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CLEANLINESS OF COMPONENTS FOR USE IN OXYGEN, FUEL, AND PNEUMATIC SYSTEMS, SPECIFICATION FOR

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George C. Marshall Space Flight Center

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1.0 SCOPE

This specification establishes surface cleanliness requirements of components used in space vehicles and associated ground support equipment. This specification is not intended to specify cleanliness requirements for composite vessels used in cryogenic service. General cleaning requirements, verification procedures, drying and packaging requirements are provided. Each user may require subtier documents to address processing, system cleanliness, maintenance and verification. An engineering assessment shall be necessary to establish requirements for each system.

NOTE: It is the responsibility of the user of this specification to assure suitability of the end item for its intended use.

1.1 Cleanliness Levels - Cleanliness levels for particulate and NVR (nonvolatile residue) are listed in Table 1. Unless otherwise specified, the minimum cleanliness levels for new or recleaned systems, subsystems and components are specified in paragraph 3.2 and Table 2. The cleanliness levels for Space Shuttle propulsion elements and existing MSFC test facilities are specified in 7.0 Appendix.

1.2 Alternate Procedures - Methods and procedures other than those enumerated in this document may be utilized with prior approval of the procuring activity.

Table 1: CLASSIFICATION OF CLEANLINESS

	PARTICULATE LEVELS		NVR LEVELS	
CLASS	PARTICLE SIZE IN MICRONS	MAX. NUMBER PER 0.1 m^2	LEVEL	MAXIMUM mg/0.1 m^2
I	>2500	0	A	1
	700<X<2500	1		
	175<X<700	5		
	NO SILTING			
			B	5
II	>1000	0		
	NO SILTING			
III	>800	0		
	NO SILTING			
IV	>400	0		
	NO SILTING			
V	VISUALLY CLEAN/NO SILTING			

NOTE: For the purpose of this specification 0.1 square meter = 1 square foot.

2.0 APPLICABLE DOCUMENTS

Unless otherwise noted the latest revision of the following documents are applicable to the extent specified herein. Equivalent grades of chemicals may be used upon approval from the procuring activity.

2.1 Government

2.1.1 Specifications

MIL-T-27602, Trichloroethylene

MIL-P-27401, Type 1, Grade A - Nitrogen

BB-N-411, Type 1, Class 1, Nitrogen

MIL-C-81302, Type 1, Trichlorotrifluoroethane (CFC 113)

MIL-T-81533, 1,1,1-Trichloroethane (Methyl Chloroform)

KSC/MTB-402, Physical and Chemical Test Results of Plastic Films

PPP-T-60, Tape, Packaging, Waterproof

NHB 8060.1B/C, Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion

2.1.2 Standards

MIL-STD-129, Marking for Shipment and Storage

MSFC-STD-246, Design and Operational Criteria of Controlled Environment Areas

2.1.3 Procedures

MSFC-PROC-404, Gases, Drying and Preservation, Cleanliness Level and Inspection

MSFC-PROC-1831, The Analysis of Nonvolatile Residue Content

MSFC-PROC-1832, Sampling and Analysis of Nonvolatile Residue Content on Critical Surfaces

MSFC-PROC-1721, Tape Lift Particle Counting

2.1.4 Reference

KSC-C-123, Cleanliness Levels, Cleaning Protection, and Inspection Procedures for Parts, Field Parts, Assemblies, Sub Systems, and Systems for Fluid Use in Support Equipment

SN-C-0005, National Space Transportation System, Contamination Control Requirements

SSC-79-001, SSC Facility Cleanliness Requirements for Propellant, Gas, and Hydraulic Systems

KSC MTB-402-85, Physical and Chemical Test Results of Plastic Films

2.2 Industry

ASTM-F-312, Standard Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters

3.0 REQUIREMENTS

3.1 General - All parts, components, assemblies, systems or related equipment for use in space vehicles and related Ground Support Equipment (GSE) shall be cleaned and inspected in accordance with this specification. Assembled parts which may be damaged during the cleaning operation shall be disassembled to a level to permit cleaning. Designs for systems and system components should, where practical, include the capability to remove all valves and components from the system for precision cleaning.

SAFETY PRECAUTION - It is the responsibility of all users of this specification to review pertinent Materials Safety Data Sheets (MSDS's) and materials specifications to assure safety of personnel and protection of the environment and facilities in fulfilling the requirements of this document.

3.2 Cleaning - All significant surfaces of system hardware shall be pre-cleaned to remove dirt, grit, scale, corrosion, grease, oil and other foreign matter prior to any final precision cleaning process. Metallic items shall be surface treated (cleaned, passivated, and/or coated), as applicable, to prevent latent corrosion and contamination. Assembled items that do not lend themselves to this type of treatment shall be treated prior to assembly. Surface treated areas degraded during subsequent fabrication and assembly shall be reprocessed, as required, to restore the original protective finish.

Significant surfaces of system hardware which have been pre-cleaned shall be visually clean prior to proceeding to any precision cleaning operation. Scale-free discoloration due to welding or passivation is permitted.

All significant hardware surfaces shall be precision cleaned to meet the requirements of 3.3 and Table 2 or as specified in 1.1. Precision cleaning operations shall be performed in an environment compatible with the component cleanliness requirements to preclude adverse effect on the functional performance. Exemptions may be requested for hardware which due to size or other considerations cannot meet this requirement. As a minimum, cleaning shall be performed in an environment that does not adversely affect the function of the hardware. Precision cleaned articles shall be packaged per 3.5 immediately after verification and drying operations or suitably protected prior to leaving the controlled environment.

3.2.1 Process Approval - Cleaning processes except as noted in 3.2.2 shall be left to the discretion of the user, however, the process shall not be detrimental to hardware being cleaned and process approval shall be obtained from the procuring activity prior to cleaning and handling. To obtain approval, the contractor shall submit to the procuring activity the following information:

a) Proposed cleanliness levels including analysis and rationale for the selected cleanliness levels.

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 as specified in 3.2.2.

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.

f) Controlled environment levels to be maintained for cleaning and handling. MSFC-STD-246 shall be used to evaluate applicable areas.

g) Preservation methods and materials.

h) Verification Methods

NOTE: Documentation from all subcontractors shall be maintained and made available for review by the government.

Table 2: PRODUCT CLEANLINESS REQUIREMENTS

System	Cleanliness Level
LOX/GOX Systems	
Metallic & Fluorocarbon Components	I A
Metallic Vessels	I B
Nonmetallic (except Fluorocarbons)	V
Fuel Systems	
Metallic & Fluorocarbon Components	I
Metallic Vessels	I
Nonmetallic (except Fluorocarbons)	V
Pneumatic System	
Metallic & Fluorocarbon Components	
Not Interfacing with Oxygen Systems	I
Interfacing with Oxygen Systems	I A
Metallic Vessels	
Not Interfacing with Oxygen Systems	I
Interfacing with Oxygen Systems	I B
Nonmetallic (except Fluorocarbons)	V

3.2.2 Materials - Selection of materials used in processing is left to the discretion of the user, however, the fluids must be compatible with the item being cleaned. The following compatibility issues, as applicable, must be considered and evaluated in the selection of processing materials.

a) corrosion
b) stress corrosion cracking
c) embrittlement
d) leaching
e) masking of crack-like indications
f) residue
g) crazing (non-metallics)
h) reversion (non-metallics)
i) hydrolysis (non-metallics)

3.2.3 - Final Rinsing Solution - The final rinsing solution shall meet or exceed the cleanliness requirements for which they are intended and meet the following specific requirements at the point of use:

a) There shall be no particle greater than 175μ in any dimension and no more than 5 particles between 100 and 175 μ per 500 ml when tested per ASTM-F-312. Particle corrections by subtracting the test solvent particle count from the final particle count are not allowed.

b) Nonvolatile residue shall not be greater than 10 milligrams per 500 milliliters, as determined by MSFC-PROC-1831 or equivalent approved by the procuring activity.

c) If water is used as the final rinse fluid it shall meet the requirements of (a) and the minimum specific resistance (maximum conductance) shall be 50,000 ohms/cm and the pH shall be between 6.0 and 8.0.

3.3 Verification - Precision cleaned components and vessels shall be verified to meet applicable cleanliness requirements specified in Table 2. Verification shall be performed in an environment that is compatible with the environment in which cleaning was performed. MSFC-STD-246 shall be used by the procuring activity to evaluate the applicable environmentally controlled area.

Alternate verification procedures and/or corresponding cleanliness levels may be used only upon demonstration of equivalence in accordance with 5.0 and upon written approval by the procuring activity.

Supplemental information concerning chemical species of contaminant and their potential reactivity may be useful in determining alternate acceptance criteria.

CAUTION: It has been observed that both NVR and particulate levels increase after a system has been exposed to cryogenic media. This increase in contamination levels should be taken into consideration in establishing methods for system verification.

3.3.1 Visual cleanliness - Surfaces of all components that will contact the respective service medium shall be visually free of contaminants such as moisture, corrosion, scale, dirt, oil, grease, wax, gum and other foreign material when inspected in accordance with 4.3.1. Scale-free discoloration due to welding or passivation is permitted. Surfaces inaccessible to visual inspection shall be accepted or rejected based upon 3.3.3 and 3.3.4.

3.3.2 Acidity or Alkalinity - Surfaces which have been cleaned and rinsed with aqueous media shall register a pH between 6.0 and 8.0 when evaluated in accordance with 4.3.2.

3.3.3 Nonvolatile residue - Nonvolatile residue, as defined in 6.0, shall not exceed the levels specified in Table 2 when tested in accordance with 4.3.3. The baselined procedure for NVR sampling shall be MSFC-PROC-1832.

3.3.4 Particulate contamination - Particulate contamination shall not exceed the limits as specified in Table 2 when tested in accordance with 4.3.3.

NOTE: It is permissible to qualify particulate requirements different than those listed in Table 2 based upon system design/analyses and upon approval by the procuring activity.

3.3.5 Silting - Silting, as defined in 6.0, shall not be permitted.

3.4 Drying

3.4.1 Procedure - Components shall be thoroughly dried to remove residual cleaning, rinsing, and/or verification media. Effluent gas shall not exhibit an increase in moisture content greater than 5 ppm or measurable increase in concentration of residual organic solvents when tested in accordance with 4.3.4. Items which do not lend themselves to this type of drying or testing procedure shall be dried and tested in accordance with procedures approved by the procuring activity.

CAUTION: Most solvents are not oxygen compatible; it is the user's responsibility to assure removal of these substances prior to packaging or placing hardware into service.

3.4.2 Materials - Gases used in drying processes shall conform to the following and to cleanliness and quality assurance requirements for gases as specified in MSFC-PROC-404.

3.4.2.1 Nitrogen - MIL-P-27401, type 1, grade A or BB-N-411, type 1, class 1, grade B

3.4.2.2 Air - For drying/purging of tanks/vessels, air shall meet the following minimum requirements:

- No particulate matter >100 microns
- Relative humidity - 60% maximum
- Hydrocarbon content 10 PPM maximum except 20 PPM when the carbon chain of 5 or above does not exceed 5 ppm.

3.5 Packaging and Protection

3.5.1 Components - All significant surfaces or openings to significant surfaces shall be protected from contamination by sealing the surfaces or openings with approved coverings (3.5.3.1) and secured with tape (3.5.3.2), or other approved method. Protected components shall be placed in visually clean bags meeting the requirements of 3.5.3.1. Interior of the bags and parts shall be purged with a drying gas meeting the requirements of 3.4.2.1; bags shall be completely sealed to assure an inert storage package. Sealed bags shall be over packed as necessary to prevent damage during storage and handling.

Other packaging materials compatible with the applicable service media may be used, however, gas purging and over packaging requirements shall be as listed above. If alternate methods are used, prior approval of materials and procedures shall be obtained from the procuring activity.

Packaging operations involving cleaned and verified components should be accomplished within the same environmentally controlled area in which verification was performed. However, where impractical to package in the same environment, the environment must not adversely impact the function of the hardware/component. Outer wrapping and over packing may be performed outside the controlled area.

Desiccants, when required for additional corrosion protection, shall not be placed in such a manner as to contaminate cleaned surfaces. Provisions shall be made for monitoring desiccants.

3.5.2 Containers - Immediately after drying, openings shall be covered with approved precleaned dry covers (3.5.3.1) secured in a manner to prevent detachment or damage during handling, storage, or shipment. Covers shall be designed to facilitate container venting and to prevent recontamination of tank interior. If exposed to uncontrolled environments, a positive pressure purge shall be maintained until the system is closed.

3.5.3 Materials

3.5.3.1 Protective Materials and Devices - Protective materials and devices that serve as contamination barriers in contact with or exposed to significant surfaces for oxygen service shall be determined compatible with NHB 8060.1 Test 13A. Refer to KSC MTB-402-85 for properties and compatibility data for packaging materials. Prior to use, materials or devices shall be cleaned and dried to a level compatible with the component end item cleanliness requirements. Under normal usage, materials or devices shall be lint-free, and shall not delaminate, peel, disintegrate, slough or otherwise deteriorate in a manner that will contaminate the cleaned item.

3.5.3.2 Tape - Tape used for precision-cleaned packaging shall not contact or otherwise contaminate significant surfaces and shall meet the requirements of PPP-T-60 or equivalent.

3.6 Marking/Identification - Unless otherwise specified by the procuring activity, cleaned items shall be identified per MIL-STD- 129 with appropriate certification tags and shall contain as a mimimum the following information:

a) Part or identification number.
b) Contractor identification
c) Contractor cleaning and packaging procedure identification
d) Date of cleaning
e) Title, date, and number of this standard
f) Service medium or intended use of component
g) Manufacturer's serial number
h) Acceptance stamps
i) Cleanliness level

3.7 Post-Verification Operations - Fluids or gases contacting cleaned surfaces after final cleaning or testing for cleanliness shall, as a minimum, meet the requirements for verification fluids per 3.2.3 and drying gases per 3.4.2.

3.8 "Excepted" Components - Excepted components shall consist of items and systems that cannot be processed per the requirements of this document. Components that cannot be cleaned and certified using normal procedures or facilities because of size, construction, materials of construction, etc. may be processed as excepted components. Excepted components require written approval of the procuring activity and concurrence of the government. These items shall be cleaned as to the intent of this specification as practical and identified as "EXCEPTED" on all tags and documentation.

3.9 Field Cleaning - Field cleaning (ground test only) shall be performed only when one of the following criteria is met:

1. The item is a part of a fixed installation and cannot be removed to a remote cleaning site.

2. Cleaned spare parts are not available and removal to a remote site would unduly impact operations.

Field cleaning shall be performed using system flow velocities greater than 3 m/s, pressurized spraying, and rapid draining to achieve visual cleanliness. Alternative cleaning methods may be approved by the procuring activity.

3.10 Ground Test Systems - Ground or facility test equipment for LOX, GOX, and Fuel systems shall be evaluated for cleanliness on a predetermined schedule or upon assessment of need. An engineering evaluation shall be made to identify the component or area to be tested based upon the systems configuration and pressure. As a minimum, the evaluation should identify the component most likely to accumulate contaminants due to geometry, location, internal surface finish, and other technical considerations.

For operational oxygen systems, the selected component(s) shall be evaluated per 3.3.3 except the minimum criteria shall be as follows;

- An NVR analysis or equivalent shall not exceed 5 mg/0.1 square meter for systems operating at 5000 psig or greater.

For systems operating at less than 5000 psig the following criteria applies:

- An NVR analysis or equivalent of 5 mg/0.1 m^2 or greater shall require approval of the organization's Test Director for continued operation.

- An NVR analysis or equivalent of 10 mg/0.1 m^2 or greater shall require the approval of the organization's Director of Safety /Quality Assurance or designated authority with concurrence of applicable Materials and Test organizations for continued operation.

- An NVR analysis or equivalent of 20 mg/0.1 m^2 or greater shall be cause for discontinued use until the entire system is recleaned and verified clean to a minimum of Class I B as defined in Table 1.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection - The cleaning activity is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the cleaning activity may utilize his own or any other inspection facilities and services acceptable to the procuring activity. Inspection records of examinations and tests shall be kept complete and available to the government as specified in the contract or order. The government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to assure supplies and services conform to specified requirements.

4.2 Inspection Sample Size/Frequency

4.2.1 Visual Inspection - The sample for the visual inspection test of 4.3.1 shall consist of all cleaned components except as noted. Components, such as small diameter tubing (1/2 inch diameter or less), having limited accessibility to visual examination shall be accepted or rejected on the basis of the inspections of 4.3.2 and 4.3.3.

4.2.2 Acidity/Alkalinity - Surfaces which have been cleaned and rinsed with aqueous media shall be evaluated in accordance with 4.3.2

4.2.3 Particulate/NVR Sample - Except as noted in 4.2.3.1, 4.2.3.2, and 4.2.3.3, the quantitative analysis sample for the test of 4.3.3 shall consist of a minimum of 5% of the items cleaned, but not less than one sample for each group of 20 or less of the items cleaned. The sample shall be selected at random from production items that have been cleaned, examined in accordance with 4.3.1 and found acceptable. The sample shall be selected in a manner that will provide maximum representation of the affected lot. In this context a lot does not necessarily require identical parts but does include all hardware processed in one operation. The test sample and the segment of production that it represents shall be clearly identified as specified by the procuring activity. All items shall be verified visually clean and inspected for silting.

4.2.3.1 Small Components - Reliability samples for small components (components having a significant surface area less than 0.1 m^2) shall consist of a sufficient number of components to make up 0.1 m^2 of surface area. When the total quantity of items procured have a combined surface area less than 0.1 m^2, a quantity of cleaned items sufficient to make up 0.1 m^2 of surface area shall be used in preparation of the reliability sample or a special test procedure may be used upon written request to and approval by the procurring activity. For particularly small items with a total area significantly less than 0.1m^2, the criteria is 1 milligram NVR maximum, or equivalent, per 500 ml of verification solvent.

4.2.3.2 Containers - All containers shall be submitted for acceptance testing per 4.3.3.

4.2.3.3 Rigid Tubing - Reliability of the cleaning procedure for rigid tubing may be determined and the cleaning process qualified as specified herein. After qualification of the procedure and equipment, reliability sampling shall be left to the discretion of the procuring activity. Samples for qualification of the cleaning process shall be selected as follows:

a) Select a minimum of 5 cleaned tubes with a minimum of 3 feet cumulative length and having a minimum combined significant surface area of 0.1 m^2 from each size (diameter) and type tube (material) to be cleaned. Tubes shall have been cleaned in accordance with the exact procedures and utilizing equipment approved in accordance with 3.2.

b) Evaluate samples in accordance with the tests of 4.3.3, as applicable, to meet requirements of 3.3.3 and 3.3.4.

c) Upon satisfactory qualification of the cleaning procedure and equipment to meet applicable requirements of 3.3.3 and 3.3.4 periodic spot checks in addition to the inspections of 4.3.1 and 4.3.2 shall be made to insure cleaning procedures continue to be effective.

4.2.4 Drying Sample - The quantitative analysis reliability sample for 4.3.4 shall consist of a minimum of 5% of items dried, but not less than one sample for each group of 20 or less of items dried. The sample shall be selected at random from production items that have been cleaned, verified and dried in accordance 3.2, 3.3, and 3.4, as applicable. The sample shall be selected in a manner that will provide maximum representation of the affected lot. A lot does not necessarily mean identical parts but does include all hardware processed in one operation. The reliability sample and the segment of production that it represents shall be clearly identified as specified by the procuring activity.

Alternately, the reliability of the drying procedure may be established for each hardware configuration, and drying process qualified as specified herein. After qualification of the procedure and equipment for a specific hardware configuration, reliability sampling shall be left to the discretion of the procuring activity. Samples for qualification of the drying process shall be selected as follows:

a) Select a minimum of 5 cleaned, verified and dried items of each of the hardware configurations to be qualified. Parts shall have been cleaned and dried in accordance with the exact procedures and utilizing equipment approved in accordance with 3.2, 3.3, and 3.4, as applicable.

b) Evaluate samples in accordance with 4.3.4 to meet the requirements of 3.4.1.

c) Upon satisfactory qualification of the drying procedure for each hardware configuration, the established drying cycle requirements shall be implemented. Periodic spot checks shall be made to insure that drying procedures continue to be effective.

4.3 Acceptance Inspection Procedures - Unless otherwise specified by procuring activity acceptance inspection shall be performed as specified herein.

4.3.1 Visual Inspection - Surfaces of all components that will contact the respective service medium shall be visually inspected with no magnification (see definition of visually clean in 6.0). An external light or borescope may be required to examine internal surfaces. The presence of contamination shall require test/evaluation to determine acceptance or rejection. Scale-free discoloration of a surface due to welding and passivation shall be permitted.

4.3.2 Acidity/Alkalinity Evaluation - External and internal surfaces which have been cleaned with aqueous media shall be tested for pH while the component is still wet from final rinse, or if dry, by wetting the surface of the component with a few drops of water (see 3.2.3). The pH indicating paper or other approved indicator shall be sensitive to the pH range of 6.0 to 8.0.

4.3.3 Particle/NVR Cleanliness Tests - Hardware shall be tested and accepted for visual inspection per 4.3.1 and acidity/alkalinity per 4.3.2, if applicable, prior to being submitted for tests. Cleaned components selected by the contractor or supplier for tests shall be tested as specified herein. Alternate methods may be used after qualification and written approval by the procuring activity in accordance with 5.0.

4.3.3.1 Materials - Test fluids shall be selected from among the following and shall meet particle requirements and nonvolatile residue requirements of 3.2.3. The selected solvent must be chemically compatible with the component. Alternate test fluids may be approved per the procedure outlined in 5.0.

a) Trichlorotrifluoroethane (CFC-113) conforming to MIL-C-81302, or equivalent, as approved by the procuring activity.

b) 1,1,1 - Trichloroethane (Methyl Chloroform) conforming to MIL-T-81533, or equivalent, as approved by the procuring activity.

c) Trichloroethylene conforming to MIL-T- 27602, or equivalent, as approved by the procuring activity.

4.3.3.2 Procedure for Obtaining Reliability Sample - Reliability samples for quantitative analyses shall be obtained as follows. Hardware shall be thoroughly dried after the flushing operation.

Where component flushing is impractical, particle count may be performed by the tape lift method (MSFC-PROC-1721).

4.3.3.2.1 Components with Surface Area Less than 0.1 m^2 - Sampled and analyzed per . 4.2.3.1.

4.3.3.2.2 Components with Surface Area Between 0.1 and 0.5 m^2 - A 500 ml, nominal, test solution shall be flushed over the significant surfaces and collected for quantitative analysis per 4.3.3.3.

4.3.3.2.3 Components with Surface Area Greater than 0.5 m^2 -The significant surfaces shall be flushed with 100 ml, nominal, of test solvent per 0.1 m^2 of surface area. The test solution shall be collected and thoroughly agitated. A 500 ml sample shall be obtained from the agitated solution for quantitative analysis per 4.3.3.3.

4.3.3.2.4 Containers -Large containers/vessels shall be verified by a procedure submitted by the user and approved by the procuring activity.

4.3.3.3 Quantitative Analysis of Reliability Sample - Unless alternative methods are qualified by the user and approved by the procuring activity NVR analysis shall be conducted per MSFC-PROC-1831 and particulate analysis shall be per MSFC-PROC-1721 (Tape Lift) or ASTM-F-312.

4.3.4 Drying Test - Unless otherwise approved by the procuring activity, reliability of the drying procedure for items subjected to liquids during cleaning or drying procedures shall be determined as follows:

a) Flow prefiltered drying gas (3.4.2) through or over affected surfaces of the item being tested.

b) For hardware processed with aqueous media, monitor the dew point of the drying gas entering and leaving the affected item to determine presence of moisture on cleaned and dried surfaces. An increase in moisture content of the drying gas of 5 ppm or greater shall necessitate additional drying prior to packaging or application of protective coverings.

c) For hardware processed with halogenated solvents, monitor effluent drying gas with a halogen detector, to determine if affected surfaces are free from residual organic solvents. If no measurable concentrations are indicated by the halogen detector, affected surfaces shall be considered free from excessive residual organic solvents. Any measurable concentration above ambient in the drying gas shall necessitate additional drying prior to packaging or application of protective coverings.

d) For hardware processed with alcohols or other hydrocarbons, monitor the effluent drying gas with a hydrocarbon detector. Any measurable concentration above ambient in the drying gas shall necessitate additional drying before packaging or application of protective covering.

e) Visual inspection for dryness is allowed where appropriate and the user receives approval from the procuring activity.

4.4 Rejection

FAILURE TO MEET ANY REQUIREMENT OF SECTION 3.0 SHALL BE CAUSE FOR REJECTION.

5.0 APPROVAL OF ALTERNATE VERIFICATION PROCEDURES

Alternate verification procedures may be used only upon qualification and written approval by the procuring activity. For qualification of alternate procedures, the following methodology is required; in all instances statistically significant data must be provided to the procuring activity before alternative verification methods can be considered.

a) **Sample Selection** - Hardware and contaminant(s) must be representative and reasonably reflect worst case configuration/conditions.

b) **Verification** -

1. Verify hardware cleanliness using an approved solvent process for 50% of test items. Flush or immerse hardware surfaces three times with the same 500 ml total collection of approved solvent. For large hardware (where solvent quantities greater than 500 ml would normally be required) the sampling location should include the most probable contamination areas. Analyze for particulate and NVR per 3.3.

2. Verify hardware cleanliness of the balance of item (1) using alternative verification process/procedure.

3. Statistically equate verification equivalence. The mean and variance of the proposed alternate process shall be provided. The variance of the proposed process must be statistically equivalent to or less than the variance of the baseline process. Variance shall be determined from a minimum of seven (7) configuration tests and the test plan shall be approved by the procuring activity.

6.0 DEFINITIONS

- **Cleaning** - Removal of particulate and incompatible materials from significant surfaces of components and systems.
- **Contaminant** - Any material that could chemically interact or mechanically interfere with the component or system function.
- **Control Solvent** - Baselined Solvent - Interchangeable terms for chemical which has been analyzed and/or purified for use in measuring contaminants removed from an article.
- **Fiber** - a particle having a length to width ratio of 10 as a minimum i.e., length-to-width ratio of 10 to 1 or greater.
- **Inert Storage Package** - A barrier material used to encase a cleaned item to maintain item cleanliness level and which, when properly sealed, cannot introduce contaminants to the protected item.
- **Micron** - 0.001 millimeter
- **Milligram (mg)** - 0.001 gram
- **Non Volatile Residue (NVR)** - The quantifiable substance remaining after filtration and controlled evaporation of final flush.
- **Organic Hydrocarbon** - A compound containing a carbon-to-hydrogen bond.
- **Particle** - a minute quantity of matter, metallic or non-metallic, with observable length, width and thickness.
- **Procuring activity** - The first tier customer of the user of this standard.
- **pH** - A unit of measure from 0-14 representing acidity/alkalinity of an aqueous solution.
- **Significant Surface** - All component surfaces that may come into contact with the respective service medium.
- **Silting** - an accumulation of minute particles in the size range normally not counted but of sufficient quantity to interfere with sample analysis.
- **Visually Clean** - An article is classified visually clean when free of dirt, scale, oil, or other contamination when viewed at a distance of 0.5 meters under a minimum of 50 foot-candle lighting with normal or corrected vision. A borescope is allowed to aid visual examination.

7.0 APPENDIX - SPACE SHUTTLE CLEANLINESS REQUIREMENTS

Shuttle Main Engine	Cleanliness Level
GSE & Engine System	
Metallic & Fluorocarbon Components	
Oxygen	III A
Fuel	IV
Pneumatic (Flight)	IV
Pneumatic (GSE)	IVA
Non-Metallic	V
Propellant & Pressure Vessels (Metallic)	
Oxygen	III B
Fuel	IV
Pneumatic (Flight) - If filtered feed system	II
Pneumatic (GSE) - If filtered feed system	II A
Test Facilities - Except Vessels	
Metallic & Fluorocarbon Components	
Oxygen	IV A
Fuel	IV
Pneumatic	IV A
Non-metallic Components (excluding composite vessels)	V

Shuttle External Tank Hardware	Cleanliness Level
Tanks/Vessels	
Oxygen	II B
Fuel	II
System Equipment	
Oxygen - Downstream of Screens	III A
Fuel - Downstream of Screens	IV
Pneumatic - Flight	I
Electrical Installations in Oxygen System	II A
Electrical Installations in Fuel System	II
Miscellaneous Nonmetallics - Except Fluorocarbons	V
MSFC Ground Test Systems	III A