Langley Research Center

LPR 1740.5 G

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LANGLEY RESEARCH CENTER STANDARD FOR PRECISION CLEANING AND TESTING OF SYSTEMS AND EQUIPMENT

Responsible Office: Safety and Mission Assurance Office

National Aeronautics and Space Administration

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PREFACE

P.1 PURPOSE

a. This Langley Procedural Requirement (LPR) establishes precision cleaning levels, processing, handling, cleaning, test methods, packaging, protection, and inspection procedures for critical surfaces of fluid systems and equipment at Langley Research Center (LaRC).

b. This LPR shall be used for cleaning equipment for oxygen service, including parts, components, assemblies, and subsystems, and other services requiring a similar degree of cleanliness.

c. This LPR does not apply to the cleaning of oxygen breathing equipment.

Note: If cleaning is required for oxygen breathing equipment, contact the LaRC Oxygen Working Group for assistance.

P.2 APPLICABILITY

a. These requirements apply to all persons performing work at LaRC, including civil servants, contractors, research associates, and others.

b. Non-compliance with this LPR will result in appropriate disciplinary action that may include termination for a civil servant employee or exclusion from the Center for a contractor employee, research associate or others.

c. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.

d. In this directive, all document citations are assumed to be the latest version, unless otherwise noted.

P.3 AUTHORITY

a. Occupational Safety and Health Standards, 29 CFR pt. 1910.

b. Compressed gases standard, 29 CFR 1910.101.

c. Oxygen standard, 29 CFR 1910.104.

d. Hazardous Materials Regulations, 49 CFR pts. 171-180.

P.4 APPLICABLE DOCUMENTS

a. Occupational Safety and Health Standards, 29 CFR pt. 1910.

b. Protection of Environment, 40 CFR.

c. Transportation, 49 CFR.

d. LPR 1710.40, Langley Research Center Pressure Systems Handbook.

e. LPR 1740.2, Facility Safety Requirements.

f. LMS-CP-4759, Acquisition of Hazardous Materials.

g. NASA-STD-6001, Flammability, Offgassing, and Compatibility Requirements and Test Procedures.

h. JSC-SPEC-C-20, Water, High Purity Specification for.

i. JSC-20584, Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants.

j. KTI-5210, Material Selection List for Oxygen Service.

k. KTI-5212, Material Selection List for Plastic Films, Foams, and Adhesive Tapes.

l. MPCV 70156, Cross Program Fluid Procurement and Use Control Specification.

m. LF 615, LaRC Request for Cleaning.

n. MIL-C-81302, Cleaning, Compound, Solvent, Trichlorotrifluoroethane.

o. MIL-E-17555H (2), Electronic and Electrical Equipment, Accessories, and Provisioned Items (Repair Parts): Packaging of.

p. MIL-PRF-27401, Propellant Pressurizing Agent, Nitrogen.

q. MIL-STD-129, Military Marking for Shipment and Storage.

r. MIL-STD-2073, Standard Practice for Military Packaging.

s. MIL-STD-889, Dissimilar Metals.

t. A-A-1689, Tape, Pressure-Sensitive Adhesive (Plastic Film).

u. A-A-3174, Plastic Sheet, Polyolefin.

v. ASTM D1193, Standard Specification for Reagent Water.

w. ASTM D1414-15, Standard Test Methods for Rubber O-Rings.

x. ASTM D471-16a, Standard Test Method for Rubber Property-Effect of Liquids.

y. ASTM D4081, Standard Specification for Drycleaning-Grade Perchloroethylene.

z. ASTM D4376, Standard Specification for Vapor-Degreasing Grade Perchloroethylene.

aa. ASTM F312-97 (2003), Standard Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters.

ab. ASTM G93, Standard Practice for Cleaning Methods and Cleanliness Levels for

Material and Equipment Used in Oxygen-Enriched Environments.

ac. ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation.

ad. ISO 14644-1, Cleanrooms and Associated Controlled Environments – Part 1: Classification of Air Cleanliness by Particle Concentration.

ae. ISO 14644-2, Cleanrooms and Associated Controlled Environments – Part 2: Monitoring to Provide Evidence of Cleanroom Performance Related to Air Cleanliness by Particle Concentration.

af. NFPA 53, Recommended Practice on Materials, Equipment, and Systems Used in Oxygen Enriched Atmospheres.

ag. SAE AMS3647, Polyfluoroethylene Propylene Film and Sheet.

ah. SAE AMS3649, Film, Polychlorotrifluoroethylene (PCTFE) Unplasticized.

P.5 MEASUREMENT/VERIFICATION

None.

P.6 CANCELLATION

None

Trina M. Dyal 9/27/24

Deputy Director Date

DISTRIBUTION:

Approved for public release via the Langley Management System; distribution is unlimited.

CHAPTER 1. INTRODUCTION

1.1. GENERAL

1.1.1. All parts, components, assemblies, subsystems, systems, or related equipment requiring cleaning shall be disassembled, cleaned, and inspected in accordance with this Langley Procedural Requirement (LPR).

1.1.2. All in-house cleaning at LaRC shall use approved solvents per Section 2.7.3, Table 2 and cleaning agents per Section 2.7.4, Table 3.

1.1.3. All cleaning shall use final cleaning verification solvents and cleaning agents that are compatible with oxygen service and meet the final cleaning level requirements as defined in the LPR, and as specified by specification, task, contract, or work order, subject to final verification by the Government.

1.1.3.1. Initial and intermediate solvents that are not oxygen compatible shall only be used as long as the final cleaning verification fluid is oxygen compatible with the materials being cleaned.

1.1.3.2. Contractors other than those performing cleaning at the Component Cleaning Lab (CCL) in Building 1188 shall provide a cleaning procedure submittal for Government approval prior to cleaning.

Note: The CCL operates with approved Standard Operating Procedures (SOPs) and solvents.

1.2. REQUEST FOR CLEANING

1.2.1. A Langley Form (LF) 615, “LaRC Request for Cleaning,” shall be filled out for all parts and components to be cleaned at the CCL.

1.2.2. Work requests for cleaning in accordance with the requirements of this LPR shall specify the following:

a. Title, number, and date of the specification;

b. Cleanliness level and testing procedure required;

c. Whether preproduction approval is required (see Section 2.10.3);

d. Whether functional testing is required on items disassembled for cleaning (see Section 3.9); and

e. Whether special preservation, packaging, packing, and marking are required beyond the requirements of Chapter 2.

1.3. QUALITY ASSURANCE

Quality assurance provisions for inspection and testing for the acceptance of parts, components, assemblies, subsystems, systems, and other related equipment that have been cleaned to a specific level of cleanliness shall be as specified in Chapter 3.

1.4. ENVIRONMENTAL, HEALTH, AND SAFETY

1.4.1. This LPR allows the use of materials, processes, and equipment that may be hazardous, toxic, and/or detrimental to the environment. This LPR does not address all of the environmental, health, or safety problems associated with the use of these materials, processes, and equipment.

1.4.2. It shall be the responsibility of the user of this LPR to review pertinent Safety Data Sheets (SDS), material specifications, and work instructions to ensure safety of personnel and protection of the environment and facilities in fulfilling the requirements of this specification. All materials and processes required to fulfill the requirements of this LPR shall be subject to applicable Federal, State, and Local environmental, health, and safety regulations, standards, codes, and operating procedures (e.g., work instructions).

1.4.3. It shall be the responsibility of the performing organization to determine and establish the appropriate environmental, health, and safety practices that are in compliance with all applicable regulations. Questions regarding these activities, including air emissions, spills, solid and hazardous waste inventory, storage, removal, disposal, discharges, and waste minimization (e.g., recycling), shall be referred to the Center Operations Directorate's Standard Practice and Environmental Engineering Branch.

1.4.4. All work on systems requiring confined space entry shall be in accordance with LPR 1740.2, "Facility Safety Requirements."

1.5. HIGH-PRESSURE SYSTEMS

1.5.1. High-pressure systems constitute a hazard in themselves in addition to the hazards involved when hydrocarbons or other contaminants are present in an oxygen-rich environment. The failure of a container charged with high-pressure gas can result in an explosion and fragmentation of the container. Additional information about high-pressure systems can be found in LPR 1710.40, "Langley Research Center Pressure Systems Handbook."

1.5.1. High-pressure gases shall receive particular attention to ensure a safe system. As a gas is compressed, energy is added, and it heats due to several factors, i.e., compression and frictional forces associated with container boundaries. If a hydrocarbon lubricant is present in an oxygen-rich system, a condition is approached similar to that found in diesel engines and ignition can occur. Consequently, the only way to eliminate the possibility of ignition, fire, and explosion is to eliminate the fuels in high-pressure, oxygen-rich, gas systems.

1.6. NOISE

Noise associated with "bleed off" or pressure relief of high-pressure gas reservoirs through a small orifice can reach sound pressure levels of sufficient intensity to cause acute damage to the ear with a resultant loss of hearing. Since acoustical control of this noise is impractical, personnel shall wear hearing protection when exposed to hazardous noise levels.

1.7. VAPOR CONCENTRATION

1.7.1. The chemicals prescribed in this LPR shall be stored in ventilated areas.

1.7.2. If large amounts of cleaning chemicals or solvents are permanently stored in an inhabited work area, chemical sensors shall be installed.

1.7.3. The user shall refer to the appropriate Safety Data Sheet for additional information on hazards and required protection for any chemical prescribed in this LPR.

1.7.4. Unprotected workers (i.e., workers not wearing personnel protective equipment) shall not exceed the permissible exposure limit (PEL) at any time.

1.7.5. Although normal air movement is usually sufficient to keep vapors below this threshold limit, the atmosphere shall be monitored in the work area to ensure that safe limits are not exceeded.

1.7.6. Additional ventilation may be required to maintain exposure levels below allowable limits. If necessary, airline respiratory protection shall be used.

1.8. HAZARDOUS MATERIALS

1.8.1. The user shall adhere to LMS-CP-4759 “Acquisition of Hazardous Materials.”

1.8.2. The user shall ensure accurate hazardous material data and inventory information of the chemical(s) being used are in the Chemical Material Tracking System (CMTS).

1.8.3. All employees who routinely work in a facility shall be aware of the physical and chemical hazards of the materials with which they routinely work or may encounter in the facility in any foreseeable emergency (prior to use).

1.9. WASTE MINIMIZATION (RECYCLING)

It shall be the user's responsibility to implement waste reduction practices. Materials, especially test fluids, shall be recycled where applicable. Test fluids shall be considered as in-process recyclable materials as long as the nonvolatile residue (NVR) level does not exceed 200 milligrams per liter (mg/L). Test fluids with NVR levels in excess of 200 mg/L shall be made available for other reuse/recycling activities or disposed of in accordance with applicable Federal, State, and Local regulations.

1.10. TRAINING

1.10.1. Cleaning, disassembly, and assembly operations on components shall be performed only by competent personnel who have been trained and certified to perform these functions.

1.10.2. Personnel shall be properly trained in the use of oxygen and oxygen systems and be familiar with the following:

a. Personnel who handle and use oxygen or design equipment for oxygen systems shall be familiar with its pertinent physical, chemical, and hazardous properties.

b. Personnel shall know what materials are compatible with oxygen and the cleanliness requirements of oxygen systems.

c. Personnel shall be thoroughly familiar with oxygen system fire hazards and the associated system barriers, controls, and interlocks to avoid or limit damage and injury from fires.

1.10.3. The processing organization or contractor shall ensure that all personnel responsible for contamination control functions are trained as required to ensure proficiency within their assigned task.

1.10.4. The processing organization or contractor shall establish a personnel certification process with traceable documentation.

CHAPTER 2. REQUIREMENTS

2.1. GENERAL

2.1.1. Assembled component flushing by LaRC in-house personnel with Freon 113 shall be used for precision cleanliness verification only as long as all components, lubricants, and soft goods are compatible with Freon 113. If the flush verification shows the component to be contaminated then disassembly shall be required for cleaning.

2.1.2. All parts or components that might be damaged during cleaning shall be removed, disassembled, and cleaned as separate items.

2.1.3. Cleaning or disassembly operations on components shall be performed only by competent personnel who have demonstrated the capability of performing the necessary operations.

2.2. CLASSIFICATION OF CLEANLINESS LEVELS

2.2.1. Cleanliness levels are listed in Table 1, particulate matter contamination levels are listed in Table 1A, nonvolatile residue (NVR) contamination levels are listed in Table 1B, and visible contamination levels are listed in Table 1C.

2.2.2. The following facilities at LaRC shall have a standard product cleanliness level of 300A for oxygen systems:

a. 8-Foot High Temperature Tunnel, Building 1265.

b. Direct Connect Supersonic Combustion Test Facility, Building 1221.

c. Component Verification Facility, Habco Oxygen Clean Test Stand (HOCTS), Building 1267.

2.3. NON-PRECISION CLEANLINESS LEVELS

2.3.1. GC (generally clean) is freedom from manufacturing residue, dirt, oil, grease, scale, processing debris, or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. Parts subjected to chemical cleaning (e.g., passivation, electropolishing, alkaline cleaning) are also considered GC. This level shall not be designated for hardware or systems that are sensitive to contamination. GC is the only cleanliness level that does not require items to be packaged.

2.3.2. VC (visibly clean) is the absence of all particulate and non-particulate matter visible to the normal unaided (except corrected-vision) eye. Particulate is identified as matter of size with observable length, width, and/or thickness. Non-particulate matter is normally a film or residue without definite dimension. Scale free discoloration due to surface treatments (e.g., passivation, anodizing, etching) or

thermal processes (e.g., welding, heat treatments) is permitted. Level VC is commonly referred to as “commercially clean.”

2.4. PRECISION CLEANLINESS LEVELS

2.4.1. UV (Visibly Clean plus Ultraviolet) VC (as defined above) shall be inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 angstroms wavelength (3.2 x 10-7 to 3.8 x 10-7 meters). This level requires precision-cleaning methods but no particle count. Any visible contamination or fluorescence shall be cause for re-cleaning. If re-cleaning fails to remove or reduce fluorescence, an investigation shall be made to determine whether the fluorescing material is contamination or the basic material is naturally fluorescent. Some acceptable materials may fluoresce (e.g., anodizing or chemical films). Fluorescence is a possible indicator of hydrocarbon contamination; however, inspection under ultraviolet light will not detect all types of oils and greases.

2.4.2. Level 1000 is the lowest precision-cleaning level that requires a sample fluid flush for cleanliness certification (i.e., qualitative particle count).

Table 1, Classification of Surface Cleanliness Levels.

(Table 1A) Particulate Matter Contamination Levels			(Table 1B) NVR Contamination Levels		(Table 1C) Visible Contamination Levels	
Level	Particle Size Range (micrometer)	Maximum Number of Particles per 0.1 m^2	Level	Maximum quantity of NVR (mg. / 0.1 m^2)	Level	Definition
25	<5 5 to 15 >15 to 25 >25	**Unlimited*** 19 4 0	A	1.0	GC (Generally Clean)	Freedom from manufacturing residue, dirt, oil, grease, etc.
50	<15 15 to 25 >25 to 50 >50	**Unlimited*** 17 8 0	B	2.0	VC (Visually Clean)	The absence of all particulate and non-particulate matter visible to the normal unaided eye or corrected-vision eye.
100	<25 25 to 50 >50 to 100 >100	**Unlimited*** 68 11 0	C	3.0		
150	<50 50 to 100 >100 to 150 >150	**Unlimited*** 47 5 0	D	4.0		
200	<50 50 to 100 >100 to 200 >200	**Unlimited*** 154 16 0	E	5.0	UV (Visually Clean Plus Ultraviolet)	Visually clean and inspected with ultraviolet light.
250	<100 100 to 200 >200 to 250 >250	**Unlimited*** 39 3 0	F	7.0		
300	<100 100 to 250 >250 to 300 >300	**Unlimited*** 93 3 0	G	10.0		Notes Allowable particulate and NVR are based on 0.1 m^2 (1 ft^2) Dew point and moisture can be waived if the critical surface is normally opened to the atmosphere.
500	<100 100 to 250 >250 to 500 >500	**Unlimited*** 1073 27 0	H	15.0		
750	<250 250 to 500 >500 to 750 >750	**Unlimited*** 205 9 0	J	25.0		
1000	<500 500 to 750 >750 to 1000 >1000	**Unlimited*** 34 5 0				

*** No silting permitted**

2.5. SPECIFYING PRODUCT CLEANLINESS LEVEL

2.5.1. Product cleanliness levels shall be determined by program and system requirements, which shall be specified as in the following examples:

a. Level 300 refers to size and count limits on particulate contamination only.

b. Level A refers to nonvolatile residue (NVR) limits only (i.e., 1 milligram [mg]/square meter [m^2]).

c. Level 300A refers to size and count limits on particulate contamination and NVR limits.

d. Level 300A is a more stringent cleaning level than level 300B for NVR.

e. A component cleaned to a more stringent cleanliness level than is required for a system application may be used in the system application (e.g., a component cleaned to level 200A may be used in a system application requiring a less stringent cleanliness level (e.g., level 300 or 300A or UV)).

f. Level VC is a more stringent cleaning level than GC. No other alphanumeric or other designations are associated with the visible cleaning levels (GC, VC, or UV). For example, no 300VC or 100UV levels exist.

g. No particulate count or NVR limit shall be required for any visible cleanliness level (GC, VC, or UV).

2.5.2. A system specific analysis shall be conducted to determine the cleanliness requirements for a system that needs to be precision cleaned per this LPR.

a. For oxygen systems (including associated GN2, air, and helium purge systems), this analysis shall determine the particulate and NVR cleanliness levels to preclude fires. Reference ASTM G93, NFPA 53, and ASTM Manual 36 for analysis guidance and methods.

b. For non-oxygen precision clean systems, the analysis shall determine the cleanliness level required to ensure the correct and reliable operation of the system.

2.6. OXYGEN SYSTEM MINIMUM CLEANLINESS LEVEL

2.6.1. All systems and components containing an Oxygen-Enriched Atmosphere (OEA) of >23.5% oxygen or non-oxygen systems (such as nitrogen or helium), used to pressurize, test, or purge an OEA system shall meet the following minimum cleanliness requirements:

a. Non-Volatile Residue (NVR) cleanliness Level “E” or cleaner.

b. Particulate Level 1000 or cleaner.

Note: These minimum requirements may not be adequate to mitigate the risk of fire in all oxygen systems. A system specific analysis shall be required to determine the cleanliness level required.

2.7. TEST FLUIDS

2.7.1. General

2.7.1.1. The test fluid shall meet the following requirements:

a. Particulate filtration requirements for test fluids shall be equal to, or better than, the "unlimited" particle size listed in Table 1 for the cleanliness level required or shall exceed the filtration requirements of the system or component under test. For example, for level 100, a minimum filter size of 25 µm shall be used. For particle analysis where NVR analysis is not required, the maximum allowable NVR level of the test solvent shall not exceed 50 mg/L.

b. Isopropyl alcohol and ethyl alcohol shall not be used as the test fluid for oxidizer systems and hardware.

c. Subtraction of the test fluid blank particle count from the test sample particle count shall not be allowed.

d. The quality of the test fluids shall be verified at least once a day (every 24 hours) prior to use.

2.7.2. Compatibility

2.7.2.1. Test fluids shall be compatible with the item being verified or rinsed and shall not cause immediate or latent degradation (e.g., leaching of plasticizers, swelling of soft goods or hardware corrosion).

2.7.2.2. The performing organization or contractor shall ensure that verification and rinsing processes employing dissimilar fluids do not degrade hardware.

2.7.2.3. Compatibility of nonmetallic materials with the applicable test fluid shall be determined prior to testing.

2.7.2.4. Permission to remove nonmetallic materials prior to testing shall be granted at the discretion of the Contracting Officer (CO).

2.7.2.5. Halogenated solvents shall not be used on titanium alloys.

2.7.3. Solvents

2.7.3.1. The solvents approved for use as test fluids are presented in Table 2, with the maximum allowable NVR levels shown for specific test fluid applications. In some cases, the maximum allowable NVR level of the test fluid is less than the procurement specification value; therefore, it may be necessary to distill the solvent to obtain the required quality (NVR level) of solvent.

Table 2, Solvents, Maximum Allowable Nonvolatile Residue.

Solvent/Specification and Grade Type	Maximum Allowable NVR Procurement Specification (mg/L)	Test Fluid (mg/L)
Trichlorotrifluoroethane (CFC 113) ODS		
MIL-C-81302, Type I	1.57	10
MIL-C-81302, Type II	3.14	10
Perchchloroethylene		
ASTM D 4081	40.6	10
ASTM D 4376	162.4	10
ACS Spectrometric Grade	8.1	10
Vertrel MCA (1) (2) MPCV 70156	10	10
Methoxy-nonafluorobutane HFE 7100 MPCV 70156	10	10

Notes

ODS = Ozone-depleting substances that are illegal to purchase without approval by the United Nations Environment Programme (UNEP)
(1) = Not for use with hydrazine-based fuel
(2) = Not for use as final verification fluid for oxidizer service. Can be used in a dual solvent-cleaning process as long as the final verification fluid is 100-percent compatible

2.7.3.2. **Trichlorotrifluoroethane (Freon 113)**

2.7.3.2.1. Trichlorotrifluoroethane used as test solvent shall conform to JSC-20584, "Spacecraft Maximum Allowable Concentrations for Selected Airborne Contaminants."

2.7.3.2.2. Trichlorotrifluoroethane is a nonflammable solvent. However, it shall not be used near open flames, welding, or high temperature because high temperatures result in the solvent vapors decomposing into toxic and corrosive products.

2.7.3.2.3. Trichlorotrifluoroethane shall not be used with rubber, plastic, or coated components with which it is not compatible. Incompatibility can result in change in polymer structure and molecular weight, dissolution of plasticizers, and an increase in brittleness, swelling, and so forth.

2.7.3.2.4. Where specific information with respect to compatibility is lacking, tests shall be conducted.

2.7.3.2.5. Compatibility tests shall consist of immersion of test specimens in the

cleaning compound at 80 ± 9 °F for 16 ± 1 hour.

2.7.3.2.6. Conditions of immersion and testing shall be in accordance with ASTM D1414-15 and ASTM D471-16a.

2.7.3.2.7. Test specimens shall be completely surrounded by the fluid during immersion.

2.7.3.2.8. Fluid volume shall be not less than 12 times the total volume of the specimen.

2.7.3.2.9. Tensile strength, elongation, and hardness shall be determined by the "Properties after Evaporation of Test Liquid" method of ASTM D471-16a.

2.7.4. **Cleaning Agents**

The cleaning agents approved for use are presented in Table 3, with material compatibility shown for various metals, soft goods, and glassware.

Table 3, Material Compatibility for Cleaning Agents.

Material	Oakite HD126	Brulin 815 GD	Brulin 1990GD
Carbon Steel	X	X	X
Stainless Steel			
300 Series	X	X	X
pH Series	X	X	X
400 Series	X	X	X
Monel	X	X	X
Inconel	X	X	X
Hastelloy	X	X	X
Titanium	X	X	X
Aluminum		X	X
Brass	X	X	X
Copper	X	X	X
Coated or Plated Metal		X	X
Teflon	X	X	X
Kel-F	X	X	X
PCTFE	X	X	X
Viton	X	X	X
Nylon	X	X	X
Elastomeric Material		X	X
Glassware	X	X	X

X = Compatible

2.7.5. **Deionized Water**

Deionized water used as a cleaning solvent or in aqueous detergent cleaning shall conform to JSC-SPEC-C-20, "Water, High Purity Specification for," Grade A, with a pH between 5.0 and 8.0.

2.7.6. **Aqueous-Based Fluids**

2.7.6.1. Aqueous-based fluids shall utilize reagent water. The reagent water shall conform to ASTM D1193, Type II, except for the requirement that the carbon content be below 20 micrograms per liter (µg/L).

a. Residue of constituent ingredients of the aqueous-based fluid shall be compatible with liquid oxygen in accordance with NASA-STD-6001.

b. High-purity water in accordance with JSC-SPEC-C-20, Grade A, shall be an acceptable substitute for reagent water.

c. Under operation conditions, the resistance of rinse water shall not be less than 50,000 ohm-cm (0.2 microsiemen) and the pH of the rinse water shall be between 5.0 and 8.0.

2.7.7. **Hydraulic Fluid**

Use of hydraulic fluid shall be limited to only particle population analysis and functional testing of hydraulic systems and components.

2.8. TEST METHODS

The cleanliness level test methods are summarized in Table 4. Determination of a component or system's cleanliness level shall be made by using Test Method I or II.

Table 4, Cleanliness Level Test Methods.

Test Method	Sampling Technique	Analysis Method
Method I - Liquid Flush Test for Particle Population and Representative NVR Remaining on Critical Surfaces of Items Cleaned in a Controlled Environment	Flush with or immerse in test fluid	Filtration, manual particle count, NVR analysis
Method II - Liquid Flow Test for Particle Population and Representative NVR Remaining on Critical Surfaces of Items Cleaned in the Field	Flow-through with test fluid	Filtration, manual particle count, NVR analysis
Method III - Gas Flow Test for Moisture Remaining on Critical Surfaces After Cleaning	Purge with test gas	Dew point analysis
Method IV - Liquid or Gas Flow Test for Specified Service Requirements	Discharge service fluid under normal operating conditions	Filtration, manual particle count, NVR analysis, dew point analysis

2.9. FIELD CLEANING

2.9.1. General

2.9.1.1. All field cleaning per this LPR shall use final cleaning verification solvents and cleaning agents that are compatible with oxygen service and meet the final cleaning level requirements as defined in this LPR and as specified by specification, task, contract, or work order, subject to final verification by the Government.

2.9.1.2. Any performing organization shall keep accessible, accurate, hazardous material data and inventory information on site.

2.9.1.3. Field cleaning is often complex because the size and configuration of large items make it difficult to circulate or spray solutions and to remove effluent completely. Whenever possible, rough cleaning operations shall be accomplished prior to installation. Equipment and materials used shall be compatible with the system and non-contaminating.

2.9.1.4. Used systems shall be disassembled into subsystems or subassemblies whenever possible for cleaning.

2.9.2. Preparation Prior to Field Cleaning

2.9.2.1. Approvals

2.9.2.1.1. All field cleaning shall have a detailed procedure approved by the chairman of the LaRC Oxygen Working Group, the Safety and Facility Assurance Branch (SFAB), the Contracting Officer (CO), and the LaRC Facility Safety Head (FSH).

2.9.2.1.2. To obtain approval, the submitted field verification procedure shall include the following information:

a. If the cleanliness level is not specified on the engineering drawing or documentation, include the analysis and rationale for the proposed/selected cleanliness level in the process document.

b. Description of items to be cleaned including identification of materials.

c. Processing materials, to include, as applicable, trade names, specifications, chemical and physical properties, and compatibility information.

d. Processing equipment and cleaning procedures to be used.

e. Quality assurance provisions to be utilized. This shall include in-process control procedures to prevent contamination, latent corrosion, or other degradation of surfaces and opened systems or vessels; and procedures to perform inspections and verify test results.

f. Controlled environment levels to be maintained for cleaning and handling.

g. Packaging methods and materials.

h. Verification methods and materials.

2.9.2.1.3. All cognizant activities or on-site agencies having jurisdiction shall be advised of the scheduled procedures, and the necessary appropriate approvals and permits shall be obtained.

2.9.2.2. **Decontamination**

2.9.2.2.1. Decontamination shall be performed in accordance with Section 2.10.2 of this LPR.

2.9.2.3. **Component Removal**

2.9.2.3.1. All systems, subsystems, or other related field equipment components where complete removal of cleaning, flushing, and rinsing fluids cannot be assured, and/or degradation of components may occur, shall be disassembled prior to cleaning to the extent that areas of entrapment are eliminated and sensitive components are removed.

2.9.2.3.2. These removed components shall be completely disassembled, cleaned, and tested in accordance with Section 2.10.4 of this LPR.

2.9.2.3.3. All removed components shall be replaced by temporary hardware.

2.9.2.3.4. A low point drain (at the lowest feasible point) shall be chosen or installed as a sample port for system validation.

2.9.2.3.5. A high point vent shall be added to eliminate entrapping fluid.

2.9.2.4. **Installation of Temporary Hardware**

2.9.2.4.1. All temporary hardware necessary to perform or validate the cleaning process shall be compatible with the processing materials and the subsystem, system, or other related field equipment that is to be cleaned.

2.9.2.4.2. All surfaces near openings resulting from the removal of components shall be visibly clean of contamination, such as dirt, scale, and grease, prior to the installation of temporary hardware.

2.9.2.5. **Cleaning of Temporary Hardware**

2.9.2.5.1. Temporary piping and/or components that are required for system flushing and testing shall be cleaned as specified for the system being cleaned prior to each use and tested in accordance with Section 2.10.6.10.9 of this LPR.

2.9.2.5.2. Interconnected piping and components in the piping systems shall be cleaned and maintained clean.

2.9.2.6. **Marking of Temporary Hardware**

All temporary hardware installed in or attached to an item to be cleaned shall be legibly marked as temporary hardware to ensure its removal from the item prior to final acceptance.

2.9.2.7. **Validation of System Integrity**

2.9.2.7.1. Unless otherwise specified, the integrity of the subsystem, system, or other related field equipment shall be validated by a pressure test using water, pneumatics (e.g., nitrogen, compressed air), or a solvent after the installation of all temporary hardware and prior to the beginning of the cleaning process if corrosive or hazardous fluids are to follow.

2.9.2.7.2. The system integrity test pressure shall be at least 110 percent of the maximum (anticipated) cleaning process working pressure, and it shall be held for a minimum of 5 minutes.

2.9.2.7.3. Under no circumstances shall the working pressure of the original subsystem, system, or other related field equipment be exceeded without prior written approval of the CO.

2.9.3. **Field Cleaning Equipment**

2.9.3.1. **Closed-Loop Cleaning Equipment**

Note: The circulation of cleaning solution in a closed loop shall be used only on items in which the total volume can be filled by the solution and all critical surfaces can be wetted by the solution.

2.9.3.1.1. The following equipment shall be required for cleaning and testing subsystems, systems, or other related field equipment by recirculation of the cleaning media in a closed loop:

a. Containers of sufficient capacity to store, retain, or recirculate the process materials used on the item being cleaned.

b. Heating and heat transfer equipment having sufficient capacity to control and maintain the specified temperatures of the process materials at the flow rates used. There shall be no dilution of solutions during heating.

c. Circulating pumps, valves, and other components of sufficient size and capacity to minimize pressure losses in the cleaning system and capable of maintaining the required flow rates. Cleaning fluids shall be flowed at a minimum of 4 ft/s to ensure satisfactory cleaning of the subsystems, systems, or other related equipment.

d. Calibrated flow measuring equipment to measure the liquid flow rates required to achieve specified velocities.

e. Calibrated pressure gauges capable of interpretation in the middle 80 percent of the scale and accurate to 1 percent of full scale.

f. Filter to maintain the cleaning solution to a 10-micron absolute level.

g. Receiving vessels of sufficient volume for the spent cleaning/rinse solution.

2.9.3.2. **Spray Equipment**

2.9.3.2.1. In addition to the equipment specified in Section 2.9.3.1 of this LPR, spray equipment such as spray wands and rotating-head spray machines shall be provided for impinging process solutions on and wetting all internal surfaces of large items such as storage vessels or large-diameter pipes that cannot be cleaned by closed-loop circulation**.**

2.9.3.2.2. Spray equipment shall be capable of delivering process solutions to provide a spray pattern that forcibly impinges process solutions on and completely wets the entire interior surface of the item being cleaned.

2.9.4. **Field Cleaning Procedures**

2.9.4.1. **Pre-Cleaning**

2.9.4.1.1. All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall be visibly free of corrosion, dirt, grease, scale, or other foreign matter prior to final cleaning.

2.9.4.1.2. Pre-cleaning shall be performed by using one or more of the following techniques:

a. Mechanical cleaning.

b. Solvent wipe.

c. Detergent scrub.

d. Detergent flush.

e. Acid treatment (Reference ASTM G93).

f. High-pressure wash.

g. Detergent spray.

2.9.4.2. **Mechanical Cleaning**

2.9.4.2.1. This method shall be used only when contaminants generated can be removed and when physical damage to the item being cleaned will not occur.

2.9.4.2.2. Mechanical cleaning shall be accomplished by brushing, shot peening, grit blasting, tumbling, or grinding.

2.9.4.2.3. Corrosion-resistant steel surfaces shall be cleaned by brushing with a corrosion-resistant steel brush, grinding, or using an abrasive material.

2.9.4.2.4. Abrasive materials used on corrosion-resistant steel surfaces shall not contain ferrous or ferric materials.

2.9.4.2.5. The use of the same corrosion-resistant steel brush for corrosion-resistant steels and carbon steels shall not be permitted.

2.9.4.2.6. All loose dirt, scale, and other debris shall be completely removed from the item by vacuum cleaning, brushing, blowing, or flushing with clean water.

2.9.4.3. **Cleaning by Closed-Loop Circulation of Solution**

2.9.4.3.1. The circulation of the cleaning solution in a closed loop shall be used only on items in which the total volume can be filled by the solution and all critical surfaces can be wetted by the solution.

2.9.4.3.2. Where possible, adequate low point drains shall be installed to prevent entrapment of fluid or particulates.

2.9.4.3.3. Equipment for use in closed-loop circulation shall meet the requirements of Section 2.9.3.1 of this LPR.

2.9.4.4. **Cleaning by Solution Spraying**

2.9.4.4.1. Items having a size or configuration that cannot be cleaned by circulating a fluid through the item shall be cleaned by the use of spray equipment.

2.9.4.4.2. Equipment for use in solution spraying shall meet the requirements of Section 2.9.3.2 of this LPR.

2.9.4.5. **Final Cleaning/Verification**

2.9.4.5.1. Final cleaning shall be accomplished using a cleaning verification fluid that is oxygen compatible, as well as being compatible with the materials being cleaned, per the piping solvent flush sampling methodology in Section 3.11 of this LPR.

2.9.4.5.2. Final cleaning verification solvents and cleaning agents that are compatible with oxygen service and meet the final cleaning level requirements per Section 1.1.3 shall be used as the final cleaning and testing medium for oxygen systems.

2.9.4.5.3. Approval shall be obtained from the Government representative before the final flush is performed.

2.9.4.5.4. The background contamination level of the cleaning solvent shall be

checked prior to use in oxygen piping systems.

2.9.4.5.5. The background particulate matter contamination level shall not exceed level 100 per Table 2 of this LPR.

2.9.4.6. **System Dryness**

After the final flush and the system is certified clean, the system shall be dried with dry nitrogen gas and tested for dew point per Section 3.5 of this LPR.

2.9.4.7. **Work Flow**

2.9.4.7.1. All steps in pre-cleaning procedures shall progress in an uninterrupted workflow through the final rinse and drying operation.

2.9.4.7.2. If the workflow is unavoidably interrupted, the pre-cleaning procedure shall specify a recycling operation.

2.9.4.7.3. Pre-cleaning procedures shall include, as a minimum, protection of the item by interim packaging or other approved means to prevent recontamination through all subsequent operations.

2.10. CLEANING

2.10.1. General

2.10.1.1. Cleaning is comprised of two categories: rough and precision. Adequate contamination control is imperative to minimize hazards and component failures that can result from contamination. Contaminants shall be removed from hardware surfaces in accordance with applicable engineering documents or NASA approved procedures.

2.10.1.2. Cleanliness is a perishable condition. Careful planning is necessary to achieve and maintain clean surfaces—this includes corrosion protection, surface treatments, material degradation, packaging, handling, processing, controlled environment, etc. If there is a concern regarding the effectiveness of the cleaning process or possible adverse effects, trial runs using test specimens shall be conducted.

2.10.1.3. The cleaning process removes all contaminants such as loose scale, rust, grit, filings, and other foreign particles, as well as oil, grease, and other organic materials.

2.10.1.4. Special attention, as outlined in this LPR, shall be paid when cleaning subassemblies that have threaded joints; press or shrink fits; dead-end spaces, pockets, and small recesses; or are assembled in such a manner that later cleaning or inspection would be difficult.

2.10.2. Decontamination

2.10.2.1. All systems, subsystems, components, and equipment that have been exposed to toxic propellants or hazardous materials shall be decontaminated to the required level of safe handling prior to initial cleaning operations.

2.10.2.2. Under no circumstances shall propellant-contaminated systems,

subsystems, or components be cleaned or transported directly to a cleaning facility prior to decontamination.

2.10.2.3. Decontamination shall be accomplished using established and proven methods for the removal and neutralization of propellant residues in place or in an area specifically designated for decontamination operations.

2.10.2.4. Decontaminated items shall be clearly and legibly marked to indicate that they have been decontaminated.

2.10.2.5. No items shall be accepted for cleaning without proof of decontamination.

2.10.3. **Preproduction Cleaning and Preservation Process Approval**

2.10.3.1. Unless otherwise specified in the contract or order, the performing activity or contractor's facility may be inspected by the Government or its agent prior to performing any cleaning under this specification.

2.10.3.2. The Contracting Officer (CO) shall be authorized to stop the Cleaning Contractor (CC) from performing any cleaning under this LPR if noncompliance with the requirements of this LPR and approved procedures are observed or suspected.

2.10.3.3. The CO shall authorize the cognizant quality surveillance organization to take a representative sample of cleaned components and verify they meet the final cleaning requirements as specified per requested product cleanliness level.

2.10.3.4. The cleaning facility may be re-inspected on an annual basis at the discretion of the CO. The following items shall be inspected and reviewed:

a. Adequate procedures, processes, and test methods to operate the facilities and equipment and to perform cleaning, testing, and packaging in accordance with this specification.

b. Maintenance of facilities and equipment, such as cleanrooms, work areas, logistics areas, and offices to perform cleaning, testing, and packaging in accordance with this LPR.

c. Adequate supply of materials to perform testing and packaging in accordance with this LPR.

d. Knowledge of personnel of procedures, processes, test methods, proper shop practices, and cleanroom protocol to demonstrate performance of cleaning, testing, and packaging in accordance with this LPR.

e. Appropriate materials control and quality assurance personnel are on staff to direct, manage, and oversee the handling and processing of the parts, components, subsystems, and systems to be cleaned, tested, and packaged in accordance with this LPR and the hazardous materials and waste associated with the cleaning operation.

f. Record maintenance of personnel training and control of cleaning solutions and materials used to perform cleaning, testing, and packaging in accordance with this LPR.

g. Compliance with Federal regulations 29 CFR 1910 and 40 CFR, and 49 CFR where applicable.

2.10.3.5. Materials and methods not within the scope of this specification shall be used only with written approval of the CO.

2.10.4. **Component Cleaning and Functional Testing**

2.10.4.1. Components shall be assembled using cleaned parts that have been inspected and functionally tested in accordance with Section 3.9. Conformance to the applicable cleanliness level, other than levels GC, VC, and UV, shall be determined by the test fluid-flush procedure (Test Method I) for individual parts. A component assembled from clean parts in cleanroom facilities shall be certified to the cleanliness level of the component parts. Acceptance inspection by analysis of test fluid flow-through flush (Test Method II) of assembled components shall be prohibited except in the following cases:

a. Hydraulic components.

b. Components designed for flow-through testing.

2.10.4.1.1. **Hydraulic Components**

Hydraulic components may be sampled by (Test Method II) for particulate population analysis utilizing hydraulic fluid, provided the component has been assembled using clean parts that have been inspected in accordance with Sections 3.3 and 3.6. When specified, functional testing in accordance with Section 3.9 shall be performed following cleaning and inspection. Hydraulic fluid used for particulate population analysis and functional testing shall be as specified by the procuring activity.

2.10.4.1.2. **Components Designed for Flow-Through Testing**

Components specifically designed so that lubricated surfaces and soft goods de-graded by test fluids are not exposed to fluid-flow paths through the components may be sampled by (Test Method II). Flow-through components shall be evaluated for areas of entrapment and for actuation of moving parts, e.g., poppets, during cleaning. Consideration shall also be given to proper drying methods for assembled items.

2.10.5. **Cleanroom and Workstation Requirements**

2.10.5.1. Cleanroom facilities and work stations used for precision cleaning, cleanliness verification, assembly, and packaging of cleaned items shall meet the requirements of the international standards ISO 14644-1, “Cleanrooms and associated controlled environments – Part 1: Classification of air cleanliness by particle concentration,” and ISO 14644-2, “Cleanrooms and associated controlled environments – Part 2: Monitoring to provide evidence of cleanroom performance related to air cleanliness by particle concentration.”

2.10.5.2. The cleanroom level shall be consistent with the cleanliness level requirements of the item being cleaned.

2.10.6. **Oxygen Cleaning**

2.10.6.1. The cleaning of an oxygen system component shall begin with disassembly to the elemental or piece part level.

Note: If cleaning is attempted by flowing solutions through a component, vulnerable internal elements can be damaged by the solution required to clean the major elements of the component. Contaminants and cleaning solutions also can become entrapped in component recesses and can ultimately react with oxygen.

2.10.6.1.1. When the component has been disassembled, the parts shall be grouped according to the method of cleaning.

2.10.6.1.2. Special cleaning procedures shall be developed to remove entrapped contaminants.

2.10.6.1.3. Disassembly also allows assessment of the serviceability of the component elements.

2.10.6.1.4. If sealing surfaces are damaged or cracks are observed in the metallic parts, the component shall be repaired or replaced.

2.10.6.1.5. Special attention shall be directed to the component soft goods.

2.10.6.1.6. Damaged or worn soft goods shall be replaced.

2.10.6.2. Cleaning or disassembly operations of precision components that might affect tolerances or impair calibration shall be performed only under the supervision of personnel qualified in the handling, calibration, and assembly of the components.

2.10.6.3. When individual parts of an assembled component have not been cleaned prior to assembly, the assembled component shall be rejected and reprocessed for cleaning, disassembly, rework, and retesting.

2.10.6.4. All components and assemblies shall be cleaned of all contaminants and kept in this condition until the equipment is delivered to its final destination, as most nonmetallic materials are highly combustible in oxygen service.

2.10.6.5. A functional test of the components shall be conducted after reassembly.

2.10.6.5.1. Testing shall be documented on appropriate component functional test report forms.

2.10.6.6. **Pre-cleaning Procedures**

Each item requiring precision cleaning shall be pre-cleaned (rough cleaned) to the VC level prior to its placement in a cleanroom or clean workstation.

2.10.6.7. **Pre-cleaning Process Controls**

2.10.6.7.1. Pre-cleaning of parts shall remove all visible contaminants without removing or changing the characteristics of the base materials.

2.10.6.7.2. All traces of pre-cleaning materials shall be removed from the parts at the completion of the pre-cleaning process to prevent the future formation of mineral salts and corrosion products.

2.10.6.8. **Rough Cleaning**

2.10.6.8.1. All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall undergo rough cleaning prior to precision cleaning.

2.10.6.8.2. Rough cleaning is used to achieve level VC clean articles. Rough cleaning removes contaminants such as weld scale, heat treat scale, corrosion, oxide films, oils, grease, shop soil, fuel, and carbon deposits.

2.10.6.8.3. The cleanliness level achieved by rough cleaning does not normally require verification beyond visual inspection.

Note: Wipe test, water break test, ultraviolet inspection, special lights, and mirrors are considered aids to visual inspection.

2.10.6.8.4. Rough cleaning is considered a normal shop process and usually does not require special environmental controls, packaging, handling, or storage beyond accepted good practice.

2.10.6.9. **Precision Cleaning**

2.10.6.9.1. This method is used to achieve a level of product cleanliness greater than the level detected by visual means and requiring cleanliness verification by particle analysis and nonvolatile residue analysis as specified. Articles shall be cleaned to level VC prior to precision cleaning**.**

2.10.6.9.2. Precision cleaning shall be performed in a controlled environment and is intended to remove particles, films, biological forms, and other forms of contaminants that are usually not visible but could degrade the product or process.

2.10.6.9.3. The level of precision cleanliness shall be verified, and evidence of inspection and acceptance shall be provided.

2.10.6.9.4. Precision-cleaned articles shall be packaged immediately after verification of cleanliness or suitably protected prior to leaving the controlled environment.

2.10.6.9.5. Precision-cleaning solutions or material shall not react with, combine with, etch, or otherwise cause immediate or latent degradation of the item being cleaned.

2.10.6.9.6. Precision-cleaning fluids shall be filtered and controlled.

2.10.6.9.7. Their cleanliness level shall be verified as being sufficient to achieve the specified product cleanliness as specified by Chapter 3 of this LPR.

2.10.6.10. **Types of Pre-Cleaning**

2.10.6.10.1. **Mechanical Cleaning**

2.10.6.10.1.1 Mechanical cleaning can be accomplished by brushing, shot peening,

grit blasting, tumbling, or grinding.

2.10.6.10.1.2 Mechanical cleaning shall be used only when contaminants generated can be removed and when physical damage to the item being cleaned cannot occur.

2.10.6.10.1.3 Corrosion-resistant steel surfaces shall be cleaned by brushing with a corrosion-resistant steel brush, grinding, or using abrasive material.

2.10.6.10.1.4 Abrasive materials used on carbon steels shall not be reused on stainless steels.

2.10.6.10.1.5 All loose dirt, scale, and other debris shall be completely removed from the item by vacuum cleaning, brushing, blowing, or flushing with clean water.

2.10.6.10.2. **Mechanical Descaling**

Mechanical descaling removes contaminants by abrasive action.

2.10.6.10.2.1 This method shall be used only when contaminants generated by this abrasive action can be removed or when physical damage to the item being cleaned cannot occur.

2.10.6.10.2.2 Mechanical descaling shall be accomplished by brushing, shot peening, grit blasting, vapor honing, tumbling, or grinding.

2.10.6.10.2.3 Surfaces that contain scale and/or oxides and all steel or stainless steel welds that are exposed to gas or liquid and are accessible shall be thoroughly cleaned with a stainless steel wire brush, grinder, or abrasive material.

2.10.6.10.2.4 Carbon steel surfaces shall be shot blasted.

2.10.6.10.2.5 Stainless steel wire brushes used on carbon steel shall not be used on stainless steel.

2.10.6.10.2.6 Material to be used for abrasive cleaning stainless steel surfaces shall contain no ferrous or ferric materials.

2.10.6.10.2.7 Internal surfaces of pipe shall be cleaned by a “go-devil” type of device with a grinder of 150 grit abrasive or finer.

2.10.6.10.2.8 All loose dirt, abrasive, or scale shall be completely removed from components by vacuum cleaning, blowing, brushing, or flushing with clean water.

2.10.6.10.2.9 Components whose welds are not accessible for mechanical descaling shall be descaled by pickling.

2.10.6.10.3. **Ultrasonic Cleaning**

2.10.6.10.3.1 The removal of surface soils by forces created through cavitation (i.e., the implosions of vapor bubbles) is known as ultrasonic cleaning. The pulsating sound waves create three phases in the cleaning solution:

a. Degassing - Large bubbles or voids form as a result of high negative pressure on the fluid. The bubbles combine, become buoyant, and rise out of the solution.

b. Pulse - gaseous bubbles 40 microns or less pulsate several thousand times per second, causing a scrubbing action.

c. Collapse - The positive pressure of the liquid reacts with the vapor filled bubbles, which collapse and leave a void. The liquid rushes in and creates tremendous heat and pressure at the location of the bubbles (20,000 °F and 10,000 psi). The suction or vacuum of these implosions pulls soil from the component.

2.10.6.10.3.2 The operational factors below shall be observed to ensure effective sonication:

a. Cleaning solution

(1) Select the proper cleaning solution for the cleaning job.

(2) Ensure adequate liquid levels are maintained to prevent damage to the ultrasonic unit.

b. Degassing

(1) Degas all solutions before use.

(2) Complete degassing time depends on the properties of the solution, especially temperature, tank depth, power intensity, and type of pulse.

(3) Shallower tanks, higher solution temperatures, and higher power intensity with a pulsed wave allow faster degassing.

(4) Soft or deionized water is more easily degassed than hard water. Partial degassing (80-85%) takes place in about five minutes.

(5) Complete degassing generally occurs after about 30 minutes, but the time may vary based on the above factors.

(6) Heating the solvent to within three to five degrees of its boiling point can also accomplish degassing.

c. Immersing Parts

(1) Slow immersion and removal of parts from the cleaning solution may prevent the introduction of air and the bouncing back of reflective ultrasonic waves to the transducer and generator.

(2) Parts are to be withdrawn from the tank while the cleaner is operating.

(3) If the ultrasonic tank emits sharp screeching sounds, the parts are being introduced too fast and the generator is being put under undue stress.

d. Parts loading

(1) Load parts in the ultrasonic cleaning tank such that neither the part nor the parts basket is on the tank bottom.

(2) Heavy parts (high mass) are to be exposed to direct ultrasonic waves.

(3) The sum of the parts cross-sectional area shall not exceed 75% of the tank cross-sectional area.

(4) For most effective cleaning, total parts' weight shall not exceed .351kb/Kw of generator power, even though a slightly higher weight to Kw ratio can be accommodated.

(5) Elastomers and non-rigid plastics absorb ultrasonic energy and can produce a shadowing effect; insulated parts may have to be specifically oriented.

e. Container design

(1) Incorrect basket design or a basket having too high of a mass can greatly reduce the effectiveness of an ultrasonic cleaning system.

(2) Any material more tightly woven than a 50-mesh screen acts as a solid sheet, while slightly larger openings scatter the ultrasonic waves; openings larger than 0.25 inches act as open material.

(3) Hooks, racks, and beakers can also be used to support parts.

f. Parts positioning

(1) Incorrect parts positioning can greatly reduce the effectiveness of ultrasonic cleaning.

(2) If possible, critical areas to be cleaned should face the transducer, but racked parts should be positioned vertically, rather than being stacked one on top of the other.

(3) Care shall be taken so that air is not trapped in blind holes, thereby preventing liquid contact with all surfaces.

(4) Parts shall be covered by at least 0.75 inches of cleaning fluid and, if possible, should be positioned at the correct depth to take advantage of the higher intensity at the anti-node of the ultrasonic wave.

g. Noises

(1) Audible noises of two types can be produced: (1) a buzzing or hissing noise is caused by the shock waves produced by cavitating bubbles; (2) screeches or squeals resulting from “beat notes” should be avoided.

(2) Beat notes can be caused by moving parts too fast in the tank, too violent agitation of the liquid, resonant bubbles, or two or more non-synchronized generators.

(3) Introduction of a parts basket or parts into the liquid can usually eliminate beat notes from these causes.

(4) Beat notes can also be caused by cleaning chemicals, which do not form clear solutions or by excessive accumulation of greasy soils, which are not completely soluble in the solution used.

(5) If this occurs, use a different solution or change the solution more frequently.

h. Filtering

(1) In precision cleaning, particulate matter shall be removed from the cleaning fluid.

(2) This can be done with a continuously re-circulating filtration system simultaneously with ultrasonic cleaning.

(3) The rate of flow through a filter system can be determined through experimenting with each cleaner.

(4) A depth filter should precede the absolute filter for maximum practical effectiveness.

(5) The rate of flow, to prevent the cavitation, is generally not over one to three percent of the tank volume per minute.

(6) Too high a flow rate will create turbulence and may produce screeching sounds.

2.10.6.10.4. **Detergent Degreasing**

2.10.6.10.4.1 Alkaline cleaners and detergents shall be used for removing organic and inorganic contamination, which can be removed by solution or emulsification (e.g., oils, fat, shop soils, grease).

2.10.6.10.4.2 Components shall be degreased in a solution of detergent and water.

2.10.6.10.4.3 Surfaces of the component shall be swept with a soft nylon brush. Detergent degreasing can also be done in an ultrasonic cleaner.

2.10.6.10.4.4 After degreasing, components shall be first rinsed with tap water followed by a de-mineralized water rinse.

2.10.6.10.4.5 Components shall then be oven dried.

2.10.6.10.5. **Alkaline Degreasing**

2.10.6.10.5.1 Components may be degreased with commercial alkaline cleaners.

2.10.6.10.5.2 The components shall be filled, immersed, sprayed, or scrubbed with the particular alkaline cleaner in accordance with the manufacturer’s recommendations.

2.10.6.10.6. **Drying**

2.10.6.10.6.1 Drying shall take place immediately after the final rinse using nitrogen gas, oven drying, or vacuum drying.

2.10.6.10.6.2 Drying gas shall conform to Section 2.14.

2.10.6.10.7. **Special Cleaning: Nonmetallic Materials**

2.10.6.10.7.1 For the purpose of this document, nonmetallic materials include natural rubber, Teflon, Kel-F, polyethylene, polycarbonates, and other plastics or synthetic materials.

2.10.6.10.7.2 Caution shall be taken to ensure that the cleaning solution used does

not adversely affect the materials, i.e., external damage, or absorption of the cleaning solution and consequent out gassing.

2.10.6.10.7.3 The following method or its equivalent shall be acceptable for cleaning nonmetallic materials:

a. Decontaminate using a deionized water flush until the pH of the effluent is within one-half of a pH unit of the influent.

b. Clean with a compatible solution using nylon brushes as necessary.

c. Spray rinse with deionized water (140 °F), followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohms.

2.10.6.10.8. **Special Cleaning: Transducers, Temperature Sensors, and Flow Meters**

2.10.6.10.8.1 **Pre-cleaning**

Personnel shall follow the following requirements when pre-cleaning:

a. Clean the exterior with clean, lint free cloth dampened with an approved solvent from Table 2 of this LPR.

b. Encase the item in a polyethylene bag and tape seal so that only the sensing part(s) or surfaces are exposed.

c. Using a wash bottle filled with Freon, flush interior of transducer and flush exterior sensing surfaces of temperature sensors.

d. Use fill and drain method to flush fluid passageways of flow meters.

e. Flush items until Freon is visibly clear of discoloration and particles, and the pH is within 0.5 pH of the influent.

f. Dry with hot (140 °F maximum) nitrogen gas.

g. Hold the gaseous nitrogen wand at a minimum distance of one foot from the item to provide ventilation of the item only and to prevent pressure buildup in the sensing chamber or bending of small diameter temperature sensing probes.

2.10.6.10.8.2 **Solvent Cleaning**

Personnel shall follow the following requirements with solvent cleaning:

a. Use precision cleaning solvent (MIL-C-81302, Type I), instead of water, and continue flushing until the effluent is visibly clear of discoloration and particulates.

b. Examine the sensing chamber of transducers for visible contamination on the diaphragm or threads.

c. Examine temperature sensors for visible contamination on threads and sensing surfaces.

d. Inspect fluid passageways, vent holes, vanes, etc., for visible contamination.

e. If visible contamination is evident, continue flushing.

f. Do not introduce a brush, probe, thread chaser, or any device, metal or plastic, into the sensing chamber of a transducer to dislodge contaminants from the sensing chamber or from the sensing port threads.

g. Dry with nitrogen gas (140 °F maximum) as outlined in the pre-cleaning procedure above.

2.10.6.10.8.3 **Final Cleaning**

Personnel shall follow the following requirements with the final cleaning:

a. Flush sensing chambers, probes, threads, or fluid passageways and surrounding areas with precision cleaning solvent that has been passed through a 5-micron absolute filter.

b. Continue flushing for one minute or until areas and effluent are visibly clear of contamination.

c. Repeat, using Freon that has passed through a 0.5-micron filter.

2.10.6.10.8.4 **Drying**

Personnel shall dry with nitrogen gas (140 °F maximum) as outlined above.

2.10.6.10.9. **Special Cleaning: Smooth Bore Hoses and Tubing**

2.10.6.10.9.1 **Pre-cleaning**

Personnel shall follow the following requirements when pre-cleaning:

a. Examine hoses or tubes for evidence of kinks, bends, or thread damage.

b. Decontaminate by immersion or flush rinsing with deionized water until pH of effluent is within 0.5 pH of the flushing medium.

2.10.6.10.9.2 **Detergent Cleaning**

Personnel shall follow the following requirements with detergent cleaning:

a. Detergent clean exterior surfaces of hoses or tubing with nonionic biodegradable detergent cleaner using nylon brushes as required.

b. Exposure time, temperature (not to exceed 145 °F), and concentration shall conform to manufacturer’s recommendations.

c. Rinse with deionized water.

d. Dry with hot (120 to 140 °F) air dryer.

e. Carefully clean end fittings of hoses and tubes with solvent, MIL-C-81302, Type I, using nylon brushes as required.

f. Care shall be taken to assure that the solvent does not contact the hose.

g. Install adapter fitting and connect hose or tube to be cleaned to the pump discharge line.

h. Install a restrictor fitting in the downstream end of the hose or tube being cleaned. This provides back pressure so cleaning and rinsing solutions contact all interior surfaces.

2.10.6.10.9.3 **Cleaning of Hose Assemblies**

Personnel shall follow the following requirements when cleaning hose assemblies:

a. Flush hose with nonionic biodegradable detergent cleaner for 5 to 15 minutes.

b. Change flush pump suction to deionized water that has a minimum specific resistance of 50,000 ohms and flush for one to two minutes.

c. Detach the hose from the flush pump discharge hose and remove all adapter fittings.

d. Thoroughly rinse end fittings of the hose with deionized water.

e. Dry in heated (120 to 140 °F) vacuum chamber for 25 to 35 minutes at maximum vacuum.

2.10.6.10.9.4 **Final Rinse and Cleaning**

Personnel shall follow the following requirements with the final rinse and cleaning:

a. Flush rinse hoses or tubes with 0.5 micron filtered solvent, MIL-C-81302, Type I.

b. The rinse fluid for nonmetallic items shall be deionized water.

c. The flow of fluid at the downstream end of the hose shall be restricted as necessary to provide fluid contact with all interior surfaces of the hose or tube.

d. After completion of the final rinse, continue the rinse and collect 100 mL of fluid per 0.1 m^2 of the interior surface of the hose or tube.

e. Dry interior surfaces and end fitting with 10-micron absolute filtered, hot (120 to 140 °F) nitrogen gas as per above requirements.

2.10.6.10.9.5 **Inspection**

Prior to precision cleaning and cleanliness verification, all items shall be inspected to the VC level as stated in Section 3.3 of this LPR.

2.10.6.10.9.6 **Final Cleaning**

a. All final cleaning shall be performed in a cleanroom environment following pre-cleaning operations described herein.

b. The items to be precision cleaned shall be flushed or wiped with solvent as specified in MIL-C-81302, Type I, with the exception of Section 2.10.6.7, and/or vacuum cleaned or blown off with clean dry nitrogen to prevent the entry of gross contaminants into the cleanroom environment.

c. All final cleaning processes shall be as specified in Section 3.11.3.

2.11. RECLEANING OPERATIONAL SYSTEMS

2.11.1. Systems that have successfully passed the specified quality assurance tests for initial acceptance and have been placed in operation shall be re-cleaned only when there is reason to suspect cleanliness has been compromised (e.g., dirty filter, system fluid does not meet specifications, component replacement or repair, visible contamination found when opening the system).

2.11.2. Any need for retesting shall be determined and conducted by the Government.

2.12. PROTECTION OF CLEANED SURFACES

2.12.1. **Environmental Control**

All packaging operations involving cleaned surfaces shall be accomplished within the same controlled environment as that in which the item to be packaged was sampled. Outer protective wrap, such as dimple wrap, may be applied outside the controlled area.

2.12.2. **Protection Materials**

Materials shall be compatible with the item to be protected and shall withstand the specified environment for the storage period and mode of delivery, including impact protection of critical surfaces.

2.12.2.1. **Packaging Films**

2.12.2.1.1. All plastic films used for precision packaging shall comply with the requirements of Table 5 of this LPR.

2.12.2.1.2. Acceptance inspection for conformance to the requirements of Table 5 shall be in accordance with Section 3.10 of this LPR.

2.12.2.1.3. Cleanliness level of inner wrap shall be at least equal to exposed cleaned surfaces of the item.

2.12.2.1.4. Unless otherwise specified, cleanliness of outer wrap shall be visibly clean in accordance with Section 3.10.3 of this LPR.

2.12.2.1.5. Selection of a specific film shall be dictated by compatibility with the specified service medium.

2.12.2.1.6. All parts that come in contact with liquid and gaseous oxygen in service shall be protected with an inner bag or layers of a fluorohalocarbon film, such as Aclar 22A film conforming to SAE AMS3649 or polyfluoroethylenepropylene film conforming to SAE AMS3647.

2.12.2.1.7. Other parts, components, subsystems, and systems shall be protected with an inner bag or layers of a polyamide film or a fluorohalocarbon film.

2.12.2.1.8. Polyamide films have a higher resistance to sloughing particles, while fluorohalocarbon films provide a better barrier to moisture vapor and gas permeability.

2.12.2.1.9. If unique packaging requirements exist, such as flammability, electrostatic discharge, or hypergolic propellant compatibility, a plastic film other than polyethylene may be selected from KTI-5212 for use as an overwrap material.

2.12.2.1.10. All clean film, including bags, sheeting, tubing, and roll stock that is not used immediately after cleaning shall be overwrapped and sealed in an inner bag made from clean film of the same type.

2.12.2.1.11. All film procured clean shall be overwrapped with a second bag of clean, 152 µm (6 mils), antistatic polyethylene prior to packaging for shipment.

2.12.2.1.12. Roll stock shall be wound on clean cores made from non-dusted plastic or metal.

2.12.2.2. **Packaging Tape**

Tape used for the packaging of precision-cleaned items shall conform to A-A-1689.

Table 5, Packaging Materials' Thickness and Service Requirements.

Plastic Film	Thickness Range in Micrometers	Use
Polyethylene in accordance with A-A-3174	137 to 168 (5.4 to 6.6 mils)	Overwrap, except may also be used for inner wrap of items cleaned to level VC
Nylon 6 or equivalent polyamide	43 to 58 (1.7 to 2.3 mils)	Precision packaging, not for liquid and gaseous oxygen and hypergol service
Aclar 22A per SAE AMS3649	38 to 76 (1.5 to 3.0 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service
Teflon FEP or equivalent polyfluoroethylenepropylene in accordance with SAE AMS3647	13 to 508 (0.5 to 20 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service

2.12.2.3. **Metallic Closures**

2.12.2.3.1. Metallic closure plates shall be used to seal flanged items and the materials shall be precut and drilled aluminum alloy or stainless steel with a minimum thickness of 0.125 inch.

2.12.2.3.2. To prevent electrolytic corrosion, metals dissimilar to item flanges shall not come in contact with the flange.

2.12.2.3.3. Refer to MIL-STD-889 for definition of dissimilar metals.

2.12.2.3.4. All metallic closures shall be separated from the flanged item with gaskets.

2.12.2.3.5. Gaskets shall be pre-cut from a minimum of two layers of plastic film conforming to Section 2.12.2.1 or from a sheet of polytetrafluoroethylene of 1.57 mm (0.062 in) minimum thickness.

2.12.2.3.6. The cleanliness level of metallic closures and gaskets shall be at least equal to the level of cleanliness of the cleaned item being protected.

2.12.2.4. **Protective Shields**

Although metallic closure plates per Section 2.12.2.3.1 shall be preferred, flanged items sealed with plastic film in accordance with Section 2.12.2.1 may be covered with 1/2-inch thick plywood shields to maintain the cleanliness integrity of sealed components.

2.12.2.5. **Preservatives**

Preservative materials shall not be used on items that have been precision cleaned.

2.12.2.6. **Desiccants**

Desiccant materials shall not be used except upon prior written approval of the CO.

2.12.3. **Packaging of Cleaned Items**

2.12.3.1. **Cutting**

2.12.3.1.1. When clean plastic film is to be cut, stainless steel chrome-plated or nickel-plated scissors shall be used.

2.12.3.1.2. The scissors' cut shall be started, and the scissors shall be pushed carefully through the film.

2.12.3.1.3. Sawing and hacking actions resulting from opening and closing the scissors shall be avoided to prevent the generation of particles.

2.12.3.1.4. Razor blades or other single-blade-type instruments shall not be used to cut plastic film.

2.12.3.2. **Sealing**

2.12.3.2.1. An all-purpose impulse sealer shall be used to produce effective seals with plastic films.

2.12.3.2.2. The recommendations of the manufacturer shall be followed for temperature setting and dwell time.

2.12.3.2.3. Fluorohalocarbon films such as Aclar 22A and 33C shall be sealed on all sides when fabricating bags.

2.12.3.2.4. Fluorohalocarbon films shall not be center folded. Center folding may generate particles since fluorohalocarbon films tend to be brittle.

2.12.3.3. **Detailed Requirements**

2.12.3.3.1. **Small Items**

2.12.3.3.1.1 Small items that have all surfaces cleaned shall be packaged in accordance with Section 2.12.2.1 of this LPR, sealed in accordance with Section 2.12.3.2, cushioned as applicable, bagged, and sealed.

2.12.3.3.1.2 Threaded fittings shall be double bagged and may be placed in a polyethylene bubble bag.

2.12.3.3.1.3 Sandwich packaging may be used with identical small and like items such as O-rings and gaskets. A sandwich package consists of heat sealing a number of identical items between two sheets of plastic film in such a manner that each item is in a separate heat-sealed compartment.

2.12.3.3.1.4 Each compartment shall be separable from the others by cutting without violating the integrity of the remaining compartments.

2.12.3.3.1.5 Each inner bag shall be placed in an outer bag of polyethylene with a tag in accordance with Section 2.13 of this LPR. The outer bag shall be sealed in accordance with Section 2.12.3.2.

2.12.3.3.2. **Items Internally Cleaned Only**

2.12.3.3.2.1 Items that are cleaned internally only shall have all fittings and orifices leading to the internally cleaned surfaces sealed with plastic film.

2.12.3.3.2.2 The plastic film shall be secured in place with tape conforming to A-A-1689.

2.12.3.3.2.3 The adhesive backing on the tape shall not come in contact with the body of the item whenever possible.

2.12.3.3.2.4 The sealed fittings or other orifices may be cushioned with protective film as applicable.

2.12.3.3.2.5 Small items that have been cleaned and sealed shall be placed in an outer bag of polyethylene and sealed in accordance with Section 2.12.2.1 of this LPR.

2.12.3.3.2.6 Each sealed fitting or other orifice of large items shall be overwrapped with polyethylene.

2.12.3.3.2.7 Identification shall be in accordance with Section 2.13 of this LPR.

2.12.3.3.2.8 Plastic plugs and caps shall not be used to seal openings of precision cleaned internal surfaces as plastic will generate particles that will invalidate the cleanliness of the surface.

2.12.3.3.2.9 Metal flared caps and flared plugs that have been precision cleaned shall be preferred for long lengths of pipe or tubing being shipped from LaRC over a long distance. However, appropriate plastic bagging over the ends shall be acceptable for transport within LaRC.

2.12.3.3.3. **Flanged Items**

2.12.3.3.3.1 Flanged items with only internally cleaned surfaces shall be sealed with gaskets and closures in accordance with Section 2.12.2.1 of this LPR.

2.12.3.3.3.2 A cleaned gasket shall be placed over the flange face followed by placing the closure over the gasket.

2.12.3.3.3.3 Attachment hardware shall be inserted through all the flange holes and shall be tightened to secure the closure.

2.12.3.3.3.4 The completed closure shall be overwrapped with polyethylene and secured with tape conforming to A-A-1689.

2.12.3.3.3.5 The adhesive backing of the tape shall not come in contact with the flange face.

2.12.3.3.3.6 Identification shall be in accordance with Section 2.13 of this LPR.

2.12.3.3.4. **Electrical and Electronic Items**

2.12.3.3.4.1 Electrical and electronic items that require testing after cleaning shall be packaged in an inner bag sealed in a manner that shall permit access to test points, such as leads and connectors, without violating the integrity of the inner bag.

2.12.3.3.4.2 Exposed items, such as leads and connectors, shall be cushioned as required.

2.12.3.3.4.3 Each inner bag shall be placed in an outer bag of polyethylene, sealed, and marked in accordance with Section 2.13 of this LPR.

2.12.3.3.5. **Hose and Tube Assemblies**

2.12.3.3.5.1 Hose and tube assemblies with only internally cleaned surfaces shall be sealed with plastic film.

2.12.3.3.5.2 The plastic film shall be secured in place with tape conforming to A-A-1689.

2.12.3.3.5.3 The adhesive backing on the tape shall not come in contact with the body of the item.

2.12.3.3.5.4 The entire hose or tube assembly may be overwrapped with polyethylene film as applicable and marked in accordance with Section 2.13 of this LPR.

2.13. IDENTIFICATION OF CLEANED ITEMS

2.13.1. Certification tags shall be placed between the inner and outer bags or layers of protective packaging film where practical.

2.13.2. Where the tag cannot be placed between the inner and outer packaging film, the tag shall be enclosed in a plastic bag or between layers of plastic film and securely taped to the outside of the package.

2.13.3. Tags shall be serviceable and of sufficient size to contain the following information:

a. Part or identification number.

b. Contractor identification (if applicable).

c. Number and revision of contract specification (if applicable).

d. Date of cleaning.

e. Manufacturer’s serial number.

f. Software Material List.

g. Cleanliness level of specification.

2.14. DRYING AND TESTING GAS

Nitrogen gas for drying and testing of precision-cleaned items shall conform to MIL-PRF-27401, Type I, Grade A, and shall be filtered to ensure that the particulate level of the component is not violated.

2.15. MATERIALS TO PREVENT SEIZING AND GALLING AND FOR SEALING

2.15.1. Materials for preventing seizing, galling, and for sealing shall be in accordance with KTI-5210 for liquid or gaseous oxygen. Some examples for use in both liquid and gaseous oxygen follow:

a. Lubricants:

(1) Krytox 143AC

(2) Tribolube F195

(3) Tribolube 16

(4) Krytox 240AC

b. Gaskets:

(1) Viton

(2) Teflon

(3) Kel-F

c. Thread Sealants:

(1) Teflon Tape - Only tapes made from pure virgin Teflon or another brand of tetrafluoroethylene polymer shall be used. For best results, threads should be well cut. Teflon tape shall not be used on dead-ended, unsupported members in areas of extreme vibration because of the possibility of backing off. Tape shall be applied to the male threads, starting two threads in from the end of the pipe or fitting to prevent shredding. The tape shall be wrapped in the direction of the threads and overlapped one-half turn (overlap a full turn on 2-inch or larger pipe).

2.15.2. Other materials shall not be used as thread sealants without written approval of the Center Operations Directorate Pressure Systems Manager or Chairman of the Oxygen Working Group.

2.16. CONTAMINATION CONTROL DURING CALIBRATION, REPAIR, REPLACEMENT, AND MAINTENANCE IN THE FIELD

2.16.1. This section covers contamination control requirements in calibration, repair, replacement, or maintenance operations, performed on systems, subsystems, or components that have previously been precision cleaned.

Note: The cleanliness of precision cleaned systems may be compromised by improper opening of systems in an uncontrolled environment.

2.16.2. Access to controlled work areas shall be restricted to personnel knowledgeable with, and essential to, the operation.

2.16.3. An accountability checklist shall be used to monitor the movement of all tools, equipment, and materials into and out of the controlled area at all times.

2.16.4. A Field Environmental Controls Plan shall be implemented, along with the above checklist, prior to any system break-in.

2.16.4.1. The Field Environmental Controls Plan shall address the following:

a. What is the ease of access? Is there interference with associated piping or structures?

b. Are there loose or extraneous equipment or debris to be removed from the area?

c. What is the cleanliness of the area surrounding the break-in site? Ascertain the amount of pre-cleaning, solvent rinsing, and any waste to be generated and removed.

d. What is the complexity of the task? What tools, equipment, hardware, and bagging are required for the operation to be undertaken? What is the weight of the component, or subsystem being serviced or removed? Does the surrounding piping or tubing require additional support, prior to any component removal? Will rigging assistance be required to safely remove the item(s)?

e. Identify the maximum number of personnel required at any point in time on site, while system wetted surfaces are open.

f. Factor in the weather conditions, prior, during, and post entry. Establish a means to protect the system in the event the weather changes abruptly.

g. Calculate the approximate length of time the system (e.g., pipe/tubing, tank) will require to remain open during removal or installation operations. Can the task be completed during the remaining shift time of the day? If not, reschedule operation to be completed on a different day.

h. Establish the maximum time the system will be open. If weather conditions will deteriorate, consider adding a glovebox and/or walk-in enclosure as necessary.

2.16.5. Where feasible, all systems shall have a system purge with nitrogen gas meeting the requirements listed in this LPR. The purge gas shall be filtered to a particle size smaller than the cleanliness level required of the system. The gas flow rate shall be such that a positive pressure from the system to the environment shall prevail upon opening the system. In all cases, if the configuration of the system allows for a purge, it shall be used.

2.16.5.1. In cases where a purge cannot be maintained in either or both directions, the open system shall be protected with a polyethylene bag that has an

inert purge routed into the bag.

2.16.5.2. When it is impossible to provide for a purge through the system, and all environmental conditions have attempted to be met, the connection/disconnection to the system may be done without a purge. The person doing the work shall minimize the time the system is open to the environment. When the clean packaging has been removed, the system opening shall be loosely covered with bagging until the connection is made, or in the case of disconnect, until a clean closure has been installed.

2.16.5.3. Any interference caused by piping or structures overhead of the point of access may require establishing a higher level of protection prior to entry.

2.16.6. **Controlled Environment Enclosures**

2.16.6.1. A temporary enclosure shall be placed around the open portion of the system to preclude contaminating the open system (or installation part) by exposure to the uncontrolled environment. Depending on the size of the components or the complexity of the operation, the enclosure may be a small “dry box” design or a portable, walk–in tent type configuration**.**

Note: Depending on the complexity of the required operation, consult the Oxygen Working Group for recommendations.

2.16.6.1.1. **Small “Dry Box” Enclosure**

This enclosure, normally made of polyethylene sheet, shall be large enough to admit the hands of the worker conducting the cleaning. The inside of the enclosure shall be wiped VC clean and then the system opened to admit a flow of dry filtered inert gas from the system. The gas flow pressure is such that no dust or other environmental contaminants can enter the enclosure. In instances where system purging is not feasible, a purge of filtered air shall be established through the “dry box.”

2.16.6.1.2. **Walk-In Enclosure**

The nature of the maintenance or installation operation may require the construction of a large walk-in enclosure. This enclosure shall be made of a polyethylene sheet, suitably reinforced and shall be wiped VC clean prior to use. Air shall be pumped into the enclosure to provide a controlled environment required for the system components. This shall be accomplished by properly operating a HEPA filter assembly, and temperature and humidity controls, as required. The rate of air flow into the enclosure shall be sufficient to preclude dust or other environmental contaminants from entering the enclosure.

Note: The influent airflow shall not be so great as to force contaminants into the opened system.

2.16.6.1.2.1 **Enclosure Operations**

No operations shall be conducted in walk-in enclosures unless the system purge is on. “Operations” shall include the presence of properly clothed personnel, unsealing of clean package components or tools, opening or closing the system, and installing

or removing components.

2.16.6.1.2.2 **Personnel**

Personnel in the walk-in enclosure during installations shall wear cleanroom attire as necessary to maintain the cleanliness requirements of the system components.

2.16.7. **Handling**

Special attention shall be given to all surfaces contacted by hand. Clean, lint-free gloves and tools shall be mandatory. Vacuum cleaning and wiping of the hardware or pre-cleaning the area as required in the work environment, including adjacent hardware or components, are essential for assembly and disassembly operations. Particulate generators or generating activities in the vicinity of any open subsystems shall be addressed.

2.16.8. **Cleaning and Sampling**

Repair, replacement, or maintenance operations, which may result in the contamination of interfacing items, shall require removal, and re-cleaning of the contaminated items. This assures the cleanliness integrity of the assembly being serviced.

2.16.9. **Calibrations**

2.16.9.1. Items being removed from the system for calibration shall be capped, plugged, flanged, or double bagged once removed. The open system shall have all openings covered and sealed, with caps, plugs, flanges, or double bags. If the system can only be bagged, both the inside and outside bag shall be completely wrapped with tape to seal out the environment**.**

2.16.9.2. Sometimes calibrations are required to be undertaken in the field, such as with pressure safety relief valves, or pressure switches. In instances where this is to occur, preliminary steps have to occur before connections can be attempted. All equipment associated with the test shall have been certified clean, prior to any connections being made. This includes any digital or analog gauges, hoses, and all fittings used. A cleaned spare parts relief valve kit shall be on hand, in the event the valve is found defective and has to be removed and repaired. Clean and bagged caps, plugs, adapters, and flanges shall also be on hand as necessary for the test. All ports being accessed shall be locally cleaned, prior to being disconnected. Any tubing removed shall be immediately sealed with clean plugs. The test gas used shall be inert nitrogen meeting the requirements specified in this LPR. It shall be filtered to meet particulate levels equal to or better than the system into which it is being tied.

2.16.10. **Tanks**

2.16.10.1. Operational cleaning procedures shall be pre-approved by the Oxygen Systems Working Group prior to commencement of any on-site work.

Note: No entry shall be allowed into a tank without an approved confined space permit, and the atmosphere inside the tank being sampled and accepted.

2.16.10.2. **Tank Entry**

2.16.10.2.1. The following precautions shall be observed:

a. Maintain a positive pressure in the tank at all times during these operations.

b. Open only those ports necessary for the operations.

c. Immediately after opening the ports, wipe adjacent interior and exterior surfaces with a solvent-damped, lint-free cloth.

d. Clean all tools and instruments prior to their entry into the tank, or use clean packaged tools, and remove the packaging just prior to entry.

e. Log all items, equipment, and supplies on a checklist prior to entry into the tank. Account for all items, equipment, and supplies when the task has been completed, prior to tank being sealed.

f. Personnel entering the tank shall wear cleanroom garments, to include Tyvek coveralls, head cover, facemask, safety glasses and/or goggles, gloves, and boots with shoe covers.

g. Personnel entering the tank shall be equipped with proper safety gear, including a clean nylon safety rope, breathing apparatus, or approved filtered purge air hosed inside, as required. No entry into the tank shall be allowed without a third-party safety watch at the opening at all times.

h. Contaminant sensitive components within the tank shall be covered with Aclar covering material.

i. Foam pads may be used directly under the work being performed if there is a risk of damaging the tank from tools that may be dropped.

j. After completion of all work, the tank shall be cleaned thoroughly by vacuuming and solvent spraying. Only the vacuum line and cleaning head shall be brought into the tank; the vacuum and/or pressure units shall remain outside. If a solvent spray is used, a low point drain port or vacuum drain line shall be provided.

k. The interior cleanliness of the tank shall be sampled and certified post-cleaning, but prior to being put back in service.

l. After being certified and resealed, the tank shall be purged.

Note: Purges or blowdowns shall not be used in removing contaminants, as they are ineffective.

2.17. CONTAMINATION CONTROL DURING CALIBRATION, REPAIR, REPLACEMENT, AND MAINTENANCE IN THE FIELD

2.17.1. This section establishes the minimum contamination controls necessary to prevent the recontamination of precision cleaned items.

2.17.2. Precision cleaned items shall be protected from airborne contaminants during processing performed subsequent to cleaning. This protection shall include

the use of appropriate gloves and temporary packaging or covering. Upon completion of all required processing, the cleaned item shall be double bagged.

2.17.3. The fabrication of pre-cleaned components and hardware shall be accomplished in a cleanroom. Situations requiring field assembly shall be reviewed on a case-by-case basis. Ideally, final tie in connections should be the only thing made in the field.

Note: Valve bodies that cannot be feasibly removed from a system shall have a Field Environmental Controls Plan put in place prior to any work commencing.

2.17.4. Parts being assembled in the cleanroom shall only be removed from the bagging on an as needed basis.

2.17.5. Krytox 240 AC or Tribolube 16 shall be used on all treaded joints and flared surfaces prior to assembly to preclude galling. Lubricant shall be applied with foam Q-Tips and kept out of the wetted area of the fitting.

2.17.6. Once components have been assembled, they shall have a functional test performed, with certified clean test equipment and GN2 gas that meets the requirements of this LPR.

2.17.6.1. Components that require low-pressure calibrations after assembly shall be done locally with equipment that has current National Institute of Standards and Technology **(**NIST) certification and is certified clean. High-pressure calibrations shall be taken to the Component Verification Facility to be set on the Habco Oxygen Clean Test Stand (HOCTS).

2.17.6.2. Once calibrations have been performed and the component tagged, it shall be double bagged and returned to the cleanroom for final assembly.

2.17.7. Fabricated pipe or tubing sub-assemblies shall be leak checked with certified clean test equipment and GN2 gas that meets the requirements of this LPR, prior to installation in the system.

2.18. CONTAMINATION CONTROL OF CLEAN SYSTEMS OR SUBSYSTEMS BEING MODIFIED

Modifications to clean systems shall be handled on a case-by-case basis. A justification shall be provided for the modification, including marked up drawings showing the changes. Approvals by the Facility Safety Head, Standard Practice Engineer (SPE) for Pressure Systems, and the Oxygen Systems Working Group shall be required.

2.18.1. Modifications to pre-existing, in service panels, shall require environmental controls invoked to preclude contaminating the hardware prior to the system being opened.

2.18.2. All temporary fittings used for dimensional fit up, shall be certified clean and shall only be removed from the bagging just prior to use. Once component, tubing, or piping assemblies have been mounted, all parts that have internal

surfaces that will contact the wetted media shall be removed and sent in for cleaning. All flared or swaged tubing shall be hydro-tested prior to cleaning.

2.18.3. All pre-existing open joints shall be capped, plugged, or double bagged with Aclar and Polyethylene, once temporary hardware has been removed. If component or sub-system integrity come into question, it shall be removed and re-cleaned.

CHAPTER 3. QUALITY ASSURANCE PROVISIONS

3.1. RESPONSIBILITY FOR INSPECTION

3.1.1. Any vendor supplying a product or service to the Government shall be responsible for the performance and documentation of all inspections and tests specified in this LPR associated with that product or service.

3.1.2. Equipment provided by an approved manufacturer of oxygen equipment shall be cleaned and packaged per this LPR and certifications provided by the manufacturer.

3.1.3. Inspection and test records shall be kept complete and, upon request, made available to the CO in accordance with the provisions of the contract or order.

3.1.4. The Government reserves the right to perform any or all of the inspections and tests set forth in this procedure to assure end item or services conform to all specified requirements.

3.2. GENERAL

Quality assurance and verification provisions shall be subject to the same requirements stated in Section 1.3 of this LPR.

3.3. VISUAL INSPECTION

3.3.1. Visual inspection shall be performed to verify visible cleanliness levels (GC, VC, and UV).

3.3.2. A visual observation shall be made with the unaided eye (corrective lenses shall be acceptable) under a white light of sufficient intensity to illuminate the surface being inspected.

3.3.3. Visual examination of the direct surface under strong white light shall verify the following:

a. No evidence of moisture.

b. Freedom of corrosion products.

c. Freedom of loose (or potentially loose) dirt, scale, slag, weld spatter or other foreign matter.

d. Freedom of organic material such as oil, grease, crayon, paint, etc.

Note: Scale-free discoloration due to welding and passivation shall be permitted.

3.3.4. Borescopes, mirrors, and other devices may be used to increase accessibility during inspection, but magnifying lenses may be used only to further identify visible contaminants.

3.3.5. Items having limited accessibility for visual inspection shall be accepted or

rejected based on the quality assurance inspections of Sections 3.6, 3.7, and 3.8.

3.3.6. The presence of visible contamination, which discloses a particle population greater than the level specified, shall be cause for rejection.

3.3.7. Discoloration of a surface due to welding and passivation shall be permitted provided no weld scale or other contaminants remain.

3.3.8. Discoloration of a surface due to flash rust shall be permitted provided it does not prevent the system or component from meeting cleanliness requirements.

3.4. BLACK LIGHT (UV) INSPECTION

3.4.1. A visual inspection shall be made of the item with the unaided eye under UV light (having a power of at least 100 watts and 3,200 to 3,800 angstroms wavelength) for the presence of hydrocarbons.

3.4.2. Accumulations of lint or dust that are visible under the black light shall be removed by blowing with dry, oil-free nitrogen per MIL-PRF-27401.

3.4.3. Any contamination detected by the visual inspection or the black light inspection shall be cause for rejection and re-cleaning.

3.4.4. If re-cleaning fails to remove fluorescent indications, an investigation shall be made to determine if the item material is naturally fluorescent.

3.4.5. If natural fluorescence cannot be established, the part shall be replaced.

3.4.6. Some contaminants, e.g., Krytox, do not fluoresce under black-light inspection.

3.4.7. Therefore, black light shall not be the sole criteria for acceptance for oxygen cleaning.

3.4.8. If the surface to be inspected is inaccessible to black light inspection, a wipe test shall be performed with a lint-free medium, and the medium observed for the presence of contaminants. Care shall be taken not to wipe too hard since soft metals, such as aluminum, may soil the medium, giving an erroneous indication of contamination.

3.4.8.1. The wiping medium shall be subjected to visual inspection and the black light test specified in Sections 3.3 and 3.4 of this LPR, respectively.

3.4.8.2. When the wiping medium is subjected to further tests, such as black light or hydrocarbon evaluation, a baseline reading of the black wiping medium shall be determined and accounted for in subsequent evaluations.

3.5. DEW POINT ANALYSIS

3.5.1. Dew point determinations shall be made using a calibrated dew point meter; the initial reading shall be recorded.

3.5.2. The system or container shall be maintained under static pressure whenever

feasible for a 15-minute interval.

3.5.3. The dew point reading shall be re-verified.

3.5.4. If the dew point temperature has increased more than 5 °F during the interim period, the purging shall be continued until the acceptable dew point is verified.

3.5.5. GN used as a purging or drying medium shall be filtered to meet the cleanliness level specified for the item being tested.

3.5.6. Dew point of purge or drying gas shall be -65 °F minimum.

3.5.7. Effluent gas moisture content shall be 20ppm or less.

3.5.8. Manufacturer's directions shall be followed for operation of the particular instrument.

3.6. ACIDITY AND ALKALINITY TEST

3.6.1. All surfaces that have been cleaned shall be tested for acidity and alkalinity with pH paper, or an approved calibrated meter, while the surfaces are wet from the final pre-cleaning rinse water.

3.6.2. Dry surfaces of completed items may be wetted with a few drops of distilled water to permit testing as required.

3.6.3. Acceptable test results shall range between 6 to 8 pH.

3.7. ACCEPTANCE INSPECTION OF ITEMS CLEANED IN A CONTROLLED ENVIRONMENT

Items cleaned in a controlled environment, except those processed to level VC and/or level UV, shall be tested for conformance to the applicable cleanliness level by the test fluid-flush procedure (Test Method I).

3.8. ACCEPTANCE INSPECTION OF ITEMS CLEANED IN THE FIELD

Items, such as tubing, piping, and vessels cleaned in the field, shall be tested for conformance to the applicable cleanliness level using either (Test Method I) or (Test Method II). Testing procedures shall be determined by the configuration of the item being cleaned and by the method of dispensing the test fluid.

3.9. ACCEPTANCE INSPECTION OF ITEMS BY FUNCTIONAL TEST

3.9.1. Functional items, such as valves, regulators, cylinders, flexhoses, tube assemblies, vessels, and installed systems, shall be functionally tested as specified herein.

3.9.1.1. Calibrated Instrumentation

Test parameters, such as pressure, temperature, time, voltage, current, and resistance, shall be monitored and recorded using calibrated instrumentation capable of measuring the specified parameters. The instrumentation shall be calibrated using reference or working standards traceable to the National Institute of Standards and Technology (NIST).

3.9.1.2. **Hydrostatic Testing**

Functional items, such as flexhoses, tube assemblies, vessels, and systems that require hydrostatic testing, shall be tested prior to the final or precision-cleaning operation using an appropriate test fluid at the specified temperature and pressure.

3.9.1.3. **Component Testing**

Functional components, such as valves, solenoid valves, regulators, actuators, and cylinders, shall be assembled using clean parts in accordance with Section 2.10.4 and shall be functionally tested with gaseous nitrogen conforming to MIL-PRF-27401, Type 1, Grade A. The component shall be tested at the specified conditions.

3.10. ACCEPTANCE INSPECTION OF PACKAGING MATERIALS

3.10.1. **Environmental Control**

3.10.1.1. All quality assurance operations shall be accomplished within a cleanroom conforming to ISO 14644-1 and ISO 14644-2, which is consistent with or cleaner than the packaging material being inspected.

3.10.1.2. Care shall be taken not to contaminate the packaging materials.

3.10.2. **Sampling**

3.10.2.1. Packaging materials shall be examined and tested to determine compliance with the cleanliness requirements of Section 2.12.2.1 of this LPR.

3.10.2.2. All the plastic film of one type, one size, and one configuration, such as tubing, flat roll stock, sheet, and fabricated bags offered by one manufacturer at one time, shall be considered one lot.

3.10.3. **Visual Inspection**

No evidence of oil, solvents, paints, grease, dirt, ink, metal chips, or other foreign matter shall be permitted on either the external surfaces or the internal surfaces of packaging materials when inspection is made with the unaided eye.

3.10.4. **Thickness of Packaging Film**

3.10.4.1. The thickness of plastic films used for packaging shall conform to the limits specified in Table 5 of this LPR.

3.10.4.2. Measurements shall be made with a micrometer caliper having a flat anvil and capable of being read to the nearest 2.5 µm (0.0001 in).

3.10.5. **Verification of Cleanliness Level**

3.10.5.1. All plastic films of one lot shall have their cleanliness level verified prior to use.

3.10.5.2. When a lot contains a large number of plastic films, test one bag in every hundred.

3.10.6. **Minimum Critical Surface Area for Testing**

3.10.6.1. The minimum interior critical surface area for verification of cleanliness

level shall be 0.1 m^2.

3.10.6.2. Sampling shall be according to Section 3.10.2 of this LPR, except that additional sample material from the offered lot shall be used when necessary to make the minimum interior critical surface area of 0.1 m^2.

3.10.7. **Sample Preparation**

3.10.7.1. Fabricated bags shall be sealed across the open end.

3.10.7.2. Tubular packaging material shall be fabricated into a bag by cutting off a length conforming to the requirements of Section 3.10.6 of this LPR and sealing both ends.

3.10.7.3. Flat roll sheet and stock shall be fabricated into a bag by cutting out a section with an area conforming to the requirements of Section 3.10.6 of this LPR, folding the section, and sealing the section as necessary.

3.10.7.4. The cutting technique shall be in accordance with Section 2.12.3.1 of this LPR.

3.10.7.5. The sealing technique shall be in accordance with Section 2.12.3.2 of this LPR.

3.10.7.6. All items shall be handled in a manner that minimizes exposure of the interior critical surfaces to airborne particles.

3.10.7.7. One comer of the completely sealed test bag shall be cut off so that an opening of a maximum of 19 mm (0.75 in) in length is created.

3.10.8. **Rinsing Procedures**

3.10.8.1. Test solvent that conforms to the cleanliness level of Section 2.7.1 shall be used in the ratio of 100 mL of fluid per 0.1 m^2 of critical surface area.

3.10.8.2. The following rinsing procedure shall be used:

a. Introduce test solvent into the sealed bag through the previously cut opening.

b. Close the bag by folding over the cut corner.

c. Gently agitate the test solvent with the bag for a minimum of 15 seconds, wetting all surfaces.

d. Pour the used test solvent into a precision-cleaned beaker, taking care to exclude airborne contamination.

e. Analyze the test solvent for particulate population and NVR in conformance with Section 2.7.3, Table 2 of this LPR.

3.11. SOLVENT FLUSH SAMPLING – PIPING

3.11.1. **Configuration**

3.11.1.1. The system shall be intact and in its final configuration.

3.11.1.2. Any part or component that might be damaged during the verification flush/rinse shall be removed, and if that removal would cause an opening/leak in the

system, the leak shall be sealed by hand with a precision cleaned item.

3.11.2. **Test Solvent**

3.11.2.1. Test solvent per Table 2 of this LPR shall be used for flush sampling.

3.11.2.2. Contractors shall use test solvent approved in their cleaning procedure submittal for flush sampling.

3.11.3. **Solvent Volume for Analysis**

3.11.3.1. **Test Procedure**

3.11.3.1.1. The solvent-flush test procedure shall be as follows:

a. Ascertain the total volume of test solvent necessary to flush the cleaned systems or sub-assemblies.

b. Flush all critical surfaces uniformly with the test solvent. Tubing, piping, and hoses shall be flushed at 1.25 m/s (4 ft/s) minimum.

c. Catch the test solvent in a precision cleaned glass container from the low point drain, sample port.

d. Immediately upon the completion of the above step, dry the tested system using the dry gas previously specified.

e. Test Gas Purge - Items such as vessels, pipe, tubing systems, and flex hoses shall be maintained under a 5 psig minimum purge, until all ports, orifices, and fittings are sealed. Test gas shall be in accordance with Section 2.14 of this LPR.

3.11.4. **Particle Analysis of Solvent-Flush Sample**

3.11.4.1. The solvent-flush sample shall be analyzed for particle population as described in the following sections.

3.11.4.2. **Particle Population Analysis (Microscope)**

3.11.4.2.1. Particle population per square foot shall be determined based on the critical surface area.

3.11.4.2.2. The total volume of test solvent, or a representative sample of the test solvent not less than 100 mL, shall be analyzed as follows:

a. Assemble a cleaned filtration apparatus.

b. Using clean forceps with non-serrated tips, place a filter membrane (47-mm diameter with 0.45-micron pores) in position in the filter holder.

(1) The filter membrane shall be compatible with the test solvent.

(2) Prior to insertion, the filter membrane shall only be rinsed with filtered test solvent to remove any adherent contamination.

c. Fill the filter funnel approximately three-fourths full of test solvent and turn on the vacuum pump. Avoid splashes on sides of funnel.

d. Add the remaining test solvent to the filter funnel at a rate necessary to maintain the funnel more than half-full until all of the test solvent has been added.

(1) Do not allow the test solvent to pour directly onto the filter membrane after filtration has started.

e. When filtration is completed, remove the filter membrane from the holder and place it in a disposable Petri dish or equivalent until the particles are counted.

(1) Do not subject Petri dish to jostling or turn it upside down, as particles can fall off the membrane.

f. Retain the filtrate for analysis of the NVR in accordance with Section 3.12.5.

g. Place the filter membrane under the microscope.

h. Direct a high-intensity light source of 5,000 to 6,000 candelas onto the filter membrane from an oblique position to obtain maximum definition for sizing and counting.

(1) High-intensity illumination is a critical requirement.

i. Use magnification of approximately 40 to 50 power for counting particles.

j. Count the particles in accordance with the method of ASTM F312-97 over the entire effective filtering area of the membrane.

k. Calculate the particles per 0.1 square meter (for items having less than 0.1 square meter (1 square foot) of surface area, use 0.1 square meter) of the critical surface as follows:

$$\frac{\text{Particles}}{0.1\ m^2} = \frac{(\text{Particles counted}) \times (\text{total volume of test solvent used})}{(0.1\ m^2 \text{ of surface}) \times (\text{volume of sample filtered})}$$

l. Particular matter contamination shall meet the cleanliness level specified in Table 1 of this LPR. Visible silting shall be cause for rejection.

(1) Place the filter in a small plastic bag with a sealable strip and attach to the report.

3.12. SOLVENT FLUSH SAMPLING – COMPONENTS

3.12.1. The components shall be disassembled to the elemental or piece part level.

3.12.2. Several small parts shall be grouped together if they belong to the same cleaning order.

3.12.3. Care shall be taken to avoid parts rubbing or crashing into each other.

3.12.4. **Test solvent**

3.12.4.1. **Solvent Volume for Analysis**

3.12.4.1.1. Requirements for selecting the solvent volume for analysis shall be as follows:

a. For surfaces of 0.1 m^2 to 0.5 m^2, use a minimum of 500 mL.

b. For surfaces that total less than 0.1 m^2, assume surface equals 0.1 m^2.

c. For surfaces greater than 0.5 m^2, use 100-mL solvent for every 0.1 m^2.

3.12.4.2. **Test Procedure**

3.12.4.2.1. The solvent-flush test procedure shall be as follows:

a. Ascertain the total volume of test solvent necessary to flush the cleaned item or items.

b. Flush all critical surfaces uniformly with the test solvent.

(1) Where flushing does not reach all interior surfaces, the test solvent shall be introduced, and the item manually shaken.

c. Catch the test solvent in a precision cleaned glass container.

d. Immediately upon the completion of the above step, dry the tested items using the dry gas specified.

3.12.4.3. **Analysis of Solvent-Flush Sample**

3.12.4.3.1. Particle Population Analysis (Microscope) population per square foot shall be determined based on the critical surface area.

3.12.4.3.2. The total volume of test solvent or a representative sample of the test solvent not less than 100 mL shall be analyzed as follows:

a. Assemble a cleaned filtration apparatus.

b. Using clean forceps with nonserrated tips, place a filter membrane (47-mm diameter with 0.45-micron pores) in position in the filter holder.

(1) The filter membrane shall be compatible with the test solvent.

(2) Prior to insertion, the filter membrane shall only be rinsed with filtered test solvent to remove any adherent contamination.

3.12.5. **Nonvolatile Residue (NVR) Analysis**

The NVR analysis shall be determined using the gravimetric method described below.

Note: When particulate and NVR analysis are to be done together, the Particulate filtrate shall be reused for the NVR analysis.

3.12.5.1. **Test Procedure – Piping**

The solvent-flush test procedure shall be as follows:

a. Ascertain the total volume of test solvent necessary to flush the cleaned item or items.

(1) Flush all critical surfaces uniformly with the test solvent.

b. Tubing, piping, and hoses shall be flushed at 1.25 m/s (4 ft/s) minimum.

c. Catch 1,000 mL of the test solvent in a precision cleaned glass container.

(1) For each 100 square meters (1,000 sq. feet) in the system after the first 100 square meters, collect an additional 1,000-mL sample.

d. Immediately upon the completion of the above step, dry the tested items using dry nitrogen gas.

3.12.5.2. **Test Procedure – Components**

3.12.5.2.1. The solvent-flush test procedure shall be as follows:

a. Ascertain the total volume of test solvent necessary to flush the cleaned item or items.

b. Flush all critical surfaces uniformly with the test solvent.

(1) Where flushing does not reach all interior surfaces, the test solvent shall be introduced and the item manually shaken.

c. Catch the test solvent in a precision cleaned glass container.

d. Immediately upon the completion of the above step, dry the tested items using dry nitrogen gas.

3.13. GRAVIMETRIC METHOD

3.13.1. The NVR shall be determined by weighing the residue left after evaporation of the solvent flush fluid.

3.13.2. The NVR shall be reported as milligrams per 0.1 square meter (mg/0.1 m^2).

3.13.3. The NVR shall be calculated by the method shown below.

3.13.3.1. In the following description, "solvent" means clean solvent per Table 2 of this LPR, and “sample" means the solvent flush fluid that has been used to flush the system being cleaned.

3.13.4. **Equipment Required**

3.13.4.1. The following equipment shall be required:

a. Aluminum foil dish with smooth sides and a capacity of about 65 mL.

b. Graduated cylinder, 1,000 mL capacity with 10 mL divisions.

c. Beaker, 660 mL capacity with 50 mL graduations.

d. Watch glass to cover 600 mL beaker.

e. Oven, capable of temperature setting at 100 °F.

f. Desiccator with indicating type silica gel.

g. Balance, capable of weighing to 0.0001 gm (0.1 mg).

3.13.5. **Procedure**

3.13.5.1. A sample shall be obtained as follows:

Milligrams per 0.1 square meter method: A known surface area (typically 0.1 m^2 or 1 ft^2) shall be rinsed with enough solvent to obtain a reasonably sized sample (e.g., 500 mL of solvent).

Note: The sample shall be collected using section 3.12.5 as a guide.

3.13.5.2. Once a sample has been obtained, the following procedures shall be observed:

a. All glassware and the aluminum weighing dish shall be cleaned with clean solvent before use.

b. The aluminum dish shall be dried in the oven at 100 °F for one hour and cooled in the desiccator before weighing.

(1) The dish shall be weighed and its weight recorded to 0.0001 gram.

(2) Use the formula shown in this section.

c. The sample shall be measured in the graduated cylinder.

(1) About 500 mL shall be transferred to the beaker, covered with the watch glass, and evaporated at a gentle boil on the hot plate.

(2) Add additional sample periodically as the material in the beaker boils away.

(3) This process shall be conducted in an appropriately vented location, such as a fume hood.

d. When the sample volume has evaporated to less than 100 mL, wash the sides of the beaker a few times with solvent.

e. When the sample volume has evaporated to less than 40 mL, pour the beaker contents into the pre-weighed aluminum dish.

(1) Rinse the beaker with a small volume of solvent to transfer all residue into the aluminum dish.

f. Evaporate the contents of the aluminum dish to dryness on a low temperature setting of the hot plate.

(1) The sample shall not boil actively.

(2) Remove the dish from the hot plate as soon as dryness is reached and place in the 100 °F oven for one hour.

(3) Cool the dish in the desiccator, weigh to 0.0001 gram, and record its weight.

3.13.6. **Calculation**

3.13.6.1. NVR shall be calculated as follows:

Milligrams per square foot method

(Weight of dish+residue)* - (weight of dish)** = (weight of residue, grams)

$$\text{NVR in mg/0.1 m}^2 = \frac{\text{(weight of residue, gram) x (1000 mg/g)}}{\text{area of test surface (0.1 m}^2\text{)}}$$

*Last step, Section 3.13.5

**Second step, Section 3.13.5

3.13.6.2. The aluminum foil dish with residue shall be placed in a small plastic bag with a sealable strip and attached to the report.

3.13.6.3. Where specifications call for both particle analysis and NVR analysis, the test can be combined to conserve test solvent.

3.13.6.4. The particle filtrate can be analyzed via the gravimetric method for NVR.

CHAPTER 4. PREPARATION FOR DELIVERY

4.1. PRESERVATION AND PACKAGING

Preservation and packaging of cleaned items shall be in accordance with Chapter 2 of this LPR.

4.2. PACKING

4.2.1. Cushioning material used to pack packaged precision-cleaned items shall be nonflammable and non-contaminating in nature.

4.2.2. **On-site Transportation of Small Items**

4.2.2.1. Small, packaged precision-cleaned items protected in accordance with Section 2.12.3 of this LPR shall be packed as required.

4.2.2.2. Cushioning material shall be used to immobilize the item and prevent damage to the packaging.

4.2.2.3. When a number of small, individually packaged items are packed, cushioning material shall be used to separate and to immobilize the individually packaged items.

4.2.2.4. Cushioning materials, such as excelsior, shredded newspaper, and similar materials that generate large numbers of particles and fibers, shall not be acceptable.

4.2.3. **On-site Transportation of Large Items**

4.2.3.1. Large or heavy items, protected in accordance with Section 2.12 of this LPR, shall be placed on skids or pallets designed to support and protect the items from damage during handling.

4.2.3.2. All items shall be secured to the skids or pallets by bolts, suitably tensioned, and cushioned steel straps, tie down rods, or lumber hold downs.

4.2.3.3. Cushioning shall be placed between the item and all support points and the base of the skid or dolly to prevent physical damage to the item.

4.2.4. **Offsite Shipment**

4.2.4.1. Packing of precision-cleaned items for offsite shipment shall be in accordance with level A or B of MIL-STD-2073 or MIL-E-17555H as applicable to the type of item being packed.

4.2.4.2. Level A packing shall be used when storage conditions are indeterminate and may involve outdoor storage.

4.2.4.3. Level B packing shall be used when item is handled under cover and warehouse storage are probable.

4.3. MARKING FOR SHIPMENT

Shipping containers shall be marked in accordance with MIL-STD-129 and shall include special marking in addition to that specified in MIL-STD-129 to the effect that precision-cleaned items are contained therein.

CHAPTER 5. RESPONSIBILITY

5.1. PERSONNEL

The appropriate Facility Safety Head and Facility Coordinator shall be jointly responsible for maintaining the integrity of an oxygen clean system after its acceptance.

5.2. INTERPRETATIONS

Questions concerning content, interpretation of this procedure, or unusual situations not covered in this text shall be referred to the Oxygen Working Group or Center Operations Directorate Pressure Systems Manager for final resolution.

APPENDIX A. DEFINITIONS

Accuracy	Accuracy is how close the measured value is to the "true" value.
Assembly	An assembly is two or more parts having a common mounting and being capable of performing a definite function. For example, filter element, housing, and 0-ring become part of a filter assembly.
Blank	A blank is the result for an analytical sample of the test fluid prior to use in performing a cleanliness verification test.
Component	A component is an article that is normally a part of a subassembly or assembly and is a self-contained element within a complete operating system.
Component Cleaning	Any cleaning activity taking place in a centralized facility dedicated to cleaning components, assemblies, and subassemblies. The cleaning process includes the following tasks: check in, disassembly (if necessary), pre-clean, precision clean, verification, reassembly (if required), and functional testing.
Condensable Hydrocarbon	A condensable hydrocarbon is a hydrocarbon capable of going from a gaseous to a liquid or solid state at ambient temperature and prevailing pressure.
Contracting Officer (CO)	The cognizant officer or representative individual overseeing a specific design, system, or procurement. The CO requests work from the Cleaning Contractor (CC).
Controlled Environment	An area, such as a cleanroom, in which factors such as humidity, temperature, particle matter, and contamination are precisely controlled.
Critical Surface	Any surface of an item that contacts the critical service medium (liquid oxygen, pneumatic gases, etc.) is considered a critical surface. A critical surface is subject to the cleaning procedures and cleanliness requirements of this specification.

Dewar	A dewar is a double-walled vessel with the annular space between the walls evacuated to provide insulation.
Dew point	Dew point is the temperature at which condensation of water vapor takes place at prevailing pressure (usually atmospheric pressure).
Effluent	An outflow or discharge of liquid waste.
Fiber	A fiber is a nonmetallic, flexible structure having a length-to-width ratio of 10 to 1 or greater.
Field Cleaning	The processes of rough cleaning and precision cleaning of large components and systems that cannot be processed in a controlled environment (such as a cleanroom).
Fluid	For the purpose of this specification, a fluid is defined as a gas or liquid.
Generally Clean (GC)	Generally clean (GC) is freedom from manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. This level shall not be designated for hardware that is sensitive to contamination.
Hydrocarbon	A hydrocarbon is an organic compound consisting exclusively of the elements of carbon and hydrogen.
Hypergolic Propellant	A hypergolic propellant is any fuel/catalyst (monopropellant) or fuel/oxidizer (bipropellant) combination that spontaneously ignites and is used in propelling a rocket.
Micrometer	One micrometer is equivalent to 0.001 millimeter, 0.000001 meter, 0.0000394 inch, or 0.0394 mil (one mil is equal to 0.001 inch).
Nonvolatile Residue (NVR)	Nonvolatile residue is soluble or suspended material and insolubly particulate matter remaining after temperature-controlled evaporation of a filtered volatile liquid.

Oxidizer	A chemical that initiates or promotes combustion in materials, thereby causing fire either of itself or through release of oxygen or other gases; a substance that gives up oxygen readily or otherwise supports combustion. For the purposes of this specification, gaseous oxygen and breathing air shall be considered oxidizers.
Part	A part is one piece of two or more pieces joined together in such a way that it is not normally disassembled without destruction of the designed use. Fittings, O-rings, and poppets are normally considered parts of a valve.
Particle	A particle is a unit of matter with observable length, width, and thickness and is usually measured by its largest dimension in micrometers.
Parts per Million (ppm) by Weight	An absolute weight relationship expressed on an equivalent basis in any weight unit. The user may employ a weight unit that is convenient. One ppm may be 1 gram per million grams, 1 pound per million pounds, 1 milligram per liter (approximately), etc.
Passivation	Passivation is the process by which a corrosive-resistant layer is bonded to a metal surface by submerging the surface in an acid solution.
pH	A value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the logarithm of the reciprocal of the hydrogen ion concentration of a solution. The pH is measured over the nominal range of 0 to 14. A pH reading below 7 is acidic, pH 7 is neutral, and pH above 7 is alkaline.
Pickling	Pickling is the chemical or electrochemical process by which surface oxides are removed from metals.
Precision Cleaning	Precision cleaning is a cleaning process used to achieve cleanliness levels more stringent than level VC.
Repeatability	Repeatability is reproducibility to acceptable level of precision.

Rough Cleaning	Rough cleaning is the cleaning process normally used to achieve cleanliness level VC.
Silting	Silting is an accumulation of particles (approximately 2 to 20 µm) of sufficient quantity to cause a haze or obscuring of any portion of a grid line or any portion of the grid of a filter membrane when viewed visually or under 40--power maximum magnification.
Subsystem	A subsystem is two or more assemblies joined together to perform a definite function. A subsystem may be capable of independent operation when interconnected into a system.
System	A system is a series of subsystems joined together to perform a definite function.
Test Fluid	Test fluid is either a liquid solvent or an aqueous solution that is utilized to determine fluid system wetted-surface cleanliness level.
Threshold Limit Value	A level to which a worker can be exposed day after day for a working lifetime without adverse effects.
Unprotected Worker	Worker not wearing personnel protective equipment.
Validate/Validation	Validate/validation is the process or method of proving that an item subsystem or system does meet the specified requirements (for example, to validate the integrity of the system).
Verify/Verification	Verify/verification is the process or method to establish the truth, accuracy, or reality of the cleanliness level of a cleaned item (for example, to verify the cleanliness level of a system).

Visually Clean (VC)	Visually clean is the absence of all particulate and nonparticulate matter visible to the normal unaided (except corrected vision) eye. Particulate is identified as matter of miniature size with observable length, width, and thickness. Nonparticulate is a film matter without definite dimension. This level, with the exception of the orbiter payload (cargo) bay, payload canister, and payloads, requires precision cleaning methods but no particle count.
Visually Clean Plus Ultraviolet (UV)	UV is visually clean (VC) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 angstroms wavelength (3.2×10^{7} to 3.8×10^{7} meters). This level requires precision cleaning methods but no particle count. Fluorescents indicate possible hydrocarbon contamination. If re-cleaning fails to remove fluorescent indications, an investigation shall be made to determine if the item material is naturally fluorescent.
Volatile Hydrocarbon	A volatile hydrocarbon is a hydrocarbon capable of going from liquid or solid to a gaseous state at ambient temperature and prevailing pressure.

APPENDIX B. ABBREVIATIONS AND ACRONYMS

AMS	Aerospace Material Specification
ASTM	American Society for Testing and Materials
C	degrees Celsius
CC	Cleaning Contractor
CFR	Code of Federal Regulations
CO	Contracting Officer
F	degrees Fahrenheit
FEP	fluorinated ethylene propylene
ft/s	feet per second
g	grams
GN2	gaseous nitrogen
h	hour
HEPA	high-efficiency particulate air
LaRC	Langley Research Center
m	meter
max	maximum
mg	milligram
mL	milliliter
mm	millimeter
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NVR	nonvolatile residue
ppm	part per million
psig	pounds per square inch
s	second
SAE	Society of Automotive Engineers
SPE	Standard Practice Engineer
TLV	threshold limit value