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Oxygen System and Component Cleaning and Packaging

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) provides recommended practices for cleaning aircraft oxygen equipment such as tubing, pieces parts (including regulator and valve parts), cylinders and ground-based equipment that may be used to support aircraft oxygen systems. These methods may apply to gaseous and liquid oxygen equipment. This document specifies work area details, methods to select suitable cleaning chemicals, cleaning methods, test methods to verify cleanliness level, and methods of packaging the components and parts after cleaning. Person designated to clean oxygen equipment should be qualified and trained to clean oxygen equipment. Cleanliness levels achieved are strongly dependent on the capabilities of the persons performing the cleaning operation.

1.1 Purpose:

The purpose of this document is to provide recommended methods to clean aircraft oxygen equipment and ground-based equipment to support aircraft oxygen systems. It is desirable to keep combustion hazards within an acceptable level of risk. Combustion hazards are discussed in AIR825/13. Even very small amounts of contamination can pose combustion hazards in oxygen equipment. Contamination may also cause improper operation of moving parts or block or restrict the flow of oxygen when the components are assembled. When oxygen parts and tubing are manufactured, hydrocarbon oils may be used. Parts may also collect contamination while in storage or shipment. Parts may have undesirable residue from corrosion treatments. When cleaned, parts may also have cleaning chemicals that may be combustible. All this contamination must be removed. This document outlines minimum accepted practices to clean oxygen parts. It is intended that oxygen equipment cleaning operations not only be suitable to preclude toxic and fire hazards, but also be cost effective.

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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR825/13	Guide for Evaluating Combustion Hazards in Aircraft Oxygen Systems
ARP598	The Determination of Particulate Contamination in Liquids by the Particle Count Method

2.1.2 ASTM Publications: Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM G 93	Standard Practice for Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments
ASTM G 120	Test Method for the Determination of Soluble Residual Contamination in Oxygen System Materials and Components by Soxhlet Extraction
ASTM G 121	Practice for Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents for Use in Oxygen-Enriched Systems and Components
ASTM G 122	Test Method for Evaluating the Cleaning Effectiveness of Cleaning Agents
ASTM G 127	Standard Guide for the Selection of Cleaning Agents for Oxygen Systems
ASTM G 128	Standard Guide for the Control of Hazards and Risks in Oxygen Systems
ASTM G 131	Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques
ASTM G 136	Standard Practice for the Determination of Soluble Residual Contaminants of Materials and Components by Ultrasonic Extraction
ASTM G 144	Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustor Analyzer

2.1.3 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

BB-A-1034	Air, Compressed, for Breathing Purposes
BB-N-411	Nitrogen, Technical
FED-STD-209	Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones
FED-STD-313C	“Material Safety Data" Transportation Data and Disposal Data for Hazardous Materials Furnished to Government Activities
MIL-D-16791	Detergents, General Purpose (Liquid, Non-Ionic)
MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program (Note: MIL-STD-1246 was made Inactive For New Designs June 15, 1998, but is still a valuable reference for any oxygen equipment cleaning operation)
MIL-STD-1330	Cleaning and Testing of Shipboard Oxygen, Nitrogen and Hydrogen Gas Piping Systems (Note: Only revision D and later revisions are applicable)
MIL-HDBK-407	Contamination Control Technology Precision Cleaning Methods and Procedures

2.1.4 NASA Publications: Available from NASA, Documentation, Marshall Space Flight Center, AL 35812.

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

2.1.5 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

2.2 Definitions:

AQUEOUS CLEANING: A cleaning process using clean non-ionic water to clean equipment. A cleaning agent maybe 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.

CLEAN: Cleaned to a specified cleanliness level by the removal of contaminants. Clean refers to the absence of scale, particulate, oil, and grease contaminants at 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.

CLEAN AREA: An enclosed working area employing control, as necessary, over the particulate matter in air with temperature, humidity, and pressure control. Flow control may also be used if a higher level of cleanliness is desired. Refer to Section 4 for clean area requirements.

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 all contaminants and loose particles.

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 items such as ventilation, filtration, temperature, humidity, pressure, personnel, clothing, and room maintenance. Refer to Section 4 for clean room requirements.

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.

2.2 (Continued):

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 are tubes, ducts, tanks, valves, actuators, reservoirs, and accumulators.

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

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 AREA: A controlled 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 areas are most often used for cleaning oxygen equipment where a high degree of cleanliness is necessary, but not so stringent as in a 100,000-class clean room. Refer to Section 4 for controlled 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, assembly and package oxygen equipment. There should be some control exercised over the room to maintain the cleanliness needed to clean to the levels needed. General clean rooms are the most commonly used areas or rooms to clean aircraft oxygen equipment. Refer to Section 4 for general clean room requirements.

GROSS CLEANING: Preliminary or rough cleaning to remove scale, rust, metal chips, dirt, etc. This cleaning is done in a normal work area to visual inspection standards. Gross cleaning is not appropriate to do 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.

2.2 (Continued):

NON-VOLATILE RESIDUE: The material remaining on the surface after evaporation of the solvent or volatile liquid is called non-volatile residue (NVR). This is also often referred to as the NVR cleanliness verification test.

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: That surface or part that comes in direct contact with oxygen in the equipment under consideration is referred to as that parts which sees oxygen service. This is also referred to as the wetted surface. In other words, it sees “oxygen service.”

PARTICULATE: A general term used to describe a finely divided solid of organic or inorganic matter, including metals. The population of a specific micrometer size usually reports these solids as the amount of contaminant. See ARP598 for particle size and population 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.

SOLVENT CLEANING: 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. Examples include halogenated solvents such as HCFC-141b, which is non-flammable, and hydrocarbon solvents such as isopropyl alcohol (IPA) which is very flammable.

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

3. CLEANLINESS LEVELS:

3.1 General Requirements:

All oxygen systems and components must be free of incompatible oils and grease, or any other combustible fluid or compound. Oxygen equipment types and minimum cleaning levels recommended are outlined in Table 1. The components must also be free of organic particles that can oxidize or react with oxygen and shreds of easily oxidizable metals, such as aluminum, magnesium, iron, lint, excelsior, shredded paper, or any other combustible material.

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.

3.3 Cleanliness Levels Applicable:

The cleanliness is classified by the NVR left behind. The goal in cleaning will be based on how much contamination is on the surface of the item after cleaning. For the purposes of cleaning aircraft oxygen equipment levels A, B, and C are used. Level A is 1 mg/ft^2. Level B is 2 mg/ft^2. Level C is 3 mg/ft^2. This has been a common designation used in the past to clean oxygen equipment. Note this is different as specified in ASTM G 93.

3.4 Equipment Classification:

Engineering must establish equipment categories to determine the appropriate cleanliness levels and facilities needed to clean the equipment. Cleaning facilities and methods for cleaning various categories of equipment are discussed in the following sections.

For the purpose of this standard, breathing oxygen equipment should be classified as follows:

Category 1 - Parts and assemblies exposed to oxygen pressures over 450 psi (3.1 MPa) or liquid oxygen.

Category 1A - Parts and assemblies that are at high risk. Past experience has shown fires and explosions.

Category 1B - Parts and assemblies that are at moderate risk. Past experience has shown no fires and explosions, but analytical evaluations point out that there is a potential for fire and explosions.

Category 1C - Parts and assemblies that are at low risk. Past experience has shown no fires and explosions, and analytical evaluations point out that there is a low potential for fire and explosions.

Category 2 - Parts and assemblies exposed to oxygen pressures from 10 to 450 psi (6.89 kPa to 3.1 MPa).

Category 3 - Parts and assemblies exposed to oxygen pressures up to 10 psi (6.9 kPa) (such as facemasks, large bore hose, oxygen masks and connector hoses, etc.).

Special conditions may apply. The equipment may be used on applications that are expensive. The equipment fire and explosion could result in catastrophic loss of life or air vehicle. It may be desirable to specify the more conservative category if these concerns apply.

3.5 Recommended Cleaning for Equipment Classifications:

Each classification of equipment need only be cleaned to the level recommended. Cleaning equipment to a higher cleanliness level when not needed may be a waste of time and money. On the other hand, some equipment must be cleaned more to keep combustion hazards within acceptable risks limits or to allow proper operation. The equipment classification methods given in 3.3 are intended to facilitate the choice of cleaning level needed. Table 1 outlines recommended cleaning levels for each equipment classification and the associated work area or clean room needed to do this task. This is primarily based on the combustion hazard concern. It should be noted however that Category 2 or 3 equipment might need to be cleaned to more stringent level to ensure proper operation and prevent blockage from occurring in small orifices or capillaries. For example, a breathing regulator is a Category 3 piece of equipment downstream of the pressure-reducing valve. The regulator may have capillaries that are so small that particulate or residue may block the capillaries restricting proper operation. In this case, cleaning to more stringent levels would be desired even though there is not the combustion hazard concern.

TABLE 1 - Recommended Cleanling Level and Work Area for Each Type of Equipment

Category	Pressure Level	Cleaning Level Recommended (Note 1)	Work Area Recommended (Note 2)
1A	450 psig and higher	50A or 100A	Class A, 100,000 (see 4.1)
1B	450 psig and higher	100A or 200A	Class A, 100,000 (see 4.1)
1C	450 psig and higher	300C	General Clean Room with a Localized Laminar Flow Bench
2	10 to 450 psig	Visibly Clean NVR of Level C	General Clean Room
3	10 psig and less	Visibly Clean	Controlled Area

NOTE 1: When specifying clean level such as Level 100A, the particulate level would be 100 with a NVR Level A. NVR of A means a non-volatile level of 1 mg/ft^2. NVR of C means a non-volatile level of 3 mg/ft^2. The particle sizes and counts for each clean level is specified in Table 2.

NOTE 2: See 4.1 through 4.1.7 for detailed information on work areas.

A NVR of A or B may not be practical, especially if it is decided that a NVR level of C is adequate to preclude all risk of combustion hazards or physical blockage within the equipment. The NVR level is not meaningful if it cannot be practically achieved and if it cannot be verified. The particle sizes and counts for each clean level is specified in Table 2.

TABLE 2 - Allowable Particle Sizes and Count Per Clean Level
Reference: NASA JSC/WSTF Specification No. 022

Clean Level	Micrometers (Note 1)	Particle Count
50	<15	Unlimited (Note 2)
	15 thru 25	17
	>25 thru 50	8
	>50	0
100	<25	Unlimited (Note 2)
	25 thru 50	68
	>50 thru 100	11
	>100	0
150	<50	Unlimited (Note 2)
	50 thru 100	47
	>100 thru 150	5
	>150	0
200	<50	Unlimited (Note 2)
	50 thru 100	154
	>100 thru 200	16
	>200	0
300	<100	Unlimited (Note 2)
	100 thru 250	93
	>250 thru 300	3
	>300	0

NOTE 1: Refer to the non-volatile residue test in 5.3 for details about how to determine the clean level on the equipment mentioned in this table.

NOTE 2: “Unlimited” means particulate in this size range is not counted; however, if the accumulation of this silt is sufficient to interfere with the analysis, the sample shall be rejected. 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. Furthermore, “silting” can interfere with the proper operation of a component. There is a limit on “unlimited”. The method of verification that the “unlimited” small particles not exceed recommended limits is the Non-Volatile Residue Test in 5.3.

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. Clean area or clean room.

b. Selecting suitable cleaning chemicals and substances.

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

d. Inspection of the parts and components cleaned to verify they are cleaned to the level desired.

e. Drying and purging the parts and components so that all cleaning substances and media (such as water that carries the cleaning substance if aqueous cleaning methods are used) are removed.

f. Verify that the cleaning substance(s) are also removed. (This is especially critical after the use of a precleaner if the substance is combustible in oxygen.)

g. Packaging the parts or components for removal or shipment to another area for reassembly or installation.

h. Assurances that precaution instructions are established to follow for safety and operations. For information regarding hazards with cleaning substances refer to the Material Safety Data Sheets (MSDS). Other production information may be available.

4.1 Clean Room and Controlled Area:

Oxygen equipment and parts should be properly cleaned and kept clean until reassembled or packaged. It is essential to maintain a controlled environment to prevent any contamination during cleaning, drying, assembly, testing and packaging. The cleaning of oxygen system components and assembling, testing, and packaging of these components should be cleaned in a controlled clean area or a clean room. In general the room 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 area characteristics that are very similar to that herein are discussed in MIL-STD-1330D is given in Table 3. These clean room characteristics will be consistent with standard clean rooms used throughout the world. A class 100,000 clean room in accordance with FED-STD-209 should only be used for critical applications. It could be cost prohibitive to use such a clean room for general purpose cleaning. It should be noted that the use of such a clean room class 100,000 means that the equipment must be assembled in a clean room of the same class. Any components open with surfaces that see oxygen service must be cleaned to the same level. Otherwise, the purpose of cleaning to this level may be negated. For all other applications, a general clean room should be used. A controlled area may be used for general-purpose components cleaning, precleaning and, in some cases, packaging.

TABLE 3 - Clean Room and Controlled Area Requirements

Attribute	References	Class 100,000 Clean Room	General Clean Room	Controlled Area
Structure	4.1.1, 4.2	Class A	Class B	Class C
Maintenance	4.1.2, 4.2	Class A	Class B	Class B
Average air temperature	4.1.3, 4.2	72 °F ± 5 °F	72 °F ± 10 °F	Uncontrolled
Average relative humidity	4.1.3, 4.2	30 to 50%	70% maximum	Uncontrolled
Air filtration	4.1.4, 4.2	Type A	Type B	Type B
Ventilation and air pressure	4.1.5, 4.2	Class A	Class B	Class C
Personnel clothing	4.1.6, 4.2	Class A	Class B	Class B
Tools and equipment	4.1.7, 4.2	-	-	-

4.1.1 Structure:

Class A:

All Class B requirements apply for Class A plus additional more stringent requirements. 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 FED-STD-209 class 100,000 or better. Refer to MIL-HDBK-407 for additional guidance.

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.

4.1.1 (Continued):

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. Refer to MIL-HDBK-407 for additional guidance.

e. 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 area should be eliminated before redesignation as a controlled area. Depending on the time and work involved for a particular operation, a controlled area should be one of the following:

a. Clean space located or set up adjacent to areas, which are non-contaminant producing.

b. 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 ft 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. Air movement within the confined area should be held to minimum.

c. 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.

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.

Class B:

a. Complete cleaning and wipe-down of equipment, tools, workbenches, counters, table tops, and fixtures with detergent solution and vacuuming and mopping of the floor should be accomplished at the end of each 8 h of operation. Also, this should be done prior to use if greater than 24 h has passed since the clean room was last used.

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

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 develop 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 personnel grooming is allowed. Drinking fountains are permissible.

g. Only oxygen approved lubricants should be stored and used. Items incompatible with oxygen such as hydrocarbon oil and grease and wood should not be stored or used.

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 charges 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 Air Filtration:

Type A:

The best commercial practice employing items such as high efficiency particulate air (HEPA) filters should be used to achieve and maintain a class 100,000 airborne particulate cleanliness level.

Type B:

Outside and recirculated air should be filtered to remove dust particles. Filter nominal rating should be less than 10 µm.

4.1.5 Ventilation and Air Pressure:

Class A:

The cleanest room should have a positive pressure of not less than 0.05 in of water above the ambient pressure. A differential pressure of not less than 0.01 in of water 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. Fully contained uninhabited areas such as glove bags should employ ventilation as necessary to prevent the introduction of contaminants.

4.1.6 Personnel Clothing:

Class A:

Strict control of personnel and their clothing is required to achieve and maintain a class 100,000 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 requisite for additional personnel and clothing requirements.

Class B:

a. All personnel including visitors and observers should wear clean undamaged coveralls or smocks, without buttons, exposed zippers, keys, and similar articles. Clothing should not be worn open or worn outside of the clean room or controlled area.

b. Where dirt 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, 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. 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.

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 equipment. Tools used on oxygen equipment should be dedicated to that purpose and not used for any other purpose. Where the configuration of the tool 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. It is not desirable to use any pencils or erasers in the clean area as this adds particulate to the air.

4.2 Other Special Considerations for Work Areas:

The above discussion covered general considerations for different types of oxygen equipment work areas. 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 shall be lighted to at least 100 lm on the work surface. Specials lighting may be required for inspections for cleanliness.

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

4.2.1 Ventilation: Forced filtered air is preferred. Filtration shall remove all airborne particles (for high level of cleanliness, it should remove over 100 µm size particles). Filtration or equivalent ventilation may be used, provided airborne particle size is limited to less than 100 µm size. The concentration of airborne particles shall be held to the minimum possible.

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

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

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

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

4.2.5 Storage Areas: Storage areas shall have easily cleaned surfaces.

4.2.6 Cleaning Work Areas: Work area, benches, floors, and storage areas shall be vacuum cleaned with adequate filtration daily. Airborne particle size shall be checked with standard test equipment often enough to prove the airborne particle size in the general work area is less than that desired, for example, 100 µm.

4.2.6.1 Laminar Flow Benches: Laminar flow benches may be a very cost-effective method to clean and assemble smaller parts in a structure that does not meet the requirement for cleaning. Essentially, a laminar flow bench achieves cleanliness levels one-step better than the structure in which it is included. For example, Class 100,000 clean levels may be achieved in a general clean room and general clean room levels may be achieved in a controlled area. That is, of course, dependant on the work area. If high levels of dust or particles are in the controlled area, these can penetrate the laminar flow on the workbench.

4.2.7 Tools and Solvent Storage: Tools used for handling oxygen components shall be kept in a clean condition at all times. Solvents, cleaners, or other equipment not related to the immediate work effort shall be kept away from the work area.

4.2.8 Work Clothes and Rules: All personnel should wear minimum lint producing clothes. (Angora, wool, and other fuzzy sweaters shall be prohibited.) There should be no smoking or eating in the work area. Parts should be transported and cleaned in lint-free containers. Lint producing cloths, wipers and dunnage shall be prohibited in the work area. Hands must be clean and free of hand creams and other combustible products. Worker's hair should be free of flammable hair sprays. Outside personnel traffic through the area should be prohibited.

4.3 Selecting Suitable Cleaning Chemicals and Substances:

The function of a cleaning agent is to assist in the removal of contaminants (organic and inorganic material) without degrading the parts be cleaned. It is also very desirable that the cleaning substances pose no hazard to the personnel who will be performing the operations. In the past, many cleaning substances have been banned from use because of the excessive level of hazard to personnel. The broad categories of cleaning chemical are solvent types and aqueous types. The methods of cleaning, the equipment required and to some degree the verification of cleanliness will be very different for solvent based cleaning than for aqueous cleaning. At this time the federal government and local government has rules and restrictions for chemicals used. One big concern is that ozone depleting substances (ODS) used follow all federal regulations. Many ODSs have been and are being phased out for use. In 1996 the production of the popular cleaning solvent CFC-113 was ceased and the only CFC-113 solvent available now is that stockpiled and recycled. Another big concern is that the waste products from the cleaning operations not adversely impact the environment to which it is disposed. It is the responsibility of the organization intending to establish a cleaning operation to ensure that all federal and local rules for chemicals used and disposal is followed.

A good cleaning agent should:

a. Effectively remove all expected contaminants.

b. Effectively remove all particulate (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 materials being cleaned.

4.3 (Continued):

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

g. Follow all federal and local regulations for use and disposal.

ASTM G 127 discusses further details on the methodology for solvent selection.

4.3.1 Cleaning Agents: Many cleaning substances are under consideration for use to clean oxygen equipment. Only a few are mentioned herein. It is the responsibility of the organization setting up the cleaning operation to determine what cleaning substance(s) best suit their purposes. The activity purchasing the oxygen equipment or requesting the cleaning may have special needs or requirements that need to be satisfied. Currently, the Federal Aviation Administration does not certify cleaning chemicals or operations for commercial oxygen equipment, but the military does on a limited basis. The cleaning agent, if a solvent, must have a non-volatile residue of less than the cleanliness level desired. If an aqueous or solvent cleaner, then the cleaning agent and included chemicals must not leave residue or surface film that would be cause for rejection of the cleanliness level of the part

The following ASTM standards will assist to choose a suitable cleaning substance: ASTM G 93, ASTM G 120, ASTM G 121, ASTM G 122, ASTM G 127, ASTM G 128, ASTM G 131, ASTM G 136, ASTM G 144.

4.4 Selecting the Proper Cleaning Method:

There is no single method of cleaning which will completely remove all types of contaminants. Also, it must be clearly understood that, 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 chemical. Aqueous cleaning is much different than solvent cleaning. It is desired to refer to the cleaning chemical manufacturer's recommended practices before establishing the cleaning method. The cleaning method chosen should bring a reliable cleaning agent in contact with all surfaces to be cleaned for sufficient length of time and in such manner as to remove all contaminants. 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 part 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 damage to parts and finishes.
f. Facilities available for cleaning and level of cleanliness desired
g. Rinsing requirements, if any, and drying requirements.

4.4.1 Composition of the Part to be Cleaned: The function of a cleaning agent is to assist in the removal of contaminants without attacking the material of the part being cleaned or leaving irremovable 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 part being cleaned. Cleaners suitable for use on one material may react with another material. For example, when cleaning metal parts 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 susbstances affects on cleaning metals and non-metals. Additional information may also be available from the cleaning chemical supplier.

4.4.2 Complexity of Construction: Parts or assemblies of complex construction which may trap portions of the cleaning fluid or residue that can not 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 residues may be trapped in inaccessible 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 parts shall be packaged, cleaned and marked “Oxygen Cleaned” to protect against recontamination. Clean parts or components removed from a system should be packaged immediately or cleaned again before reinstallation.

4.4.3 Properties of the Cleaning Agent: The cleaning agent should have properties, which make it useable with the cleaning materials, and equipment that are available. For example, a solvent that would be suitable for cleaning by immersing or scrubbing may not be suitable for vapor degreasing.

4.4.4 Limitations of the Cleaning Agents: Many cleaning agents have limitations such as damage to parts and finishes. Often 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 would be desirable to establish if the cleaning agent can be used for the materials under consideration.

4.4.5 Rinsing Requirements, if any, and Drying Requirements: Water soluble cleaning agents should be removed by flushing with large quantities of distilled or de-ionized water. After flushing, dry thoroughly by purging with dry, oil-free air conforming to BB-A-1034 or dry, oil-free nitrogen conforming to BB-N-411, Type I, Class I, Grade B or heat in a temperature controlled oven at a temperature not to exceed 250 °F (122 °C). Solvent cleaner should be evaporated from all surfaces by purging with warm, dry, filtered, oil-free air or nitrogen or oven dried. 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.

4.5 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.

4.5.1 Solvent Cleaning: The solvent cleaning process removes soluble organic contaminants and particulate matter by evaporation. After reacting with the solvent, the contaminants are taken away with the solvent on evaporation. Use an oxygen compatible solvent at ambient temperatures to thoroughly wash all surfaces requiring degreasing and cleaning. During the washing process, scrubbing with a soft brush or lint free cloth may be required to facilitate the removal of the contaminants. After cleaning the component, rinse or flush with additional clean solvent. In special situations where it is desired to keep the solvent away from the surrounding components, the solvent should be put onto the brush or lint free cloth. Following the cleaning process, all residual solvent should be removed by air drying or purging with a dry filtered, preferably hot, oil-free air or nitrogen, or by evacuation.

4.5.1.1 Vapor Degreasing: The 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. Parts 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 by purging with filtered, dry, oil-free air or nitrogen; or by evacuation. The vapor degreasing process removes oils, greases and other soluble organic contaminants from components. As an aside, it has been found that that solvents commonly used on oxygen equipment like CFC-113 does not effectively vapor degrease. 1,1,1 Trichloroethane (TCA or Methyl Chloroform) is a vapor degreasing chemical choice that is most effective. Any new cleaning chemical developed should vapor degrease as effectively as 1,1,1 Trichloroethane. CFC-113 and 1,1,1 Trichloroethane are ODS and production of these chemicals is currently banned.

4.5.1.2 Alcohol Cleaning: Alcohol's are a special category of cleaning oxygen equipment. Since it is extensively used 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 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. Commercial and military grades of alcohol with NVR of greater than 10 ppm may be used to clean exterior surfaces only of oxygen equipment provided special precautions are taken to avoid contact with any surfaces that may contact liquid or gaseous oxygen. Isopropanol is used as a deicer and degreasing chemical by a number of organizations to clean and degrease aircraft oxygen equipment. Testing has shown that this is not a desirable solvent for use on oxygen equipment. Should any cleaning of components with IPA that have surfaces which contact oxygen be done, extreme precautions must be taken to dry and purge the components to ensure removal of all the IPA which contains hydrocarbons and is extremely dangerous in contact with liquid and gaseous oxygen. It may be desirable to bake components in ovens to ensure of complete drying. Methanol and Ethanol alcohol's have the same concerns.

4.5.1.2.1 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. Not only will a combustible hydrocarbon residue be left behind, but also the combustible contaminants intended to be cleaned. This increases the risk of a fire and explosion. Also, NVR hydrocarbon compounds are left behind. Even in minute amounts spontaneous combustion will occur with oxygen. Alcohol will not evaporate readily with colder temperatures. This will leave a sludge behind that will take 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 very 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 and keep it from contacting the liquid oxygen. This cleaning chemical 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 in comparison to CFC-113 dries very 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 CFC-113 and alcohol requiring careful drying procedures to prevent off-gassing flammable and toxic materials. Even Teflon, the most oxygen safe non-metal known, absorbs solvents. Permanent damage to these materials may result. Ensure that the alcohol is compatible with the non-metallic material before its use is authorized.

4.5.2 Detergent and Water Cleaning: Detergent/water cleaning or aqueous cleaning is a process in which the components 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 thoroughly with clean, hot, distilled or de-ionized (non-ionic) water until all residues of the cleaning agent are removed, and dried by blowing with filtered, dry, oil-free air or nitrogen or by oven drying until all liquid is removed. Refer to MIL-STD-1330D 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 parts. 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.

4.5.2.1 Ultrasonic Cleaning: Ultrasonic cleaning is a special type of aqueous cleaning process where high frequency vibrations are used to produce a cleaning action. Items 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 items to be cleaned. Ultrasonic energy is then transmitted through the liquid in the tank to the items 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 operation, all solvent should be removed by purging with hot, dry filtered, oil-free air or nitrogen. Water and detergent solution should be removed by a distilled or de-ionized (non-ionic) water rinse followed by purging.

4.5.2.2 Special Concerns on Ultrasonic Cleaning: Ultrasonic cleaners should operate at least in a frequency range of 25 and 100 kHz and have a power range at least 3 W/in^2. This is necessary to clean parts and tubing when immersed to the capacity of the tank when using aqueous cleaning methods. (Note: This power may vary because ultrasonic cleaning tanks may have been designed for use with fluids that use a combination of agitation and vapor degreasing. In other words aqueous cleaning will not be as efficient.) Usually, the recommended ultrasonic tank temperature is 140 to 180 °F. 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 of components and parts in ultrasonic tanks should be limited to a minimum exposure of 5 min and a maximum exposure of 15 min. Exposures of less than 5 min will result in reduced soil removal performance. Exposures greater than 15 min show no significant soil removal benefit, and may risk soil redeposition and material degradation. Refer to ASTM G 131 for additional information.

4.5.2.3 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. Tap water not conditioned is not considered acceptable as it usually contains much particulate material held in solution or suspension.

5. CLEANLINESS INSPECTIONS AND TESTS:

The following inspections and test methods can be used to determine item 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, freedom from particulate and combustible residue is necessary to preclude potential combustion hazards and malfunctioning of equipment clogged with residue. The application and category of equipment is important in determining what cleanliness is necessary. Cleaning and verification of clean is not an exact science. Much past experience has been relied upon to determine how clean each category of equipment must be. Practical application and cost must always be traded against the degree of cleanliness considered necessary. On the other hand, loss of aircraft and life must always be our greatest concern. For each category of oxygen equipment, the following test methods are considered the minimum necessary for cleanliness verification. Additional inspections and tests may be used at the discretion of the organization setting up the operation.

5.1 Cleaning Process Control and Sampling Plans:

Often it is not practical or cost effective to do cleanliness inspections and tests on every part or component. This is especially valid if an aqueous cleaning operation is established. The recommended approach in this case would be to use precision tests to check samples of equipment after initially establishing the cleaning process. Once the process is established, then only visual inspections need be conducted. 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 may be monitored and replaced when necessary. It is appropriate that periodic verification of cleanliness is needed. In this case, samples of equipment shall be subjected to precision tests to check the cleanliness level. The sample must be representative of the inspection or test used. For example, if a non-volatile residue test is used, the surface area of all the equipment in the sample must be a minimum of 1 ft^2. If other tests are done based on a representative sample then the sample must be large enough based on the number of items cleaned to do a realistic check for process control and no degradation of cleanliness.

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 easliy visually witnessed. 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 rust, scale, dirt, paints, preservative and organic materials such as grease, oil, ink, and dye. The presence of such deposits will necessitate cleaning again of the part. Large items should be tested at critical points along seams, joints, threads, outlets, etc., by wiping with clean filter paper. Discoloration due to welding and passivation will be permitted providing no scale or rust is associated with the discoloration. An item is visibly clean with the absence of all particulate and non-particulate visible to the normal unaided (except corrected vision) eye. 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 50 µm. Magnification may be used if it is desired to find particulate to smaller size. Non-particulate is film matter without definite dimension. Note that the non-volatile residue test does not determine non-particulate film and therefore a visual inspection is considered desirable even if the NVR test is used. 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) will cause hydrocarbons to fluoresce. However some contaminants such as mineral oil, or animal and vegetable fats 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 parts may be inspected in a closed box with a peephole, which shields the part from visible light. Any evidence of fluorescence should be cause for cleaning again. If cleaning again does not reduce the fluorescence, an investigation should be made to determine whether the fluorescing materials are contamination or the property of the material or surface finish.

5.2.3 Wipe Inspection: The wipe inspection is made on each clean surface and normally accessible interior surface of each component 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 is 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 used should be checked for fluorescence prior to conducting this inspection to evaluate if it is suitable.

5.3 Non-Volatile Residue (NVR) Test:

Rinse the equipment surfaces with a solvent suitable for this purpose. The volume of fluid used should be 200 mL/ft^2 of surface area and in no case less than 150 mL. One-half of the solvent used for the rinse should be used for determining the weight of residue and the other half can be used for determining the particle content. The weight of residue is determined by separately evaporating to dryness one-half of the solvent used for the rinse and an equal amount of clean solvent. The evaporation temperature used is a function of type of solvent or solvent blend used. The residue from the solvent used for the rinse should not exceed that of the clean solvent by more than the following:

TABLE 4 - Cleaning Level Thresholds Applicable to the NVR Test

Cleanliness Level	Surface Area Cleaned (grams per square meter)	Surface Area Cleaned (grams per square foot)
Level A	0.01076	0.001
Level B	0.02153	0.002
Level C	0.03229	0.003

Not less than 1 ft^2 of surface area will be required for these tests. Washings from items of essentially equivalent configuration and size may be combined to provide the solvent volume to surface area ratio specified. After the inspection, all surfaces shall be dried immediately unless there is a need for cleaning again. Note that the non-volatile residue content of the solvent used must be low and calculated into the cleanliness tests. If the non-volatile residue of the solvent is greater than the level being cleaned, then after the test the part must be cleaned again. Refer to ASTM G 120, ASTM G 136 and ASTM G 144 for additional information.

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 gauge. 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 it's 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 to the atmosphere are very minimal compared to other ODSs.