-1330 for information about the cleaning substance effects on metals and non-metals. Additional information may also be available from the cleaning agent supplier.

4.3.2 Complexity of Construction

Articles or assemblies which can trap cleaning residue or particulate that cannot be removed by final rinse and drying should not be cleaned in any type of fluid cleaner. In general, components cannot be cleaned in the assembled state since solvents may damage non-metallic parts or trap contaminants in non-accessible areas. Components of complex assemblies (such as threaded joints, press fits, etc.) should be cleaned individually prior to assembly so that as many areas as possible can be inspected for cleanliness. When assembly cannot be accomplished immediately after cleaning, the cleaned articles should be packaged immediately and marked with the ARP1176 Cleanliness Code to protect against recontamination. Clean articles removed from a system should be packaged immediately or cleaned again before reinstallation.

4.3.3 Properties of the Cleaning Agent

The cleaning agent should have properties which make it useable with the equipment available. For example, a solvent suitable for cleaning by immersion or scrubbing may not be suitable for vapor degreasing.

4.3.4 Limitations of the Cleaning Agents

Many cleaning agents have limitations such as damage to articles and finishes. Aqueous cleaners must be dissolved in the proper proportions to water or damage can result. Some cleaners may damage non-metals. As a starting point, the manufacturer's data should be consulted, and if this is not sufficient, then testing is desirable to establish if the cleaning agent can be used for the materials under consideration.

4.4 Different Methods of Cleaning

There are several general methods of cleaning oxygen equipment that will require not only different cleaning agents, but different equipment and procedures. Not all inspection methods will apply to all methods of cleaning.

4.4.1 Solvent Cleaning

The solvent chosen for a solvent cleaning process should dissolve all organic contaminants adhering to the articles. During cleaning, pre-cleaning may be required, a soft brush or lint-free cloth may be used with the solvent to loosen any thick build-up of contamination and/or particles. After all organic contaminants are dissolved and all inorganic particles are loose, the articles should be rinsed and/or flushed, with clean solvent to remove contaminants and clean the articles. Following the cleaning process, all residual solvent should be removed (see 4.5).

In a test program by Beeson, Biesinger, Delgado, and Antin at NASA White Sands Test Facility various solvents were examined for their ability to clean oxygen gauges (see Other Publications: "Evaluation of Solvent Alternatives for Cleaning of Oxygen Systems"). Several solvents were found suitable to clean gauges and had similar cleaning properties to CFC-113. AK 225 is considered an acceptable substitute for CFC-113 for the NVR test as it is not flammable and cleans very similarly to CFC-113. Other solvents are discussed when AK 225 is not available, but all have flammability concerns.

NOTE: AK 225 is a concern for general solvent cleaning because its toxicity threshold is about one-fifth that of CFC-113, and the effects on persons is not well understood, since it is a relatively new chemical.

NOTE: AK 225 is a Class II ODS, but the Environmental Protection Agency recommends its use because its effects on the atmosphere are very minimal compared to other ODSs.

4.4.1.1 Vapor Degreasing

Vapor degreasing is another form of solvent cleaning that consists of using a vapor degreaser chemical heated in a tank or pit. This creates a vapor area above the boiling solvent in such a manner that the vapor will condense on and flush all surfaces within the vapor area. Articles to be cleaned are placed in a screen basket, which is lowered into the vapor. Vapor phase tanks are equipped with cooling coils below the tank top to recondense vapors, which would otherwise escape, and an exhaust system to maintain atmospheric concentrations of solvent vapors below toxic levels. Vaporizing the solvent in a separate tank and blowing the vapors into the tank being cleaned may clean oxygen storage and transfer tanks. The solvent condensate is drained from a bottom outlet. Following the vapor degreasing process, tube assemblies and other items that have irregular interior shapes should be power flushed with solvent that is provided directly from the vapor degreaser's still. Following the vapor degreasing and power flush treatment, if required, all solvent should be removed (see 4.5). The vapor degreasing process removes oils, grease, and other soluble organic contaminants from articles.

4.4.1.2 Alcohol Cleaning

Alcohols are a special category of solvent for cleaning oxygen equipment. Since it is used extensively and since there are many limitations and concerns with its use, this information is included. Alcohols refer to a general class of compounds with similar properties. The term "alcohol" is very widely taken by laymen to mean ethanol, which is one type of alcohol. Isopropanol (commonly called isopropyl alcohol and IPA), methanol (methyl alcohol), and ethanol (ethyl alcohol) are the most commonly used cleaning alcohols. Any solvent that is used for cleaning, including alcohol, should have an NVR lower than the NVR target to which the article is being cleaned. As a result, this disqualifies many industrial grades of alcohol, including those of a low grade purity, for oxygen cleaning. When using isopropyl alcohol, or any other solvent, the process should ensure that all surfaces are dried completely. When a solvent is used for external wipe applications, particularly outdoors, consideration needs to be given to whether the conditions of use will allow it to evaporate completely in a timely manner. The use of a lower grade of solvent to clean the exterior of equipment that does not contact the oxygen stream directly may be justifiable. If this is done, it is important that the people doing the work understand the difference between the precise material that is used for each of these purposes.

4.4.1.2.1 Special Considerations with Alcohol Cleaning

Laboratory tests by NASA show that alcohol is a poor solvent and does not effectively dissolve greases and contaminants commonly found on oxygen equipment. NVR hydrocarbon compounds and combustible hydrocarbon residue is left behind, increasing the possibility of fire and/or explosion. Even in minute amounts spontaneous combustion will occur with oxygen. Alcohol will not evaporate readily with colder temperatures. This leaves a sludge that takes a long time to evaporate. To counter this problem, a wipe cloth is recommended, but the effectiveness of this method is questionable. Alcohol can be used as a cleaning chemical in the shop, but its effectiveness outside is questionable. In the shop, a hot gas purge should be used to remove any residue. This is not practical to do outside or on the aircraft. Alcohol is also used as a deicer during the servicing of liquid oxygen at an aircraft. Precautions are necessary to remove any sludge to prevent it from coming into contact with the liquid oxygen. Alcohol-based cleaning agents should be used only with special precautions on oxygen equipment to carefully remove any residue and not contaminate any surfaces that may come in contact with oxygen. Alcohol is extremely flammable with a flash point of 56 °F. Also, alcohol dries slowly, and standard commercial and military grades of alcohol will have an excessive amount of NVR. This will be left behind on the surface posing a fire and explosion hazard. Grades of alcohol with a low amount of NVR (less than 10 ppm) are desired. Alcohol should be used with caution in confined spaces. Its vapors are toxic with a threshold limit value (TLV) of 400 ppm. Ensure adequate ventilation is provided or respiratory protection is necessary. Caution should be exercised when using alcohol to clean non-metallic materials. Elastomeric and plastic materials absorb solvents such as alcohol requiring careful drying procedures to prevent off-gassing flammable and toxic materials. Even Teflon, the most oxygen safe non-metal known, absorbs alcohol. Permanent damage to these materials may result. Ensure that the alcohol is compatible with the non-metallic material before its use is authorized.

4.4.2 Detergent and Water Cleaning

Detergent/water cleaning or aqueous cleaning is a process in which the articles to be cleaned are washed with a water soluble cleaner and water solution until free from oil, grease, and other contaminants. During the washing process, scrubbing with a soft brush or agitation of the solution may be required to facilitate the removal of contaminants. Following the cleaning process, all surfaces should be rinsed and dried (see 4.5). Refer to MIL-STD-1330 for detailed information to set up an aqueous cleaning operation. Aqueous cleaning methods are not acceptable for all oxygen equipment cleaning operations. For example, they will not be satisfactory as a hand wipe to clean oxygen components at the aircraft or for ground support equipment. Aqueous cleaning is best used in a controlled environment in recirculating and ultrasonic tanks. Additional tanks and hand held flushing wands may be desirable for additional cleaning capability and rinsing the articles. For example, water is forcibly flushed from a power wand through tubing to not only flush out contaminants, but to rinse out detergents and suds.

4.4.2.1 Ultrasonic Cleaning

Ultrasonic cleaning is a special type of aqueous cleaning process where high frequency vibrations are used to produce a cleaning action. Articles to be cleaned are placed in a screen basket and completely covered with liquid in an ultrasonic cleaning tank. The liquid can be a solvent or water and a soluble detergent solution depending on the type of ultrasonic equipment and the articles to be cleaned. Ultrasonic energy is then transmitted through the liquid in the tank to the articles in the screen basket resulting in a scrubbing action. It should be noted that the ultrasonic equipment, if improperly used, will not clean effectively. Following the cleaning process, all surfaces should be rinsed and dried (see 4.5).

4.4.2.2 Special Concerns on Ultrasonic Cleaning

Ultrasonic cleaners should operate at least in a frequency range of 25 to 100 kHz. This is necessary to clean articles when immersed to the capacity of the tank when using aqueous cleaning methods. Usually, the recommended ultrasonic tank temperature is 120 to 140 °F (49 to 60 °C). Higher temperatures may be considered at the discretion of the user; however, exposure times should be determined for each material cleaned and additional safety measures put in place for the user. Use of ultrasonic tanks with generator frequencies of less than 25 kHz should be avoided since cavitation damage to metals, including aluminum, may occur.

Cleaning articles in ultrasonic tanks should be limited to a minimum exposure of 5 minutes and a maximum exposure of 15 minutes. Exposures of less than 5 minutes will result in reduced soil removal performance. Exposures greater than 15 minutes show no significant soil removal benefit, and may risk soil redeposition and material degradation. Exposure duration should also consider the type of material being cleaned, and be verified by proven processes and cleanliness verification. Refer to ASTM G131 for additional information.

4.4.2.3 Water Purity

Demineralized or non-ionic water must be used for mixing with detergents and for rinsing purposes. Distilled water can be used, but this may not be cost effective for larger operations. Commercial water conditioning companies can economically install systems that provide demineralized or non-ionic water. A simple indicator may be used in line to determine water purity on an ongoing basis. An example is a light that indicates acceptable water purity. Tap water not conditioned is not considered acceptable as it usually contains much particulate material held in solution or suspension.

4.5 Methods for Rinsing and Drying

Water soluble cleaning agents should be removed by flushing with large quantities of distilled or de-ionized water. The recommended temperature range for the distilled or de-ionized water is 120 to 140 °F (49 to 60 °C).

Drying should be achieved by purging with dry, oil-free air or nitrogen, or heat in a temperature controlled oven at a temperature not to exceed 250 °F (122 °C). This method may be used after flushing water soluble cleaning agents with distilled or de-ionized water or to evaporate solvent cleaner from all surfaces.

Articles that have been cleaned or are in the process of being cleaned for oxygen service may be dried at any stage by using air or nitrogen provided that they are dry and oil-free. It is also recommended to use air that has been filtered (5 µm, nominal). Air that conforms to BB-A-1034, Grade A, or equivalent, meets all of these conditions. Nitrogen that conforms to A-A-59503, Class I, or equivalent, meets these conditions as well. Additionally, using heated air or nitrogen reduces the drying time.

Oven drying can be used in conjunction with an evacuation procedure on some equipment, such as cylinders. This method requires placing the unit in an oven, connecting it to a vacuum pump and then heating the unit during the evacuation process and maintaining the vacuum and temperature until the cleaning agent is removed. In no case should the temperature of the purging gas or oven temperature be so high as to have a deleterious effect on any material present.

Exposure duration to heat, during the drying process, should consider the type of material being dried.

5. CLEANLINESS INSPECTIONS AND TESTS

The following inspections and test methods can be used to determine article cleanliness. Some tests may be used for verification of the cleaning process and work area(s). These tests may also be used for special problems or concerns. The method(s) of cleanliness inspections and tests used should be established by the degree of cleanliness verification necessary to assure safety and reliability. In other words, reduction of particulate and combustible residue is necessary to preclude potential combustion hazards and malfunctioning of equipment clogged with residue. The application of the equipment is important in determining what cleanliness is necessary. Practical application and cost should be considered as long as safety is not compromised. The following test methods may be used for cleanliness verification. Additional inspections and tests may also be used at the discretion of the organization setting up the operation.

5.1 Cleaning Process Control

Often it is not practical or cost effective to perform cleanliness inspections and tests on every article. This is especially valid if an aqueous cleaning operation is established. The recommended approach in this case is to use precision tests to check samples of cleaned articles after initially establishing the cleaning process (see 5.1.1). Once the process is established, the validation frequency should meet all applicable requirements. Visual inspections between validations may be conducted as long as the process does not change. Any change to a cleaning process that may affect the cleanliness level achieved should be validated again.

It is likely that the process control will degrade with time. For example, the rinse water in a tank will gradually accumulate contamination and suds. This type of process control is further discussed in MIL-STD-1330. For this problem, the rinse water must be monitored and replaced when necessary. Samples of equipment should be subjected to precision tests to check the cleanliness level (see 5.1.2). The sample must be representative of the inspection or test used.

5.1.1 Process Qualification

A cleaning process should be qualified prior to the cleaning of any articles intended for use in an oxygen system. The procedure used to qualify a cleaning process should be documented in a Qualification Test Plan (QTP) and the results documented in a Qualification Test Report (QTR). The following are recommendations to consider when qualifying a cleaning process:

a. Document the requirements and the actions expected to meet these requirements in the QTP.

b. Document in the QTP how the cleaning process will meet all applicable requirements for the type of article cleaned and the challenge contaminates (e.g., particulates, oil, grease, etc. that represent contaminates that could be found in the article being cleaned). Document the cleaning agent used (including an analysis if applicable), fluids used for rinsing, gases used for drying, and any associated facility and equipment requirements.

c. If elevated temperatures will be used for drying, document in the QTP what will control the cleanliness of the equipment used for the drying, and the temperature and exposure time limits. Compare these controls against any associated requirements and verify that they have been met.

d. Document in the QTP how the cleanliness level will be verified.

e. Document in the QTP how the packaging materials (and any known properties) will be met. Consider how it will maintain the level of cleanliness of the article until use or installation.

f. Document in the QTP how any marking requirements will be met.

g. Record the results that verify that the requirements, both internal and external, have been met and document them in the QTR.

h. Use the QTR as a basis to establish procedures, requirements, and limits for a Sampling Plan to ensure that specified cleanliness levels of the articles will be achieved.

5.1.2 Sampling Plans

Sampling plans should only be considered after a process has been successfully proven and is under control, and should be used based on the requirements of the authority responsible for the cleanliness of the article. Examples of sampling plan requirements can be found in MIL-STD-1916, AS9138, or ANSI/ASQ Z1.4.

5.2 Visual Inspections

Visual inspections are usually the most common method of determining cleanliness. The best practice is the use of the white and black light visual inspections, as either one alone does not find all types of contamination. The wipe inspection is suitable for interior surfaces not easily inspected visually. Borescopes are also recommended to enable the inspector to see inside regions not easily accessible, such as cylinders.

5.2.1 White Light Inspections

Visual “daylight” inspection of all accessible surfaces which will be in contact with oxygen in service should be used to determine that there is no evidence of oxidation, scale, dirt, paints, preservative and organic materials such as grease, oil, ink, and dye. The presence of such deposits will necessitate recleaning of the article. Large articles should be tested at critical points along seams, joints, threads, outlets, etc., by wiping with clean filter paper. Discoloration due to welding, passivation, etc., will be permitted providing no scale or rust is associated with the discoloration. An article is visibly clean with the absence of all particulate and non-particulate visible to the normal unaided (and corrected vision) eye. If the area in question cannot be cleaned (welding marks, etc.) a determination will need to be made on a case by case basis as to whether the article is acceptable for production use. Particulate is identified as matter of miniature size with observable length, width, and thickness. Under proper illumination, the unaided eye should find particulate down to 70 µm. Magnification may be used if it is desired to find particulate to smaller size. Non-particulate is film matter without definite dimension. Inspection should be used to determine the maximum allowable particle size consistent with the specified particle size distribution as specified by the desired cleaning level (see Table 2).

5.2.2 Black Light or Ultraviolet Light Test

Ultraviolet light (wavelength 3200 to 3900 Angstrom units (320 to 390 nm)) will cause hydrocarbons to fluoresce. However, some contaminants, such as mineral oil, leave a residue which fluoresces weakly or not at all. The weight of the solvent residue should be checked in the solvent rinse test in addition to the ultraviolet light as a final check. Ultraviolet light inspections may be conducted in any dark location where an ultraviolet light source is set up. Small articles may be inspected in a closed box with a peephole, which shields the article from visible light. Any evidence of fluorescence should be cause for recleaning. If recleaning does not reduce the fluorescence, an investigation should be made to determine if the fluorescence is due to the contamination, to the properties of the material itself, or to the surface finish.

5.2.3 Wipe Inspection

The wipe inspection is made on each clean surface and normally on accessible interior surfaces of each article using a new clean cloth or filter paper. It is imperative that the wipe material be especially formulated for this purpose to preclude leaving any lint or paper deposits on the clean surface. This inspection should consist of at least two movements of the wipe material across the surface. There should be no discoloration of the filter paper when viewed by normal light and no fluorescence should be observed when the wipe material sample is subjected to the ultraviolet test. A representative sample of the wipe material should be checked for fluorescence prior to conducting this inspection to evaluate if it is suitable.

5.3 Cleanliness Verification Testing

Testing may be used to verify the cleanliness of an article that has been cleaned for oxygen service, and requires that a specific NVR Level or Particulate Level is met.

A test media is used to rinse the article's surface areas that will be in contact with oxygen. The test media should be suitable for this purpose and should not be the same solvent or agent used for the cleaning. The cleanliness level of the test media must be lower than the required cleanliness level of the article being tested, which can be verified by testing the test media. The cleanliness level of the test media is also referred to as the control sample, and must be calculated into the test result.

The ideal measurement of surface area to be tested is one square foot. The recommended volume of test media used for every square foot of surface area tested is 200 mL. If the surface area to be tested is not equal to one square foot, then the ratio of 200 mL/ft^2 (2153 mL/m^2) should be maintained. If desired, the test media used in the rinse can be divided into multiple portions for multiple measurements (see 7.4).

Articles of essentially equivalent configuration and size may be combined to provide the desired test media volume to surface area ratio as long as the articles have been cleaned to the same process.

5.3.1 Non-Volatile Residue (NVR) Test

NVR testing is used to verify the amount of non-volatile residue left after an article has been cleaned for oxygen service.

A clean, empty weighing dish is weighed using a high precision scale. The test media used for the rinse is placed in the weighing dish and then either evaporated or boiled off until no liquid remains, and the evaporation or boiling temperature used is a function of the test media used. This dish now represents the test sample of the article being tested. The difference between the weight of the empty dish and the test sample is the amount of residue collected from the test article. The amount of residue in the control sample should be subtracted from the amount of residue in the test sample to achieve the final result of NVR.

After the test, all surfaces should be dried immediately, unless there is a need for recleaning. If the NVR of the test media is greater than the required cleanliness level, then the article must be recleaned. Refer to ASTM G120, ASTM G136, and ASTM G144 for additional information.

5.3.2 Particulate Test

Should an increased level of assurance of an article's cleanliness be required, a particulate test may also be performed. Particulate testing may be performed using several methods, manually, automatically, or a combination of both.

The manual method for determining particle content requires that the test media used for the rinse is filtered through a membrane filter. The recommended pore size for the membrane filter is 1.2 µm or less. Once the filter has dried, the filter surface is inspected for the presence of particles using a precision microscope. The size and count of the particles present on the filter are manually identified by the test technician.

The automatic method requires the use of an automated liquid particle counter. The test media used for the rinse is placed into the counter and the particle sizes and counts are automatically identified by the counter. Typically, most counters come with a predetermined number of channels, where each channel can be programmed to measure for a particular size range. The channels should be programmed to meet the size ranges that meet the Particulate Level required (see Table 3).

Both methods may also be combined. A membrane filter is prepared in accordance with the manual method, and is then inspected using an automatic optical particle counter such as an automated microscope. The counter identifies the sizes and counts of the particles present on the filter.

5.4 Water Break Test

Many contaminants will not fluoresce. Their presence may be determined as follows. Place distilled water on the surface of the article being inspected. The water should remain as a film and not form drops for at least 10 seconds after application to indicate oil or grease free surface. Evidence of droplets or a water break will require recleaning of the article per the applicable procedure specified herein. Water should be dried from the test surface by blotting with a lint free cloth or by methods recommended in 4.5.