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**National Aeronautics and Space Administration**
**Washington, DC 20546-0001**

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# SURFACE CLEANLINESS STANDARD OF FLUID SYSTEMS FOR ROCKET ENGINE TEST FACILITIES OF THE NASA ROCKET PROPULSION TEST PROGRAM

**MEASUREMENT SYSTEM IDENTIFICATION:**
**METRIC (INCH-POUND)**

# DOCUMENT HISTORY LOG

| Status | Document Revision | Approval Date | Description |
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| Rev 1 | Rev 1 | 07.02.2012 | Minor administrative changes (agreed to in earlier edits) to sections 8.3.2 (remove paragraph c), 14.1 and 14.2 (remove “critical surface areas greater than 0.5m2”), Table 1A (Now reads Level “A” NVR for all oxidizer tanks $\leq 0.5m^2$. Level “B” for $N_2O_4$ tanks $>0.5m^2$. Level “E” for $O_2$ tanks $>0.5m^2$) and Table 2, add 100A to Hydraulic. Added Appendix G, Crossover Chart for **SSC use only**. |
| Rev 1-1 | Rev 1-1 | 04.30.2013 | Administrative change to SSC Crossover Chart: removed “oxidizer” and “oxygen” from *Note at bottom of chart. |
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| Rev 2-1 | Rev 2-1 | 03.12.2018 | Administrative change to remove note on front cover “This standard has not been reviewed for export control restrictions; consult your center/facility/headquarters export control procedures/authority prior to distribution of this document.” |
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**NOTES:**

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# DOCUMENT ACCEPTANCE AUTHORITY

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# Surface Cleanliness Standard of Fluid Systems for Rocket Engine Test Facilities

## 1. SCOPE

### 1.1. Purpose

The purpose of this standard (STD) is to specify the cleanliness levels and the minimum contamination control requirements (processing, handling, protection, and test/inspection) for surfaces that come in contact with any fluid medium. These requirements pertain to the "critical surfaces" of parts, items, components, equipment, assemblies, subsystems, and systems used for NASA's rocket propulsion test program.

### 1.2 Applicability

a. This standard is applicable to ground-based rocket propulsion test facilities for propellant, pressurant, pneumatic, and hydraulic systems that require cleanliness certification. Specifically, these are the test stands and facilities under the purview of the NASA Rocket Propulsion Test (RPT) Program.

b. All system and product cleanliness levels shall meet or exceed program or test article requirements. Program- or customer-specified requirements may impose additional cleanliness or process requirements. In such situations, process changes and supplemental procedures may be required to satisfy any additional program- or customer-specified requests.

c. This standard may be cited in contract, program, and other Agency documents as a technical requirement.

d. Mandatory requirements are indicated by the word "shall."

e. Tailoring of this standard for application to a specific program or project shall be approved by the Technical Authority for that program or project.

f. Waiver decisions may be subject to requirements for the acceptance of risks to safety and mission success in NPR 8000.4. Any requirements within this document shall follow the respective Center's approved processes in waiving technical requirements. Any such waiver may be accompanied by engineering assessments, MRB reviews, with notification to the Rocket Propulsion Test Program Office (RPTPO).

g. The RPT Program Manager may grant a temporary or permanent exclusion from this standard to a specific RPT facility or element when it is deemed to be in the best interest of the Agency's Rocket Propulsion Test capability. Center requests for exclusions shall be presented to the RPTMB, with supporting rationale and documentation. Exclusions shall be documented in a Program Directive, along with any limitations or conditions associated with the exclusion.

## 1.3 Responsibilities

### *1.3.1 General*

a. NASA and contractor personnel responsible for engineering design, manufacture/fabrication, propulsion test operations, cleaning and inspection, calibration, and analysis activities shall implement this STD.

b. NASA and the Contractor shall ensure compliance with requirements of this STD through surveillance, auditing, and process verification.

c. Design specifications and drawings shall identify cleanliness levels by the alphanumeric or numeric designations defined in this STD.

d. The user is responsible for assuring suitability of the cleaned item for its intended use.

### *1.3.2 Quality Assurance*

The performing organization's quality assurance (QA) shall review and verify that the surface cleanliness requirements for fluid systems are satisfied.

### *1.3.3 Safety and Environmental*

a. All users of this standard must review pertinent Safety Data Sheet (SDS) specifications and work instructions to assure safety of personnel and protection of the environment and facilities in fulfilling the requirements of this STD.

b. All materials and processes required to fulfill the requirements of this STD are subject to applicable Federal, State, and local environmental, health, and safety regulations, standards, codes, and operating procedures (e.g., work instructions). The performing organization is responsible for determining and establishing the appropriate environmental, health, and safety practices that comply with all applicable regulations.

c. 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 cognizant personnel within the performing organization.

### *1.3.4 Training*

a. The performing organization or contractor shall assure that all personnel responsible for contamination control functions are trained as required to assure proficiency within their assigned tasks.

b. The processing organization or contractor shall establish personnel certification with traceable documentation.

# 2. APPLICABLE DOCUMENTS

## 2.1 General

a. The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text of Section 4.

b. The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority. The applicable documents are accessible via the NASA Technical Standards System at http://standards.nasa.gov, directly from the Standards Developing Organizations, or from other document distributors.

## 2.2 Government Documents

Federal Specification

| | |
|---|---|
| A-A-1689 | Tape, Pressure-Sensitive Adhesive (Plastic Film) |
| A-A-59150 | Cleaning Compound, Solvent, Hydrofluoroether (HFE) |
| A-A-3174 | Plastic Sheet, Polyolefin |
| A-A-59503 | Nitrogen, Technical |
| TT-I-735 | Isopropyl Alcohol |

Military Specifications and Handbooks

| | |
|---|---|
| MIL-C-81302 | Cleaning, Compound, Solvent, Trichlorotrifluoroethane |
| MIL-T-81533 | Trichloroethane 1,1,1, (Methyl Chloroform) Inhibited, Vapor Degreasing |
| MIL-STD-889 | Dissimilar Metals |
| MIL-HDBK-1028/5A | Environmental Control – Design of Clean Rooms |
| MIL-PRF-27401 | Propellant Pressurizing Agent, Nitrogen |
| MIL-PRF-27407 | Propellant Pressurizing Agent, Helium |
| MIL-PRF-5606 | Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance |

National Aeronautics and Space Administration

| | |
|---|---|
| JSC-SPEC-C-20 | Water, High Purity, Specification for |

| | |
|---|---|
| MSFC-SPEC-3709 | Solvent, Cleaning, Trans-1-Chloro-3,3,3,-Trifluoropropene, Solstice® PF, Specification for |
| MSFC-STD-3535 | Standard for Propellants and Pressurants used for Test and Test Support Activities at SSC and MSFC |
| KSC SPEC-P-0019 | Solvent, Cleaning, 1,1,1,2,3,4,4,5,5,5 – Decafluoropentane (62 wt%) and Trans-1,2 – Dichloroethylene (38 wt%), Vertrel MCA, Specification for |
| KSC SPEC-P-0021 | Solvent, Cleaning, 1,1,1,2,3,4,4,5,5,5 – Decafluoropentane, Specification for |
| KSC SPEC-P-0022 | Solvent, Cleaning, 1,3-Dichloro-1,1,2,2,3, - Pentafluoropropane, Specification for |
| NASA STD 6001 | Flammability, Odor, Off-gassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion |
| NASA /TP 2015-218207 | NASA Precision Cleaning Agent Solstice |

## 2.3 Non-Government Documents

American Chemical Society (ACS)
*Reagent Chemicals: Specifications and Procedures*

American Society for Testing and Materials (ASTM)

| | |
|---|---|
| ASTM A 380 | Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems |
| ASTM D 1193 | Standard Specification for Reagent Water |
| ASTM D 4080 | Standard Specification for Trichloroethylene, Technical and Vapor Degreasing Grade |
| ASTM D 4376 | Standard Specification for Vapor-Degreasing Grade Perchloroethylene |
| ASTM D 5486 | Standard Specification for Pressure-Sensitive Tape for Packaging, Box Closure, and Sealing |
| ASTM E 2042 | Standard Practices for Cleanliness and Maintaining Controlled Areas and Clean Rooms |

| | |
|---|---|
| ASTM F 312 | Standard Test Methods for Microscopical Sizing and Counting Particles from Aerospace Fluids on Membrane Filters |
| ASTM F 331 | Standard Test Method for Nonvolatile Residues of Solvent Extract from Aerospace Components (Using Flash Evaporator) |
| ASTM G 144 | TOC NVR Method Reference |

Compressed Gas Association (CGA)

| | |
|---|---|
| CGA G-11.1 | Commodity Specification for Argon |

International Organization for Standardization

| | |
|---|---|
| ISO 14644-1 | Cleanrooms and Associated Environments – Part 1, Classification of Air Cleanliness |
| ISO 14644-2 | Cleanrooms and Associated Controlled Environments – Part 2, Specifications for Testing and Monitoring To Prove Continued Compliance with ISO 14644-1 |

Society of Automotive Engineers (SAE) Aerospace Material Specifications (AMS)

| | |
|---|---|
| SAE-AMS 3647 | Polyfluoroethylene Propylene Film and Sheet |
| SAE-AMS 3649 | Film, Polychlorotrifluoroethylene (PCTFE) Unplasticized |

General Industry

| | |
|---|---|
| IEST-STD-CC1246 | Product Cleanliness Levels and Contamination Control Program |

Society of Automotive Engineers (SAE) Aerospace Recommended Practices (ARP)

| | |
|---|---|
| SAE-ARP 598 | Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems |

## 2.4 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in applicable documents or referenced guidance documents.

# 3. ACRONYMS AND DEFINITIONS

## 3.1 Acronyms and Abbreviations

| | |
|---|---|
| AMS | Aerospace Materials Specification |
| AM&TE | Analytical Measurement and Test Equipment |
| ARP | Aerospace Recommended Practices |
| ASTM | American Society for Testing and Material |
| CGA | Compressed Gas Association |
| $C_S$ | Control Sample (Solvent Blank NVR) |
| DI | Deionized |
| EXC | Excepted |
| FEP | Polyfluoroethylenepropylene |
| FTIR | Fourier Transform Infrared |
| GC | Generally Clean |
| GH | Gaseous Hydrogen |
| GOX | Gaseous Oxygen |
| HFE | Hydrofluoroether |
| IM&TE | Inspection, Measuring and Test Equipment |
| IR | Infrared |
| ISO | International Organization for Standardization |
| JSC | Johnson Space Center |
| KSC | Kennedy Space Center |
| LH | Liquid Hydrogen |
| LOX | Liquid Oxygen |
| MMH | Monomethyl hydrazine |
| mg | milligram |
| mL | milliliters |
| $M_S$ | Measured Sample NVR concentration |
| MSFC | Marshall Space Flight Center |
| MIL | Military |
| NASA | National Aeronautics and Space Administration |
| NVR | Nonvolatile Residue |
| N2H4 | Hydrazine |
| N2O4 | Dinitrogen Tetroxide |
| PCTFE (TFE) | Polychlorotrifluoroethylene |
| PFEP (FEP) | Polyfluoroethylene-propylene |
| ppm | parts per million |
| PVC | Polyvinyl Chloride |
| QA | Quality Assurance |
| RPT | Rocket Propulsion Test (Program Office) |
| SA | Surface Area |
| SAE | Society of Automotive Engineers |
| scf | standard cubic feet |
| SDS | Safety Data Sheet |
| $S_F$ | Sensitivity Factor |

| | |
|---|---|
| SPEC | Specification |
| SSC | Stennis Space Center |
| STD | Standard |
| TCA | Total Carbon Analyzer |
| TOC | Total Organic Carbon |
| UDMH | Unsymmetrical dimethyl hydrazine |
| UV | Visually Clean Plus Ultraviolet (ultraviolet cleanliness level) |
| VC | Visually Clean |
| WSTF | Johnson Space Center's White Sands Test Facility |

## 3.2 Definitions

Analytical Measurement and Test Equipment (AM&TE): equipment used by a Science or analytical testing laboratory (e.g., IR spectrometer, gas chromatograph, scanning electron microscope, etc.). AM&TE analysis data is controlled by verification or standardization processes using chemical reference materials and/or standardized protocols (ASTM, ISO, EPA).

Assembly: two or more parts having a common mounting and being capable of performing a definite function. For example, filter element, housing, and O-ring become part of a filter assembly.

Black Light: a high intensity, long-wave, low-energy, ultraviolet (UV) light operating from 3200-3800 angstroms wavelength range.

Blank: the analytical result that describes the particulate or NVR background level of the certified test fluid before use in performing a cleanliness verification test.

Blanket Purge: the use of pressurized gas in an enclosed environment for protecting components, piping, or vessels from contamination.

Certification: a written record demonstrating that requirements have been verified and achieved.

Cleaning: the removal of incompatible materials from the significant surfaces of components and systems within the scope of this standard.

Clean Room: a room within which the concentration of airborne particles is controlled and classified, and which is designed, constructed and operated in a manner to control the introduction, generation and retention of particles inside the rooms, as referenced in ISO 1466.1.

Clean Zone: defined space within which the number concentration of airborne particles is controlled and classified, and which is constructed and operated in a manner to control the introduction, generation and retention of contaminants inside the space (e.g., laminar flow bench).

Commercial Clean: also known as visually cleaned (VC).

Component: an item that is normally a combination of parts, subassemblies, or assemblies and that is self-contained within a fluid system.

Contaminant: any material that could chemically react or mechanically interfere with a cleaned component, system, or end item.

Control Sample: a specific volume of flushing solvent that is analyzed to determine a baseline contamination level before a test or verification sample is attained. A control sample and a blank are considered to be equivalent.

Critical Surface: a surface that may come into contact with the fluid (service) medium (i.e., liquid oxygen, pneumatic gases, hydraulic fluids, etc.). A critical surface is subject to the cleaning procedures and cleanliness requirements of this specification.

Dew Point: the temperature at which a gas becomes saturated with water vapor and condensation begins (usually atmospheric pressure).

Drying: reducing moisture or dew point levels by vacuum, purge, flush, or oven-heated methods.

Excepted Component/System/Soft Good: an item or system that cannot be cleaned and certified using normal procedures or facilities because of their size, construction, or method of assembly.

Fiber: a non-metallic structure having a length-to-width ratio of 10 to 1 or greater with a minimum length of 100 micrometers (A fiber is a particle).

Field Certification: the process of certifying components in the field.

Field Cleaning: cleaning performed outside a shop or clean environment.

Field Verification: process of obtaining samples in the field for subsequent laboratory analysis to certify cleanliness levels.

Fluid: a gas or liquid.

Flushing Solvent: the solvent used to obtain the control sample and the test sample.

Foreign Object Debris (FOD): a substance, debris or article that is alien or has invaded a product, assembly, or system, and would potentially cause damage. Examples are tools, un-attached tape, metallic chips, wire clippings, loose tie-wraps, and loose hardware such as washers, nuts, and screws.

Footcandle: measures the number of lumens per area of one square foot.

Generally Clean (GC): inspection is not as rigorous as visually clean (VC) in that clumps or agglomerations of contamination are removed instead of individual particles. Cleaning is only required if the item does not pass inspection. If the item has been inspected and accepted “as is,” it does not need to be cleaned. Heat-sealed bagging protection is not required, but normal protection is required for handling, shipping, and storage. This cleanliness level should be specified for hardware that is not sensitive to contamination and is easily cleaned.

Gross Cleaning: the removal of gross contaminants, also known as rough cleaning.

Gross Contaminants: visible contaminants, such as moisture, corrosion, loose slag, oil, grease, scale, rust, soil, sludge, and grit.

Hydrocarbon: any compound containing carbon and hydrogen bonds.

Hypergolic Propellants: any fuel/catalyst (monopropellant) or fuel/oxidizer (bipropellant) combination that spontaneously ignites and is used in propelling a rocket.

Inaccessible: unable to be viewed because of physical configuration.

Inspection: the verification method performed by visual observation under ambient or black light.

Inspection, Measuring and Test Equipment (IM&TE): instrument measurement and test equipment that are calibrated by a calibration laboratory (e.g., pressure gages, flow meters, balances, volt meters, etc.) and are used to perform measurements where distinct values are required for system performance or to demonstrate conformance to specified requirements.

Item: anything smaller than or contained within a system (e.g., assembly, component, IM&TE, piece part).

Method: a technique or process used to test, inspect, or collect samples.

Micron: dimension of length equal to $10^{-6}$ m or 0.001 mm (0.0000394 inch).

Moisture: the residual water (liquid/gas) on components or systems, measured in ppm or dew point.

Nonvolatile Residue (NVR): the residue remaining after filtration and controlled evaporation of the final flushing solvent. NVR is specified in mg per square meter or square foot of significant surface. Since the predominant constituents of NVR are typically hydrocarbons, NVR and total hydrocarbon content are considered equivalent. Analytical methods that determine total hydrocarbon (Fourier Transform Infrared (FTIR), and total organic carbon (TOC) and gravimetric NVR, as referenced in ASTM F331 may be used to determine NVR.

Normalize: describe (convert or calculate) a measurement (e.g., NVR weight or particle count) per specified unit area (or volume). Example: A NVR of 0 .6 mg / was obtained from a significant surface area of 0.5 $ft^2$ equals 1.2 $mg/ft^2$ of NVR .

Oxidizer: commodities, such as liquid oxygen and nitrogen tetroxide, which when combined with fuels (liquid hydrogen and hydrazine respectively), constitute the propellants for rocket engines. Air is also considered an oxidizer.

Oxygen System: a system containing a fluid with more than 25 mole percent oxygen. Air (20.94 mole percent oxygen) at pressures exceeding 2000 psig can react like pure oxygen at the same pressure. Air under these conditions will be treated like an oxidizer.

Packaging, Primary (or Primary Packaging Film): material (or film material) used to prevent contaminant entry onto precision cleaned items or precision cleaned (critical) surfaces. This material is either used to fabricate bags that totally enclose precision cleaned item(s) or stretched across and wrapped around openings or orifices of items with internal critical or precision cleaned surfaces, This material provides limited physical protection to surfaces covered by this type of packaging, but this material is never to be the sole means/provider of this protection.

Packaging, Secondary (or Secondary Packaging Film): material (or film material) used to prevent visible contaminant entry onto the primary packaging (film). In selected cases where precision cleaned items are enclosed in bags in conjunction with protective external overwrap or containers or where covered openings of these items are small, this material provides physical protection to prevent damage to the primary packaging (film) and surfaces covered by this packaging. However, in most cases or for larger openings covered by packaging films, added protective devices are required to protect secondary packaging from damage or puncture.

Particle: a unit of matter with observable length, width, and thickness; usually measured in micrometers (microns). Particle size is measured in the longest dimension (e.g., fibril, fiber, filament, powder, soot, dirt, dust, mineral oxides, metallics, ceramics, any particulate matter).

Particulate: multiple particles.

Passivation: the process by which a chemically inert layer ( e.g., chromium oxide) is formed on a metal surface by submersing the surface in a chemical solution (e.g., nitric acid, hydrogen peroxide, etc.).

pH: a unit of measure that describes the acidity or alkalinity of an aqueous solution on a scale of 0 to 14 (a pH of 7 is neutral, a pH value below 7 is acidic, a pH value above 7 is alkaline). pH is the logarithm of the reciprocal of the hydrogen ion concentration of a solution.

Pickling: the chemical or electrochemical process by which surface oxides are removed from metals.

Performing Organization: the onsite or offsite organization performing the cleaning or cleanliness verification services.

Precision Clean: a detailed cleaning process that requires quantitative verification such as an NVR and /or particulate measurement, used to achieve cleanliness levels more stringent than visually clean.

Procuring Organization: the organization authorized to issue the procurement of goods and services (e.g., cleaning or cleanliness verification services.)

Rough Cleaning: a pre-cleaning or gross cleaning process normally used to remove gross contamination. Cleaning operations performed prior to proceeding to precision cleaning.

Sample: a selected portion or quantity of fluid collected to determine the cleanliness level of a system or component.

Significant Surfaces: any surface of a component, item, assembly, subsystem, system, and ground support equipment that comes into contact with test fluids or service/medium fluid (liquid oxygen, pneumatic gases). A significant surface is subject to the cleaning procedures and cleanliness requirements of this Standard.

Silting: an accumulation of particles below the size ranges counted and in such a quantity as to interfere with sample analysis (i.e., to cause a haze or to obscure any portion of a grid line or any portion of the grid of a filter membrane when viewed visually or under magnification).

Soft Good: polymer or polymer-containing materials that are used for integral parts of a fluid system. Ceramics are not included in the term "soft goods." Soft goods are often referred to as "nonmetals."

Test: the process used to determine the cleanliness level of a system, component, or packing material.

Test Sample: a specific volume of flushing solvent used for particulate and/or NVR analysis.

Visual Clean (VC): the absence of all particulate and non-particulate matter visible to the normal unaided (except corrected vision) eye with an illumination equal to or greater than 50 foot candles.

Ultraviolet (UV) Clean: visually clean and inspected with the aid of an ultraviolet light of 3200 to 3800 angstroms. This level requires precision cleaning methods but no particle count.

Verification: the process whereby one or more of the following methods is used for the purpose of certification: performing visual inspections, obtaining samples, analyzing/testing samples, and reviewing inspection/test data.

# 4. SURFACE CLEANLINESS LEVELS

## 4.1 Classification

Cleanliness levels imposed by this standard are listed in Table 1.

## 4.2 Non-Precision Cleanliness Levels

a. Generally Clean (GC):

   1. Freedom from manufacturing residue, dirt, oil, grease, scale, carbon deposits, process debris, or other extraneous contamination. This level can be achieved by washing, brushing, or rinsing.
   2. The GC level shall not be designated for items or fluid systems that are sensitive to contamination.
   3. GC is the only cleanliness level that does not require items to be packaged. Gloves or forceps are not required for the handling of GC items.

b. Visibly Clean (VC): 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 a film or residue without definite dimension. Scale-free discoloration due to surface treatments (i.e., passivation, anodizing, etching, etc.) or thermal processes (i.e., welding, heat treatments, etc.) is permitted. Rough cleaning is the process normally used to achieve this cleanliness level. Level VC is commonly referred to as “commercially clean.” Visibly Clean(VC) lighting requires an illumination of ≥ 50 foot candles.

## 4.3 Precision Cleanliness Levels

a. UV: Visibly clean (as defined above) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 Angstroms. This level requires precision cleaning methods.

b. Any visible contamination or fluorescence shall be cause for re-cleaning.

c. If re-cleaning does not reduce fluorescence, an investigation shall be made to determine whether the fluorescing material is contamination or if the item material is naturally fluorescent.

d. Some acceptable materials may fluoresce (e.g., anodized or chemical films). Inspection under ultraviolet light will not detect all vegetable, animal, and fluorocarbon type oils and greases, (e.g., RP-1, JP-5, kerosene, mineral oil, toluene, DC-11®, Krytox® oil, or hydraulic fluid such as MIL-PRF-5606).

e. Level 1000 is the lowest precision cleaning level that requires a fluid sample for cleanliness certification (quantitative particulate count).

### Table 1. Fluid Surface Cleanliness Levels

| **(Table 1A) Particulate Matter Contamination Levels** | | | **(Table 1B) NVR Contamination Levels** | | **(Table 1C) Visible Contamination Levels** | |
|---|---|---|---|---|---|---|
| Level | Particle Size Range µ (micrometer) | **Maximum Number of Particles per 0.1 $m^2$** | Level | **Maximum NVR (mg. per 0.1 $m^2$)** | Level | Definition |
| 25 | <5<br>5 to 15<br>>15 to 25<br>>25 | Unlimited *<br>19<br>4<br>0 | A | 1.0 | GC | Freedom from manufacturing residue, dirt, oil, grease, etc.<br>– Level GC is similar to level VC but differs in the following significant areas:<br>• Cleaning is only required if the item does not pass inspection. If the item has been inspected and accepted "as is," it does not need to be cleaned.<br>• Inspection is not as rigorous as VC in that clumps or agglomerations of contamination are removed instead of individual particles.<br>• Heat-sealed bagging protection is not required, but *normal protection is required for handling* shipping, and storage.<br>The GC level should be specified for hardware that is not sensitive to contamination and is easily and quickly cleaned or re-cleaned. |
| 50 | <15<br>15 to 25<br>>25 to 50<br>>50 | Unlimited *<br>17<br>8<br>0 | B | 2.0 | VC | The absence of all particulate and non-particulate matter visible to the normal unaided eye or corrected-vision eye; commercially cleaned. |
| 100 | <25<br>25 to 50<br>>50 to 100<br>>100 | Unlimited *<br>68<br>11<br>0 | C | 3.0 | UV | Visually clean and inspected with ultraviolet light; requires precision cleaning methods |
| 150 | <50<br>50 to 100<br>>100 to 150<br>>150 | Unlimited *<br>47<br>5<br>0 | D | 4.0 | ● NVR & Moisture Requirements<br>Critical surfaces with NVR requirements will meet:<br>Level "A" NVR for all oxidizer tanks $\leq 0.5m^2$.<br>Level "B" for $N_2O_4$ tanks $>0.5m^2$. Level "E" for $O_2$ tanks $>0.5m^2$.<br>Moisture Removal Verification by Process Control **OR** by Lab Test (per section 14.3):<br>One method of drying small parts in an oven is specified in par. 14.3 Another technique is drying/purging with ultra-high purity nitrogen per MIL-PRF-27401 or MSFC 3535. The choice of method is based on the physical features of the part per 14 or the customer's requirements. | |
| 200 | <50<br>50 to 100<br>>100 to 200<br>>200 | Unlimited *<br>154<br>16<br>0 | E | 5.0 | | |
| 250 | <100<br>100 to 200<br>>200 to 250<br>>250 | Unlimited *<br>39<br>3<br>0 | F | 7.0 | | |
| 300 | <100<br>100 to 250<br>>250 to 300<br>>300 | Unlimited *<br>93<br>3<br>0 | G | 10.0 | | |

**Table 1 - Visible Contamination Levels (Cont.)**

| | | | | | |
|---|---|---|---|---|---|
| 400 | <100<br>100 to 250<br>>250 to 400<br>>400 | Unlimited *<br>155<br>5<br>0 | UV | Non-quantitative NVR detection. | ● Dew point & Moisture Content<br>-54° C (-65 °F) 24 ppm for lines, parts, and components<br>-40 °C (-40 °F) 128 ppm for tanks and vessels Dew point & moisture is not required if the critical surface is normally opened to the atmosphere or if the critical surface is exposed to moisture during normal operations<br>● **NOTES**<br>Allowable particulate and NVR are based on 0.1 m$^2$ (1.08 ft$^2$)<br>* Silting is not permitted |
| 500 | <100<br>100 to 250<br>>250 to 500<br>>500 | Unlimited *<br>1073<br>27<br>0 | | | |
| 750 | <250<br>250 to 500<br>>500 to 750<br>>750 | Unlimited *<br>205<br>9<br>0 | | | |
| 1000 | <500<br>500 to 750<br>>750 to 1000<br>>1000 | Unlimited *<br>34<br>5<br>0 | | | |

## Notes for Tables 1A & 1B

1. If specified in work documents or engineering drawings, a gas sample for dew point and moisture is not required if the critical surface is exposed to moisture during normal and routine operations, or opened to the atmosphere (e.g., dump or vent lines), or the critical surfaces will come in contact with moisture during normal operation.

2. For such cases, the component cleanliness level shall be indicated as xxx-NDP (No Dew Point) requirement shall be appended to the cleanliness level indication. However, the presence of visible moisture is not permitted for cleanliness level VC or for any precision cleanliness level.

## 4.4 Specifying Product Cleanliness Level

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 mg/0.1 m$^2$).

c. Level 300A refers to (1) particulate size ranges and counts, and (2) NVR.

d. Level 200A is a more stringent cleaning level than 200B.

e. Level 750A NDP is the same cleanliness level as 750A except the dew point and moisture requirement is absent for the NDP designation (not required).

f. 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., an item cleaned to level 100A) and may be used in a product or system requiring less stringent cleanliness level (e.g., level 200 or 200A or UV).

g. Level VC is a more stringent cleaning level than GC.

h. No particulate count is required for any visual cleanliness level (GC, VC, or UV).

### 4.5 Facility and Fluid System Cleanliness Level Requirements

a. Table 2 provides a practical range of cleanliness levels for facility fluid systems.

b. System and product cleanliness levels shall meet or exceed program or test article requirements.

c. The precision cleanliness levels in Table 1A require quantitative tests as specified in Section 10 and conformance to visual cleanliness requirements and inspection (Section 4.2 (b).

### 4.6 Cleanliness of Operational and Legacy Systems

a. Fluid surfaces of any operational or legacy systems that were not previously cleaned or were not maintained clean (exposed to environments or conditions that degraded the cleanliness beyond the specified cleanliness requirement) or is suspected not to comply with this standard shall be sampled and analyzed to verify the cleanliness level. If the cleanliness level is not adequate, the system shall be recleaned and recertified.

b. NVR and /or particulate sampling of precision cleaned surfaces shall be representative of all surfaces; including varying substrate material/s, and surface types. The cleaning organization shall identify and sample the component or areas most likely to accumulate contaminants due to configuration, location, and other technical considerations. Liquid samples shall be processed for NVR and/or particulate, whether the sample is a liquid itself, a flush-rinse sample, an immersion sample, or from an extracted NVR wipe.

c. Documentation, including all applicable data, shall be recorded and maintained that demonstrates acceptable cleaning processes and cleanliness verifications have been performed. This applies to all parts, components, assemblies, and associated equipment for use in oxygen, pressurizing fluids, pneumatic, fuel and hydraulic systems. Subsequent handling of all hardware /components during assembly, removal, testing or maintenance operations shall be conducted to maintain the acceptable level of cleanliness per the requirements of this standard.

d. Documented procedures for contamination control (requires approval by the responsible organizations' engineering and management) shall be developed to maintain the cleanliness of clean systems, equipment and components. The procedure shall ensure all known contamination concerns and risks are identified and communicated in a common way across each center / site that adversely impacts cleanliness or test performance. For example, if system entry must be performed during adverse weather conditions, temporary protection (wind breaks, weather shields) shall be provided. Another example, when test hardware or facility system is disconnected, disassembled, uncovered, or the integrity of the closed systems is interrupted or disturbed, care should be exercised to prevent the introduction of contamination. Never perform any unnecessary task over an open port of a clean system.

e. Qualification testing of fluids (propellants, pressurizing agents, and hydraulic fluids) introduced into the cleaned systems shall meet the applicable procurement requirements specified by the test program or engineering work instructions. Subsequent handling of all commodities during storage, offloading from bulk sources, transfers and maintenance shall be conducted to maintain the acceptable level of cleanliness per the requirements of this standard.

### Table 2. Surface Cleanliness Requirements

| Fluid System | Facility Item Description | Cleanliness Level①③④ |
|---|---|---|
| LOX/GOX | Metallic and/or PTFE components | 400A |
| LOX/GOX | Nonmetallic parts and components (except PTFE ) | VC |
| LOX/GOX | Metallic Tanks or vessels | 750E |
| LOX | Emergency dump/vent system(s) | UV NDP |
| LH/GH/ $CH_4$ | Metallic and/or PTFE parts and components | 400 |
| LH / GH/ $CH_4$ | Nonmetallic parts and components (except PTFE) | VC |
| LH /GH / $CH_4$ | Tanks or vessels | 400 |
| LH /GH / $CH_4$ | Vent and flare stacks | VC NDP |
| $H_2O_2$ / $N_20_4$ | Metallic or virgin PTFE parts and components | 400A ② |
| $H_2O_2$ / $N_20_4$ | Nonmetallic parts and components (except PTFE④) | VC ② |
| $H_2O_2$ / $N_20_4$ | Metallic Tanks or vessels | 400C ② |
| Alcohols | All items | 100 |
| Hydrocarbon Fuels, less Methane ($CH_4$) | All items | 400 |
| MMH /UDMH | All items depending on connecting service | 200 to 300 |
| $N_2H_4$ | All items depending on connecting service | 200 to 300 |
| He / HPA | Metallic or PTFE items depending on connected service | 100A 400A or 750A or 1000A |
| He / HPA | Nonmetallic parts and components (except PTFE④) depending on connected service | VC |
| He | Vent or area purge | VC NDP |
| $GN_2$ / $LN_2$ | Depending on connected service | 100A 400A 750A or 1000A |
| $GN_2$ | LH barges | 1000 |
| Hydraulic | All items | 100 or 100A |

**NOTES**:

Propulsion systems containing hypergols or oxygen may require cleanliness levels more stringent than those defined in Table 2 for system performance or safety. Oxygen systems in particular require a detailed understanding of the potential hazard prior to selecting the appropriate cleanliness level. When more stringent cleanliness levels than those shown in Table 2 are required, they shall be specified on the engineering drawing or specification in accordance with (or tailored from) IEST-STD-CC1246 with cleaning, inspection, and packaging in accordance with this document.

① Depending on the site specific requirements, more stringent cleanliness levels are acceptable. A filter with an appropriate absolute rating shall be used where particulate facility system cleanliness levels are less stringent than the test article requirements.

② Critical surfaces for $H_20_2$ or for any item requiring passivation shall be passivated after rough cleaning and before performing final cleanliness verification.

③ Multiple service parts shall be cleaned to the most restrictive requirements.

④ Used in small quantities for cleanliness verification only. Under no circumstances shall PTFE be left to soak in halogenated solvents for extended periods due to the risk of swelling.

For systems, subsystems and components where cleanliness levels differ as shown above, Process and Instrumentation Diagram (P&ID) or engineering drawings or requirements shall indicate cleanliness levels.

# 5. SYSTEM CONFIGURATION AND DESIGN

The consideration of contamination control during the design phase or during system modifications is of the utmost importance. To assure the most effective contamination control, the engineering design or modification shall provide for:

a. Features that minimize or eliminate self-generating contamination.

b. Materials compatibility for contamination and corrosion control.

c. Features to facilitate contamination removal and monitoring during maintenance (items that would entrap fluids - e.g., reduce or eliminate component configurations with dead end volumes or hardware with complex physical configuration). Proper design consideration will minimize un-drainable cavities, blind holes, pockets, and other areas in which dirt and cleaning solutions might become trapped and would not provide for effective circulation and removal.

a. Incorporation of filtration and/or other control features to reduce contamination during system operation.

b. Lubricants, sealing and staking compounds, nonmetallic materials, etc., shall be selected, tested, and controlled to ensure preservation of the required cleanliness levels.

c. Selection and evaluation of these materials shall include consideration of outgassing and degradation resulting from operational and environmental conditions expected during testing.

## 5.1 System Interfaces with Different Cleanliness Levels

When fluid systems are designed or modified, cleanliness breaks shall be established to enable connection of systems that have different cleanliness levels.

a. Use a filter with an appropriate absolute rating for any cleanliness level breaks that have different particulate levels and the same NVR level (e.g., 300A and 400A) or no NVR level (e.g., 300 and 400).

b. Use dual check valves for any cleanliness level breaks that have different NVR requirements (e.g., upstream, 300A; downstream, 300E). Add filter if downstream particulate requirements are more stringent than upstream requirements (e.g., upstream 400A; downstream 100E). An upstream system must have the same or higher NVR cleanliness level requirement than the downstream system (e.g., upstream, 200A; downstream, 200E or 300B).

## 5.2 Component Removal

a. Designs for systems and system components should enable the removal of all valves and components from the system.

b. In cases where it is not practical to use removable components (e.g., V-J valves with butt-weld end connections), component design shall enable removal of all internal piece parts of the component while it is connected to its respective system.

c. All removed components shall be replaced with temporary hardware closures and shall meet the requirements in Section 6.4.5.

## 5.3 Bottles and Vessels

a. Designs of bottles and vessels shall incorporate adequate provisions for cleaning.

b. These provisions shall include, but are not limited to, man-way or "jet-mole" access (to inspect and flush/spray all significant surfaces wetted by service media) and low-point drains (to collect flush samples).

## 5.4 Materials

Selection of materials used in processing and testing must be compatible with the fluid medium and with the system items.

# 6. CLEANING

## 6.1 General

a. Cleaning comprises two categories: rough and precision. Adequate contamination control is imperative to minimize hazards and component failures that result from contamination.

b. Contaminants shall be removed from hardware surfaces in accordance with applicable engineering documents or NASA-approved procedures.

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

## 6.2 Decontamination

a. All systems, subsystems, components, and items that have been exposed to toxic propellants or hazardous materials (e.g., hypergols) shall be decontaminated to the required level of safe handling before initial cleaning operations.

b. Under no circumstances shall propellant-contaminated systems, subsystems, or components be cleaned or transported directly to a cleaning, calibration, or lab facility before decontamination.

c. Decontamination shall be accomplished using established and proven methods, either in place for removal or neutralization of propellant residues, or hazardous materials or in an area specifically devoted to decontamination operations.

d. No items shall be accepted for cleaning or testing without “proof of decontamination.”

## 6.3 Cleaning Process Requirements

a. The performing organization is responsible for complying with the requirements of this STD. The cleaning and cleanliness verification (test) methods must not be detrimental to the materials and/or to the operational requirements of the item or system.

b. The performing organization shall prepare controlled (documented) procedures containing the following information:

   1. Description of items to clean, including identification of materials and process precautions to be observed.

2. Cleaning methods used: Alkaline cleaning, acid cleaning, pickling, aqueous or semi aqueous cleaning (with or without ultrasonics or agitation, spray), vapor degreasing, mechanical cleaning (e.g., wire brushing) solvent washing, etc.

3. Orientation of hardware to allow cleaning agents to contact and drain from all critical surfaces.

4. Processing materials/chemicals to be used, including (as applicable) trade names, specifications, chemical and physical properties, and process parameters.

5. The cleaning fluids shall be controlled during use by analysis, solution replacement, or adjustment to maintain cleaning effectiveness and compatibility with the type of material being cleaned.

6. The performing organization shall maintain fluid control records.

7. Records shall indicate scheduled analysis results and any solution replacement or adjustments.

8. Inspection and test methods

9. Drying and preservation methods

10. Controlled areas/product protection and packaging methods

## 6.4 Hardware Processing

### *6.4.1 Assembled Items*

a. Assembled parts/items that may be damaged during the cleaning operation or that may entrap fluids (because of complexity) shall be cleaned before the joining operation or shall be disassembled to a level to permit cleaning.

b. Subsequent handling and assembly operations shall be conducted to maintain an acceptable level of cleanliness.

### *6.4.2 Disassembly Before Cleaning*

a. Complete disassembly is required before cleaning or verifying all components except for certain excepted components being field cleaned or verified by a NASA-approved procedure. Therefore, use of components that cannot be completely disassembled should be avoided.

b. Items that cannot be dissembled shall be processed as “excepted components” as specified in Section 6.9.

### *6.4.3 Critical Surfaces*

Items that cannot be completely immersed in cleaning solution (e.g., small diameter tubing) shall have the solution circulated through the item or shall be manually oriented so that full surface contact with the process chemicals and rinsing solvents or deionized (DI) water can be achieved.

### *6.4.4 Pressure Testing*

Functional items, such as flexhoses, tube assemblies, vessels, and systems that require hydrostatic or pneumatic tests, shall be tested before final or precision-cleaning operation using an appropriate test fluid at specified test conditions (e.g., temperature, pressure, etc.).

### *6.4.5 Temporary Hardware*

a. All temporary hardware necessary to perform functional tests or to validate the cleaning process shall be compatible with processing materials, fluid media, and system items.

b. All temporary hardware necessary to perform functional tests or to validate the cleaning process shall withstand the specified environment.

c. All temporary hardware shall be legibly marked or otherwise identified as "temporary hardware" to ensure its removal from the item or system before final acceptance.

d. All surfaces near openings resulting from removal of components or instrumentation shall be visibly clean of contamination before installation of temporary hardware. This requirement also applies when removing temporary hardware and when installing components or instrumentation.

### *6.4.6 Nonmetallic Items*

a. Nonmetallic materials (soft goods) include Teflon®, Viton®, Neoflon®, Kel-F®, PVC, nylon, Buna–nitrile, natural rubber, polyethylene, urethane, and other plastics or polymers. Take special care to ensure that the cleaning processes used will not adversely affect the materials (e.g., damage or absorb the cleaning solution and consequent outgassing).

b. Cleanliness processes for composite vessels used in cryogenic service require special cleaning procedures. Each user shall require sub-tier documents to address processing, cleanliness methods, and verification. An engineering assessment is necessary to establish cleanliness requirements for each composite vessel.

## 6.5 Controlled Area

a. Clean rooms and clean work stations required for precision cleaning (e.g., processing, assembly, functional testing, packaging, etc.) shall be in an environmentally controlled area compatible with the product cleanliness level per ISO 14644-1 and 14644-2.

b. The performing organization shall establish and implement the requirements for the periodic certification of clean rooms, clean work areas, and other environmentally controlled work enclosures.

c. Items that require field cleaning because of size, configuration, and installation features (e.g., large pipes, tanks, etc.) or other special considerations cannot be performed in a controlled area. If field cleaning approval is obtained from NASA engineering, processing and inspection shall be conducted in a manner that does not degrade the specified cleanliness level using approved procedures.

## 6.6 Rough Cleaning

a. Rough cleaning is used to achieve level VC clean articles. Rough cleaning removes contaminants (e.g., corrosion, dirt, grease, scale, gum, or other foreign matter) from critical surfaces of systems and from individual items/parts before precision cleaning. Rough cleaning may be accomplished by using one or more of the following processes or materials: mechanical cleaning, halogenated degreasers, alkaline or acid cleaners, and detergents and ambient or heated tap or DI water. Concealment of crack indications associated with rough cleaning processes should be carefully considered and evaluated.

b. Articles shall be cleaned to level VC before precision cleaning.

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

### *6.6.1 Exceptions*

Unless specified otherwise by program, customer, or engineering work requirements, the following items are exempt from rough/mechanical cleaning if the visual cleanliness requirement is met: dry film lubricated surfaces, finished machined surfaces, and anodized or chemical filmed aluminum, plated passivated items that have been protected from contamination since finishing.

### *6.6.2 Mechanical Cleaning*

a. Mechanical cleaning removes contamination by abrasive action and can be used only when contaminants generated can be removed by subsequent cleaning. Mechanical cleaning may be accomplished by wire brushing, hydro blasting, and (wet or dry) grinding. This method is used only when physical damage to the item being cleaned will not occur (wire brushing and grinding can affect dimensions, tolerances and surface finishes [e.g., anodized or chemical films or plated surfaces] - particular care must be taken to avoid damage when de-scaling thin sections, polished surfaces, and close tolerance parts). Mechanical cleaning methods may imbed brush or grinding material particles in the cleaning surface. Cleaning brush selection depends on the component or system parent material. Nonmetallic brushes are suitable for most materials to be cleaned.

b. Carbon steel brushes shall not be used on aluminum, copper, and stainless steel alloys.

c. Stainless steel brushes previously used on other metals (e.g., carbon steel) shall not be used on stainless steel.

d. All loose dirt, scale, and other debris shall be completely removed from an item by vacuum cleaning, brushing, blowing, or flushing with (ambient or heated) tap or DI water.

e. Abrasive blast cleaning should be avoided. This method uses forceful impingement of abrasive particulates and may deposit (embed) contaminants that cannot be removed from the substrate. This method can increase the residual compressive stresses in the surfaces of metallic components.

### *6.6.3 Chemical Cleaning*

a. Proprietary cleaners should be evaluated to determine whether they contain chemicals (e.g., chlorides, corrosive compounds, etc.) that could adversely affect the performance of any cleaned item or system under operational conditions (e.g., stainless steels are very susceptible to chloride ion attack). Acid and caustic compounds can corrode metallic parts and etch sealing surfaces if not neutralized upon completion of cleaning.

b. Storage or immersion tanks, pumps, and associated piping and hardware used for cleaning items or systems must be compatible with the cleaning processes (solutions, pressure, temperature, etc.) and with any acid or caustic solutions.

c. Parts must be thoroughly rinsed to prevent the cleaning solution and contaminants from re-depositing on the surface. Acid and caustic compounds can corrode metallic parts and etch sealing surfaces if not removed. Also, if the cleaning solution is not completely removed, any contaminants remaining in the cleaning solution can redeposit on the critical surface during the drying operation.

d. All surfaces shall not be allowed to dry with any chemical cleaning solution or tap water.

e. Internal and external surfaces that have been cleaned or that have come in contact with aqueous or semi-aqueous media or with chemical solutions shall be tested for acidity and alkalinity by rinsing with DI water while the surfaces are wet from the final cleaning process as required in Section 11.

f. Most chlorinated solvents are incompatible with titanium alloys and shall not be used unless specified by program requirement or approval from NASA procuring activity.

### *6.6.4 Acid Cleaners*

Materials must be degreased before using any acid cleaners. Acid cleaners are used to remove contamination (e.g., weld scale, corrosion and oxide films) not removable by other solutions. Acid cleaners include nitric acid, chromic acid, inhibited hydrochloric acid, inhibited sulfuric acid, inhibited phosphoric acid, mixed acid deoxidizers, and alcoholic-phosphoric acid. Common applications include the following:

a. Phosphoric acid based cleaning agents remove oxides, light rust, light soils and fluxes.

b. Hydrochloric acid based cleaning agents are recommended for carbon and low alloy steels. These agents remove rust, scale and oxide coating and strip chromium, zinc and cadmium platings. Hydrochloric acids shall not be used on stainless steel since it may cause stress corrosion or stress corrosion cracking.

c. Nitric acid cleaning agents are normally used for aluminum, copper and their alloys. These agents are not true cleaning agents but are used for deoxidizing, brightening, and for removal of black smut which forms during cleaning with an alkaline solution. Passivation with nitric acid or citric acid solutions are effective for removing free iron from the surface of corrosion resistant steel parts to enhance corrosion resistance. Passivation is not effective for removing scale and corrosion products.

   Passivate parts individually to avoid metal to metal contact. This is especially important with free machining stainless steels, where free flow of passivating solutions are required to diffuse away sulfide corrosion products. Do not passivate stainless steel parts that have been carburized or nitrided. Parts treated for increased surface hardness may have their corrosion resistance reduced to a point where they corrode in the passivating tank. Thorough DI water rinsing (7.5.1 or 7.5.2) must follow all passivating treatments.

d. Nitric-hydrofluoric acid (pickling) solution is most widely used on stainless steel to remove both metallic contamination, and welding and heat-treating scales.

e. Continuous exposure to pickling solutions for more than 30 minutes is not permitted. Pickling Solution use should be carefully controlled and shall not be used for de-scaling sensitized austenitic stainless steels or hardened martensitic stainless steels or where it can come into contact with carbon steel parts, assemblies, equipment, and systems.

f. Most pickling solutions loosen weld and heat treating scale but may not remove them completely. Intermittent scrubbing with a stainless steel brush or fiber-bristle brush, in conjunction with pickling acids may facilitate removal of scale particles and products.

**NOTE:**

> Acid cleaning agents should not be used unless their application and performance are known (e.g., hardenable 400 series, maraging, and precipitation hardening stainless steel alloys are subject to hydrogen embrittlement or intergranular attack when exposed to acids that can cause the generation of hydrogen on the item being cleaned. Cleaning by other chemical methods may be required).

#### *6.6.5 Alkaline Cleaners*

Alkaline cleaners are used for removal of organic and inorganic contamination (e.g., grease, shop oil, scale, and soluble metal oxides). Alkaline cleaners dissolve (etch) certain metals, like aluminum and zinc. Types of alkaline cleaner include alkaline rust strippers, heavy duty alkaline cleaners, molten alkaline, alkali, alkali with nitrate, or phosphate.

#### *6.6.6 Degreasers (Organic and Aqueous-Based Solvents)*

Degreasers are used to remove some forms of organic contamination (e.g., oil, grease, and hydrocarbons).

#### *6.6.7 Caustic Cleaners*

Caustic cleaning with highly alkaline solutions is used for the removal of heavy or tenacious surface contamination followed by rinsing operation.

### 6.7 Precision Cleaning

a. Precision cleaning is performed after rough cleaning (except as noted below) and may be accomplished by employing methods such as solvent flushing or DI water impingement or to sonicate parts in an ultrasonic bath. This method is used to achieve a level of product cleanliness greater than visual means and requires cleanliness verification by particle count and/or by nonvolatile residue analysis as described in Table 3.

b. Precision clean articles shall be packaged immediately after cleanliness verification or protected before leaving the controlled environment.

c. All precision clean items (in accessible areas) shall be visually inspected before packaging and before installation in the fluid medium or system.

d. An item used in multiple media systems shall be cleaned to the most restrictive cleanliness level/requirements.

### 6.8 Field Cleaning

Field cleaning is permitted for systems or components required to be cleaned in place due to size and configuration (e.g., fluid transmission line, large pipe, tank, vessel, etc.). For all other systems or components, the provisions of Section 6.4 must be satisfied before field cleaning is allowed.

Industrial gas transmission and distribution pipelines, bottle banks, large vessels, steam generator modules, pumps and etc. are not considered components, and due to their large size (inherent length) and configuration, it is difficult to field clean (e.g. circulate or spray solutions and to remove them completely). Whenever possible, pre cleaning (rough cleaning) should be accomplished for each pipe section (or tube /bottle segment) and/ or sub assembly to improve the cleaning effectiveness. Field cleaning and processing procedures shall be developed by the performing organization and shall be approved by engineering for the requesting organization.

Mechanical pipe / tube cleaners may also be used for pre-cleaning. These are flexible shaft driven rotating wheel assemblies that carry out a brushing action inside the pipes to remove mill scale, markings, and other foreign matter. Mechanical cleaning is not recommended for non-metallic materials or for accurately dimensioned hardware as the method can cause uneven material loss.

### *6.8.1 Preparation Before Field Cleaning*

a. Before performing cleaning, all cognizant organizations shall be advised of scheduled activities, and the appropriate process approvals and permits shall be obtained.

b. Components with moving parts, close tolerance fluid passages or zero flow velocity zones shall be replaced by pipe spool pieces, blind flanges or have all internal piece parts removed.

c. Components containing soft goods incompatible with the cleaning and test fluid shall be replaced with a temporary spool piece and/or a flange to prevent soft good degradation that could result from field cleaning/verification operations**.**

d. All pressure gages and other instrumentation shall be removed.

### *6.8.2 Decontamination*

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

### *6.8.3 System Considerations*

Cleaning or flushing large or complex systems can deposit and concentrate contaminants in stagnant areas such as dead ends, sharp tubing bends, orifices and abrupt changes in internal diameter. Also, non-volatile cleaning agents may remain in trapped spaces and later react with oxidizers or generate particulates in cryogenic systems. Both NVR and particulate levels can increase after a system has been exposed to cryogenic fluids. This increase in contamination levels should be taken into consideration in establishing field methods for system cleaning and verification. Also, these areas may be inaccessible for visual inspection.

### *6.8.4 Installation of Temporary Hardware*

All temporary hardware necessary to perform cleaning, functional and verification tests shall comply with the requirements in Section 6.4.5.

### *6.8.5 Pressure Tests*

All items that require hydrostatic or pneumatic pressure tests shall comply with the requirements in Section 6.4.4 before cleaning.

### *6.8.6 Cleaning/Verification*

Practices required for field cleaning and verification are as follows:

a. The flushing process for field cleaning/verification shall be performed by system flow through or closed loop circulation with a minimum velocity of 1.25 meters per second.

b. The flushing process shall be used only on items in which the total volume can be filled or all critical surfaces can be wetted by the solution.

c. Pressurized spraying using spray wands and rotating-head spray machines shall be required for impinging solution onto and wetting all internal surfaces of large items, such as storage vessel or pipes that cannot be cleaned or verified by flow through or closed loop circulation in Section 6.8.6(a).

d. Spray equipment shall be capable of delivering cleaning or verification solutions that forcibly impinge the entire critical surface of the item being cleaned or for cleanliness verification. It is desirable to provide provisions for draining the cleaning/verification agent faster than it is introduced to avoid accumulation.

e. Aqueous and semi-aqueous cleaning agents /residues and chemical cleaning agents / residues are often corrosive as well as incompatible with oxidizers and other commodities. Also, these cleaning agents can generate particulate matter while the system is in service. Effective rinsing with DI water (that conforms to Section 7.5.1 or 7.5.2) is mandatory to ensure that all residual cleaning agents are removed from the system. See Section 11 for acidity and alkalinity tests.

f. Solvent removal must meet the verification requirements in Section 13.

g. Quantitative test methods for precision cleanliness verification (particulate and/or NVR analysis) are outlined in Table 3.

### *6.8.7 Field Certification*

Certification of system or component cleanliness levels may be performed in the field; however, verification processes that precede certification, such as sample analysis, are best performed in a laboratory.

### *6.8.8 Controlled Area Exceptions*

a. Field cleaning operations cannot be performed in controlled areas; however, all operations shall be conducted in a manner that does not degrade hardware cleanliness.

b. The performing organization shall provide shelters, enclosures, or a positive nitrogen or air purge of sufficient quantity that meets the requirements in Section 12(a) and 12(b) to prevent contamination of systems opened in the field.

c. These preventive measures shall comply with NASA-approved procedures.

**NOTE:**

Nitrogen and inert gases can act as an asphyxiant by displacing the amount of oxygen (air) needed to support life.

### *6.8.9 Post-Verification Operations*

a. Field hardware meeting cleanliness requirements do not need to be re-verified when contamination associated with field activity is completely accessible and can be removed by handwiping or purging (e.g., removal of loose, random scattered particles).

b. A certified NVR clean, lint-free cloth (nylon or polyester) that is heat sealed or double hemmed used for handwiping shall be moistened with a verification fluid that meets the requirements of this STD,

c. Handwiping shall be performed in such a manner that the fluid does not flow into or become entrapped in the hardware.

### *6.8.10 Post-Verification Inspection*

Surfaces of all cleaned components that will contact the service fluid shall be visually inspected for the presence of gross contaminants.

### *6.8.11 Protection of Cleaned Systems/Items*

a. All surfaces near openings shall be visibly clean of contamination before removal of temporary hardware and installing cleaned items.

b. Protection material and packaging films shall comply with requirements in Section 15.

c. Assembly installation and removal of precision cleaned components shall be done with utmost care to prevent contamination.

d. Certified clean gloves and tooling shall be used when handling cleaned significant surfaces.

## 6.9 Excepted Components/Items

a. Excepted components shall consist of items that cannot be processed per the requirements of this STD. Components, items, test equipment or instrumentation that cannot be cleaned or certified using normal procedures (because of their size, configuration, materials of construction, or method of assembly) may be certified as excepted components.

b. Excepted (EXC) components shall require written approval of the cleaning and verification procedures by the customer or requester.

c. These items shall be cleaned as to the intent of this STD as practical and identified as "EXC" on all tags and documentation. EXC. items have a reduced cleanliness confidence.

## 6.10 Equivalent Cleaned Items

Items meeting cleanliness requirements/levels of this STD via specified program or customer requirements or from NASA-approved engineering drawings/requirements do not require re-cleaning or reprocessing.

# 7.0 CLEANING FLUIDS, VERIFICATION FLUIDS, AND RINSING AGENTS

## 7.1 General

a. Traceability of cleaning fluids, verification fluids, and rinsing agents must be maintained throughout the cleaning and verification process.

b. Traceability documentation shall include, at a minimum, fluid cleanliness certifications and product composition reports.

## 7.2 Compatibility

a. Cleaning fluids, verification fluids, and rinsing agents must be compatible with the item being cleaned, verified, or rinsed and shall not cause immediate or latent degradation (e.g., leaching of plasticizers or swelling of soft goods or hardware corrosion).

b. Items that are completely or partially fabricated from polychlorotrifluorethyene (e.g., Kel-F® or Neoflon®) shall not be exposed to halogenated solvents while stressed. Concealment of crack indications from cleaning fluids and cleaner residues should be carefully considered and evaluated.

c. The performing organization must also ensure that cleaning, verification, and rinsing processes that employ dissimilar fluids do not degrade hardware (e.g., halogenated solvents and water are corrosive to some metals).

d. Parts and components shall be rinsed or rinsed and dried between operations as required to prevent the formation of corrosive mixtures.

## 7.3 Approved Halogenated Solvents for Precision Cleaning

a. When used for cleanliness verification, halogenated solvents shall comply with the latest revision of the applicable procurement specifications referenced in Sections 7.3.1 through 7.3.10.

b. In addition, the solvent shall meet the cleanliness requirements of the cleaned item or system. When the required NVR level of the solvent is less than the procurement specification, the solvent may need to be distilled to obtain the required NVR level as required in Section 8.1.

### *7.3.1 Trichlorotrifluoroethane (CFC-113)*

CFC-113 may be used to perform NVR and/or particulate analysis, but it shall not be used on titanium alloys, for hydrazine-based (MMH, UDMH, or $N_2H_4$) service items, or for flushing hydraulic components or systems. For procurement specification requirements, refer to MIL-C-81302, Type 1, or to Table A–1.

### *7.3.2 HCFC-225g (AK-225g)*

HCFC-225g may be used to perform NVR and/or particulate analysis, but it shall not be used for hydrazine-based (MMH, UDMH, or $N_2H_4$) service items or for flushing hydraulic components/ systems. HCFC-225g has the following isomer ratio: cb > 98% / ca < 2%. For procurement specification requirements, refer to KSC SPEC-P-0022 or to Table A–2.

### *7.3.3 HCFC-225 ca/cb (AK-225)*

HCFC-225 may be used to perform NVR and/or particulate analysis, but it shall not be used for hydrazine-based (MMH, UDMH, or $N_2H_4$ ) service items or for flushing hydraulic components/systems. HCFC-225 has the following approximate isomer ratios: ca 45–55% / cb 44–55%. The ca isomer has a lower threshold limit value than the cb isomer (refer to appropriate Safety Data Sheet). For procurement specification requirements, refer to Table A–3.

### *7.3.4 1,1,1 Trichloroethane (Methyl Chloroform)*

1,1,1 Trichloroethane may be used to perform NVR and/or particulate analysis, but it shall not be used on titanium alloys for service with hydrazine-based (MMH, UDMH or $N_2H_4$ ) service items or for flushing hydraulic components or systems. For procurement specification requirements, refer to MIL-T-81533.

### *7.3.5 Tetrachloroethylene (Perchloroethylene)*

a. Tetrachloroethylene may be used to perform NVR and/or particulate analysis, but it shall not be used for titanium alloys or for service with hydrazine-based (MMH, UDMH, or $N_2H_4$) items, soft goods, or hydraulic components/systems.

b. When used for cleanliness verification, tetrachloroethylene shall not be used on items that contain enclosed or entrapped areas (e.g., items or assemblies with a complex geometry or close tolerance fluid passages, etc.). Tetrachloroethylene has an oxygen AIT < 400 deg. F @ 50 psig.

c. Items or systems with NVR requirements shall be pre-dried in accordance with Section 12(a) flushed with HFE-7100® AK225g or Solstice PF or PF-HP and verified to ensure solvent removal in accordance with Section 13. For procurement specification requirements, refer to ASTM D 4376 (for vapor degreasing only) or to ACS *Reagent Chemicals: Specifications and Procedures* (for cleaning and verification).

### *7.3.6 Trichloroethylene*

Trichloroethylene may be used to perform NVR and/or particulate analysis, but it shall not be used on titanium alloys, for hydrazine-based (MMH, UDMH, or $N_2H_4$) service items, or for flushing hydraulic components or systems. For procurement specification requirements, refer to MIL-C-81302 or to ASTM D 4080.

### *7.3.7 Methoxynonafluorobutane (Hydrofluoroether-7100, HFE-7100®)*

Perfluorobutylmethylether (HFE-7100®) may be used to perform NVR analysis if a knockdown (correction sensitivity) factor of 3.0 is applied to correct for the efficiency of HFE 7100 to remove non-volatile (hydrocarbon-based residue) from critical surfaces. See Appendix B.1 for an example of NVR correction factor. HFE-7100 can be used to perform particulate analysis and as a rinsing agent to remove Vertrel MCA® from items that have an NVR requirement. HFE-7100® shall not be used for flushing hydraulic components or systems with MMH, UDMH or $N_2H_4$**.** Exception: HFE-7100 may be used as a cleaning or test solvent if the removal of MMH, UDMH or $N_2H_4$ from the item/s or system is verified to be less than 5 ppm expressed as methane using a FID analyzer. For procurement specification requirements, refer to A-A-59150 or to Table A–4.

### *7.3.8 Decafluoropentane 62% & Trans-1,2-Dichloroethylene 38% (Vertrel MCA®)*

a. Vertrel MCA® may be used to perform NVR and/or particulate analysis, but it shall **not** be used for service with either MMH, UDMH or $N_2H_4$, and hydraulic fluid systems, for soft goods that have an NVR requirement, with titanium alloys, or with hydraulic components or systems.

b. Items or systems with NVR requirements shall be pre-dried in accordance with Section 13 flushed with HFE-7100® and verified to ensure solvent removal in accordance with Section 13**.** Vertrel MCA does not meet the liquid oxygen compatibility requirements of NASA-STD-6001. For procurement specification requirements, refer to KSC SPEC P 0019 or to Table A–5.

### *7.3.9 Decafluoropentane (HFC-4310 mee or Vertrel XF®)*

a. Vertrel XF® may be used to perform particulate analysis, but it shall not be used for service with either MMH, UDMH or $N_2H_4$, as a test fluid for NVR analysis or for flushing hydraulic components or systems.

b. Exception: Vertrel XF® may be used as a cleaning or particulate only test solvent if the removal of MMH from the item or system is verified to be less than 10 ppm. For procurement specification requirements, refer to KSC SPEC P 0021 or to Table A–6.

### *7.3.10 Trans-1-Chloro-3,3,3-trifluoropropene (Solstice PF or PF-HP)*

Solstice PF (Performance Fluid) or Solstice PF-HP (Solstice High Performance) also known as trans-1-chloro-3,3,3, trifluoropropene (Chemical Abstract Service [CAS] Registry Number 102687-65-00, alternate designation 1233zd(E)), conforming to the requirements of MSFC SPEC 3709 for Grade A or to the requirements in Table A-7.

## 7.4 Alcohol Solvents

a. All alcohol solvents used for testing shall comply with the latest procurement specifications.

b. In addition, the alcohol control solvent shall meet the cleanliness requirements of the item being cleaned.

c. Alcohol solvents shall not be used for cleaning, verifying, or rinsing oxidizer systems (hardware and soft goods) or on any system that feeds into an oxidizer system.

d. If approved by the procuring organization or NASA Engineering, alcohol solvents can be used to clean IM&TE or AM&TE items. Items with NVR requirements shall be flushed with AK255g or HFE 7100 and verified to ensure solvent removal in accordance with Section 13.

### *7.4.1 Isopropyl Alcohol*

Isopropyl alcohol (isopropanol) may be used to perform particulate analysis, but it shall not be used as a test fluid for NVR analysis. For procurement requirements, refer to specification TT-I-735, Grade A, or *Reagent Chemicals: Specifications and Procedures*.

### *7.4.2 Ethyl Alcohol*

Ethyl alcohol (ethanol) may be used to perform particulate analysis, but it shall not be used as a test fluid for NVR analysis. For procurement requirements, refer to *Reagent Chemicals: Specifications and Procedures*.

## 7.5 DI Water

### *7.5.1 DI Water Verification Reagent (Used for Cleanliness Verification)*

a. When used as a verification reagent or final rinse for items that have a NVR requirement, the DI water shall have a specific resistance greater than 1 meg-ohm-cm or a conductivity of less than 1 micro-Siemen/cm, the total carbon content must be less than 1 ppm (mg/L) and shall exceed the particulate cleanliness level for the cleaned item. In addition, DI water shall require use of mechanical and/or thermal energy (e.g. high velocity impingment, sonification, and/or heat).

**NOTE:**

Pouring or flushing DI water through a component/item and collecting the effluent is not an acceptable NVR verification process. Verification and analysis methods must conform to a procedure that is approved by NASA Engineering and supported with test data that demonstrates the efficacy of the process for the affected item or assembly.

b. When used as a verification reagent or final rinse for items that have a “particulate only” requirement, the DI water shall have a specific resistance greater than

1 meg-ohm-cm or a conductivity of less than 1 micro-Siemen/cm and must meet or exceed the particulate cleanliness level for the cleaned item.

c. High-purity water in accordance with JSC-SPEC-C-20, Grade A, is an acceptable substitute as an NVR or particulate verification reagent or ASTM D 1193 Type II water except that the total carbon content must be less than 1 ppm and shall meet the particulate cleanliness level for the cleaned item.

#### *7.5.2 DI Water Rinsing Agent*

a. When used for rinsing operations, the DI water shall have a minimum specific resistance of 50,000 ohms/cm or a specific conductance less than 20 micro-Siemens/cm.

b. The DI water rinsing agent cannot be used to satisfy or verify any cleanliness verification process requirements (NVR and/or particulate) or as final flush/rinse on any precision-cleaned hardware.

#### *7.5.3 Hydraulic Fluids for Cleanliness Verification*

a. Use of hydraulic fluid is limited to flushing, particle population analysis for cleanliness certification, and functional testing of hydraulic systems. Hydraulic components may be sampled by test method VIII in accordance with Table 3.

b. Hydraulic fluids used for cleanliness verification or to perform functional tests or to preserve items shall meet the component or system cleanliness level requirements.

# 8. FLUID CONTROL REQUIREMENTS

## 8.1 Solvent Control Samples

a. Verification fluids (final rinsing fluids) shall be sampled daily or before use on hardware with cleanliness levels requiring an NVR or particulate analysis.

b. Fluids dispensed from small volume (10 gallons or less) stainless steel containers and suitability protected from external contamination need only be tested after each filling or addition of fluid. Verification fluids and final rinsing agents must meet the NVR and the particulate (cleanliness) requirements of the item being verified or rinsed.

c. The control sample (also known as solvent blank) for all items that have an NVR requirement shall have no more than 1 mg NVR per 200 ml of fluid.

d. When the control sample of a fluid does not meet the appropriate NVR requirement, the fluid cannot be used. The fluid must be distilled and re-sampled to verify the NVR requirement is met. When the control sample of a fluid does not meet the appropriate particulate requirement, the fluid cannot be used. The fluid must be filtered through a clean 25 micron or smaller wire mesh filter and re-sampled to verify that the particulate requirement is satisfied.

## 8.2 Solvent Verification (Test) Samples

a. Test samples can be obtained by flushing or spraying significant surfaces with certified halogenated, alcohol solvents and hydraulic fluids that meet the requirements in Section 7.

b. Contaminant levels of critical (cleaned) surfaces in contact (flushed) with the verification fluid shall represent samples taken from $0.1m^2$.

c. Agitation and/or working of the verification fluid in the item shall be performed to ensure the cleaned surfaces are exposed to the verification fluid. Flexible ducts, bellows, spool pieces, and lines shall be verified with the verification liquid sprayed in a vertical position or flushed inclined and rotated.

d. Cleaning processes performed by offsite organizations, (cleaning steps, verification procedures, and drying requirements) shall be approved by the procuring organization and the performing organization’s Engineering and Quality Assurance. The process shall not be detrimental to the items being cleaned.

e. To calculate NVR, the control solvent sample is subtracted from the solvent verification sample. The requesting organization is responsible for making this adjustment. A negative sample NVR (exceeds 15% of the control solvent NVR) is not considered a valid test. Subtraction of control solvent from the test solvent is not allowed for particulate analysis.

f. All solvents used in NVR determination must meet the requirements in Sections 7.1 and in 7.3.

## 8.3 Solvent Volume Required For Cleanliness Verification

### *8.3.1 Items with Surface Area Less Than 0.1m²*

a. Combine similar small parts to increase surface area to $0.1m^2$ ($1ft^2$). Components selected shall provide an accurate representation of the lot (e.g. similar size and configuration). In this context, a lot does not necessarily require identical parts, but does require all parts in the lot to be cleaned using the same process. A 200ml sample shall equally represent all components, and analyzed for NVR and/or particulate.

b. For individual items less than $0.1m^2$ and cannot be processed by combing similar items, the contaminant levels of the verification liquid shall be normalized to the NVR and particulate for the surface area sampled. For example, an NVR of 0.6 mg is obtained from a cleaned surface of $0.04m^2$ ($0.4ft^2$). The cleaning organization would then report the NVR as $1.5mg/0.1m^2$ ($1.5mg/ft^2$). In cases where all critical surfaces can be sampled with 100 ml or less of test fluid, a 100ml sample shall be taken and analyzed.

c. For components less than $0.01m^2$ ($< 0.1ft^2$), the significant surface of the NVR and particulates shall not be normalized below $0.01m^2$ ($0.1ft^2$). An NVR of 0.1mg is considered equivalent to $1mg / 1ft^2$. A 100ml sample shall be collected. Analyze the NVR using FTIR spectroscopy. The NVR test method using FTIR is shown in Appendix B.3.

d. For IM&TE and AM&TE with surface areas less than $0.01m^2$ ($< 0.1ft^2$), solvent volumes less than 100ml may be used if all the critical surfaces can be flushed. Details of the cleaning process procedure shall be left to the discretion of the performing organization. For surfaces less than $0.01m^2$, report the NVR and particulates as normalized to $0.01m^2$ ($0.1ft^2$). An NVR of $0.1mg/ 0.1ft^2$ is equivalent to $1mg / 1ft^2$. Analyze NVR using FTIR spectroscopy.

### *8.3.2 Items with Surface Area Between 0.1 and 0.5m²*

Significant surfaces having an area between 0.1 and $0.5m^2$ require 200ml of sampling fluid per $0.1m^2$. 100% of the significant surfaces shall be flushed. All sample fluid shall be collected and a 200ml representative aliquot shall be taken from the total fluid collected and analyzed. Surface area calculations shall be made to account for the solvent volume used. For example, the calculated significant surface area is $0.35m^2$ (approx. $3.5ft^2$). Calculate the sample volume required for Flush = ($200ml /ft^2$) ($3.5ft^2$) = 700 ml (equals the sample volume collected.) Submit a 200ml aliquot from the 700ml sample to the lab for NVR and particulate analysis. The 200 ml aliquot represents 1 sq ft or $0.1m^2$.

### *8.3.3 Components/Items With Surface Area Greater Than 0.5m$^2$*

a. Significant surfaces having an area greater than 0.5m$^2$ shall be flushed or spray rinsed with 100ml of sampling fluid per 0.1m$^2$. If necessary, larger volumes of liquid shall be used to ensure all significant surfaces are wetted. Surface area calculations shall be made to account for the volume used. Unless, a process has been proven to be comparable to a more aggressive solvent's cleaning process, HFE 7100 shall be limited and not used to verify the NVR of components / items greater than 0.5m$^2$. HFE 7100 has low solubility (Kb 10) and low solubility transport for keeping the NVR in suspension. HFE 7100 can be used to verify the cleanliness of large components that have a particulate only requirement.

b. Large containers/vessels and gas transmission lines shall be verified by a procedure submitted by the performing organization and approved by the NASA procuring activity. Typically, items with large surface areas (e.g. tanks) shall have multiple effluent samples collected ( e.g., first, interim or mid-point sample/s and a final liquid sampe collected separately. Each sample fluid (e.g.,100ml) collected for analysis shall represent 1 sq ft or 0.1m2.

c. For a complex piping system, determining the effectiveness of a cleaning operation may be difficult. One method of designing inspection into the system is to provide a short flanged length of pipe (e.g., spool piece) at a location or locations where the cleaning is likely to be least effective. The spool piece can be removed for cleanliness verification upon completion (see method IV in Table 3). This cleanliness verification may also be used in tandem with other processing methods in Table 3 ( solvent wipes, solvent rinses from jet moles, etc.) to verify that other sections representative of the piping system are cleaned.

# 9. VISUAL CLEANING CERTIFICATION

## 9.1 Visual Cleanliness

The Visual Cleanliness category includes GC, VC, and UV (see Sections 4.2 and 4.3). All significant surfaces that contact service fluids require VC inspection: the absence of all particulate and non-particulate matter visible to the normal unaided (except corrected vision) eye unless the surface is inaccessible. If visual evidence of contamination is found in a component or system, the foreign material must be analyzed to determine its identity, source, and compatibility with the service fluid. Risk assessment for continued use is recommended. Scale-free discoloration due to welding, etching, heat treating, and passivation of lines, components, or surfaces is permitted.

VC inspection requirements must be satisfied before precision cleaning steps (e.g. UV, 100A, 200) can proceed.

## 9.2 Flash Rust

a. Visible, scale-free surface oxidation (flash rust) is allowed on significant surfaces; however, it shall not exceed approximately 10 percent of the visual internal significant surface area of systems or components.

b. Furthermore, flash rust is not acceptable if it prevents the system or component from meeting the cleanliness requirements.

## 9.3 Inspection Aids

a. Surfaces inaccessible to visual inspection may be visually inspected using a borescope and other inspection aids (e.g., swab samples). Inspection aids must meet the cleanliness requirements of the system or component on which they are used.

b. The water break test may be used to aid visual inspection on horizontal surfaces. A small quantity of 20 micron or smaller filtered DI water that conforms to Section 7.5.1 is poured over the cleaned surface. The water should form an unbroken film on the metal surface. If water collects into a series of small droplets before 5 seconds, the part shall be re-cleaned. Materials with rough or porous substrates will not always present water break-free surfaces even if cleaned (e.g., aluminum castings).

c. The DI water shall be dried from the treated surface by blotting with a cleaned swab or wipe or by purging with dry nitrogen that conforms to Section 12a.

## 9.4 UV Cleanliness Level

a. UV cleanliness is visibly clean (as defined above) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 Angstroms. This level requires precision cleaning methods.

b. Any visible contamination or fluorescence shall be cause for re-cleaning.

c. If re-cleaning does not reduce fluorescence, an investigation shall be made to determine whether the fluorescing material is contamination or if the item material is naturally fluorescent.

d. UV lights must meet the cleanliness requirements of the system or component on which they are used.

## 10. QUANTITATIVE CLEANLINESS CERTIFICATION

The quantitative cleanliness methods imposed by this standard are described in Table 3. Quantitative cleanliness verification methods. Alternative procedures may be used upon qualification and approval by NASA Engineering and/or the procuring organization.

**Table 3. Quantitative cleanliness verification methods**

| Verification Method | Sampling Technique | Analysis Method |
|---|---|---|
| Method I – Particle Size and Count Determination for items w/o an NVR requirement) | Component/Item Flush with Non-Halogenated Solvents or DI Water Verification Reagent | Filtration & Manual Particle Count |
| Method II – NVR or Particle Population Count | Component/Item Flush with Halogenated Solvent | Manual Particle Count, Gravimetric NVR, or Infrared NVR |
| Method III – NVR Using DI Water Verification Reagent | Ultrasonic Extraction or Impingement Method | TOC NVR |
| Method IV – Particle Population or NVR for Fluid Transmission Lines | Spool Piece | Manual Particle Count, Gravimetric NVR, or Infrared NVR |
| Method V – Gas Extraction Method | Gas Flow Through (1) with Sintered Porous Disc for NVR and THC (2) Membrane Filter for Particle Count | Particle Count, THC & Infrared NVR (Condensable Hydrocarbon Test) |
| Method VI – Particulate and NVR for Field Cleaned Items and for Certain Excepted Components | Solvent Flow through Method | Particle Count and NVR using Gravimetric or IR |
| Method VII – Specialized NVR | Wipe samples from representative critical surface area | Gravimetric or IR NVR |
| Method VIII – Hydraulic Fluid Test for Particulate Analysis | Flush with Hydraulic Fluid for Hydraulic Components or Systems | Filtration and Manual Particle Count |

### 10.1 Method I – Component/ /Item Flush with Non-Halogenated Solvents or DI Verification Reagent

a. Liquid flush test for particle population remaining on critical surfaces normally cleaned in a controlled environment (applicable for components, small items, IM&TE, etc. that do not have an NVR requirement) using a cleanliness verification fluid that conforms to the requirements in Sections 7.4 or 7.5.1.

b. Ascertain total volume of test fluid to flush clean item or items in accordance with Section 8.3.

c. If flushing does not reach all critical surfaces, the item shall be rolled or positioned so critical surfaces are wetted.

d. Perform particle count per ASTM F312, SAE ARP 598, Appendix B or approval by NASA Engineering and/or the procuring organization.

### 10.2 Method II – Component or Item Flush with Halogenated Solvent

a. A liquid flush shall be performed with halogenated solvents for NVR or particulate analysis on critical surfaces of items cleaned in a controlled environment (applicable for components, small items, IM&TE, etc.).

b. Use an appropriate solvent volume that conforms to the surface area requirements in Section 8.3.

c. Where flushing does not reach all critical surfaces, the item shall be rolled or positioned so critical surfaces are wetted. Perform particle count per ASTM F312, SAE ARP 598, or Appendix B. NVR methods are also provided in Appendix B or approval by NASA Engineering and/or the procuring organization.

### 10.3 Method III – NVR Using DI Water Verification Reagent

a. This NVR method uses ultrasonic agitation or impingement on components in high purity water for total carbon analysis. Total NVR is expressed as total carbon content.

b. DI water verification reagent shall conform to Section 7.5.1. An example of an acceptable method is provided in Appendix B or approval by NASA Engineering and/or the procuring organization.

### 10.4 Method IV – NVR and Particle Determination for Fluid Transmission Lines

In a complex piping system, it may be difficult to determine how effective a field cleaning operation has been. One method of performing cleanliness verification for long pipe sections is to provide a short flanged length of pipe (e.g., spool piece) at a location where the cleaning is likely to be least effective. The spool piece can be removed for NVR or particulate verification upon completion. An acceptable method is provided in Appendix C or approval by NASA Engineering and/or the procuring organization.

The sample quantities and approaches ( e.g. the number of spool pieces used and other sampling methods including the number of samples) shall be approved by NASA engineering.

### 10.5 Method V – Gas Extraction Method

A gas extraction process for measuring particulates, total gaseous hydrocarbons and condensable hydrocarbons shall be used for cleanliness verification when liquid sampling is not practical because of configuration or method of assembly or is detrimental to the hardware.  Contamination removal from surfaces via a gas extraction process is not as efficient as a solvent flush and carries an increased risk for not measuring all contaminants that may be present on the significant surfaces. This method requires NASA Engineering concurrence for any items installed in the test complex or in the site gas distribution system. For other items (e.g., lab test equipment) approval is required by the performing organization's Quality.

For level A (NVR) requirements, the effluent or discharge gas should not show a 2.0ppm increase of THC (expressed as methane) over the influent gas and the condensable hydrocarbons shall not exceed 0.25mgs when tested per Appendix D, Flow through Item by Gas. Also, the particulates shall meet the cleanliness level requirements. Particle level determination for gas shall be made using a minimum 1.0 cubic meter (35 scf) sample. If feasible, the sampling shall be accomplished at maximum system operational flow rate (see appendix D).

### 10.6 Method VI – Solvent Flow-Through Method

a. A solvent flow-through test for monitoring particle population and NVR remaining on critical surfaces of items cleaned in the field shall be performed in the following manner:

    1. Flow test fluid through the item at a minimum velocity of 1.25 meters per second (m/s) or from a sample that forcibly impinges the critical surface.
    2. Collect a representative test fluid sample in a precision-cleaned container and submit sample for testing.

b. This method shall be used only on items in which all critical surfaces can be wetted by the solvent.

c. Assembled items may be processed as EXC components by the solvent flow through method if the assembled items are designed so neither lubricated surfaces nor soft goods can be degraded by the test fluids when exposed to fluid flow paths.

### 10.7 Method VII – Wipe Samples from Representative Critical Surface Area

a. This sampling method is performed by wiping a representative area of up to $0.1m^2$ (one square foot) with a certified clean, solvent-soaked, lint-free nylon or polyester wipe. The ends of the wipe shall be double hemmed or heat sealed.

b. The minimum and maximum surface area is 0.5 sq ft and 1.5 sq ft respectively. The target area is 1 sq ft. Normalize the NVR to 1 sq ft, based on the surface area wiped.

c. After wiping the area to be verified, each wipe shall be flushed with approximately 200 ml of solvent and analyzed for NVR. Surfaces $> 0.4m^2$ will require additional random wipe tests to ensure that a representative portion of the surface area is sampled.

d. Caution is necessary on cast items and metals such as aluminum not to rub hard enough to generate lint particles or to degrade treated surfaces. This method may be used for excepted components or for large vessels or items cleaned in the field. An analysis method is provided in Appendix E**.**

## 10.8 Method VIII – Hydraulic Fluid Flush for Particulate Verification

a. Hydraulic components may be sampled for particle population analysis.

b. Hydraulic Fluid used for particle analysis and functional testing shall be specified by the requester or program requirements.

## 11. ACIDITY AND ALKALINITY TEST

a. Internal and external surfaces that have been cleaned or that have come in contact with aqueous or semi-aqueous media or chemical solutions (e.g., caustics, acids, etc.) may be tested for acidity and alkalinity by rinsing with DI water while the surfaces are wet from the final cleaning process.

b. The surface acidity or alkalinity must register a pH between 5.5 and 8.0 or ± 0.4 pH of the rinse water source.

c. Items that fail this requirement shall be reprocessed or rinsed. The rinse water shall conform to the requirements in 7.5.1 or 7.5.2.

## 12. GAS REQUIREMENTS

a. Gases used for drying, functional testing, hydrostatic or pneumatic testing of cleaned components shall comply to one of the following specifications and will be certified monthly at the “site user interface points” (e.g. commodity certification sample points).

Also, gases used at processing points (e.g., work stations), shall be tested weekly for moisture, total gaseous hydrocarbon content, and particulates per the specification requirements in this section.

1. Nitrogen ($N_2$), Federal Spec., A-A 59503, Nitrogen Technical, Type 1 Class 1 Grade B and filtered with no particles > 100 microns.
2. Nitrogen, Military Spec., MIL-PRF-27401, Type 1, Grade A and filtered with no particles > 100 microns.
3. Helium, Military Spec., MIL-PRF-27407, Grade A and filtered with no particles > 100 microns.
4. Nitrogen, Helium, or Air that meets the user interface requirements in MSFC 3535.
5. Argon, Military Spec., MIL-PRF-27415m Propellant Pressurizing Agent, Grade A or B and filtered with no particles > 100 microns.
6. Argon CGA G11.1, Commodity specification for Argon, Quality Verification Level C, D, E, or F and filtered with no particles > 100 microns.

b. Gases used for preserving (package and seal) test items shall comply with one of the following requirements:

1. Nitrogen ($N_2$), Federal Spec., A-A 59503, Nitrogen Technical, Type 1 Class 1 Grade B and filtered with no particles > 100 microns.
2. Nitrogen, Military. Spec., MIL-PRF-27401, Type 1, Grade A and filtered with no particles > 100 microns.
3. Argon, Military Spec., MIL-PRF-27415 Propellant Pressurizing Agent, Grade A or B and filtered with no particles > 100 microns.
4. Argon CGA G11.1, Commodity specification for Argon, Quality Verification Level C, D, E, or F and filtered with no particles > 100 microns.
5. Nitrogen that meets the user interface requirements in MSFC 3535.

## 13. SOLVENT REMOVAL VERIFICATION

### 13.1 Process Control - Performance Equivalent for Solvent Removal

A hydrocarbon analysis for solvent removal is not required for components < 0.5m2 and whose significant surface area are dried using a thermal and/or vacuum oven or the surfaces are dried with a continuous flow purge of Nitrogen that meets MSFC 3535 or MIL PRF 27401. Details of the drying process shall be performed using a process approved by the performing organization's quality. Testing should be performed and data must be provided to demonstrate the dryness verification procedure is valid and supports the methods and processes used in the procedure. Visual inspection (VC) shall also be performed on accessible surfaces to verify dryness. Engineering assessments may be required for items with complex configurations and possible entrapment.

### 13.2 Gas Sample

a. Following use of any solvent on items or systems with NVR requirements, verification is required to ensure that the solvent has been thoroughly removed from the item or system.

b. Solvent removal verification from significant surfaces shall be performed in accordance with a NASA-approved procedure.

c. The item or system shall be purged (or locked up for 24 hours) with a gas that conforms to the requirements in Section 12.0(b).

d. A gas sample shall be taken from the item or system and analyzed to verify that the total gaseous hydrocarbon content is less than 5 ppm expressed as methane. This verification step must be supported with laboratory test data that demonstrates removal of the solvent for the affected item or system. A solvent removal test is not required for items that are dried using the thermal vacuum bake out processes in Section 14.3.

e. The drying and solvent removal verification process shall be performed after all solvent rinse/flush procedures.

f. The same gas sample used to measure moisture or dew point in accordance with section 14 may be used for verification. If the same gas sample is not used, the requirements and limits for gas flow or pressure hold/lockup times and pressures stated in Sections 14.1 or 14.2 (for moisture removal) apply for obtaining gas samples for solvent removal verification.

## 14. DRYNESS VERIFICATION (MOISTURE REMOVAL)

a. After testing for particulate population and/or NVR analysis, all items shall be dried.

b. The item or system shall be purged or locked up with nitrogen, air or helium that conforms to the requirements in Section 12.

### 14.1 Purge Method

a. For all lines and components, flow drying gas per Section 12.0(b) through or over the affected surfaces for a minimum of 30 minutes. Monitor the dew point leaving the affected item. The moisture content of the effluent gas shall not exceed 24 ppm.

b. For tanks and vessels, flow drying gas that conforms to Section 12.0(b) through the affected surfaces for a minimum of one hour. The moisture content of the effluent gas shall not exceed 128 ppm.

c. The maximum temperature of the drying gas for metallics shall be 120ºC (248°F).

d. If non-metallics are present, the temperature of the drying gas shall not exceed 60º C (140° F) unless a higher temperature is approved by NASA Engineering or the requesting organization.

**NOTE:**

If the effluent gas exceeds the allowable limit, continue purging the items(s) periodically until the test requirements are met.

### 14.2 Static Pressurization Method

a. For lines and components, pressurize the item to at least 50 percent of the item's working pressure with drying gas that conforms to Section 12.0(b). Lock up the gas and maintain elevated pressure within the item for a minimum of one hour. Following the lockup period the moisture content of the released gas shall not exceed 24 ppm.

b. For tanks and vessels, pressurize the item with drying gas that conforms to Section 12.0(b) to at least 50 percent of the item's working pressure. Maintain the lockup pressure for a minimum of eight hours. Following the lockup period, the moisture content of the released gas shall not exceed 128 ppm.

c. The minimum temperature of the drying gas at the point of entry shall be 45º C (113° F).

d. The maximum temperature of the drying gas for metallics shall be 120º C (248° F).

e. If non-metallics are present, the temperature of the drying gas shall not exceed 60º C (140° F) unless a higher temperature is approved by NASA Engineering or the requesting organization.

f. The temperature of the lockup gas is not required to be maintained while locked in the vessel or item.

**NOTE:**

If the released gas exceeds the allowable limit, continue the lockup cycles until the test requirements are met.

## 14.3 Bakeout

### *14.3.1 Process Control – Performance Equivalents for Moisture Removal (Dew Point)*

A dew point analysis is not required for components < $0.5m^2$ and whose significant surface area are dried using a thermal and/or vacuum oven or the surfaces are dried with a continuous flow purge of Nitrogen that meets MSFC 3535 or MIL PRF 27401. Details of the drying process shall be performed using a process procedure approved by the performing organization's quality. Testing should be performed and data must be provided to demonstrate the dryness verification procedure is valid and supports the methods and processes used in the procedure. Visual inspection (VC) shall also be performed on accessible surfaces to verify dryness.

### *14.3.2 Thermal -Vacuum Bakeout*

Component parts $\leq 0.1m^2$, IMTE, AMTE and gas samplers (cylinders) can be placed in the vacuum oven. The oven shall be closed and purged with inert test gas in accordance with Section 12 (a) and then shall be heated to the desired vacuum drying temperature. Parts temperature should be governed by the following criteria:

a. The minimum target drying temperature for all parts shall be 43° C (110° F).

b. The maximum target drying temperature for parts containing non-metallics shall be 63° C (145° F). Caution: some plastics may soften at temperatures below 63° C (145° F). If plastic properties are unknown, contact the procuring activity for approval.

c. The maximum target temperature for drying metallic parts shall be 120° C (248° F).

Once the items have reached the desired temperature, a vacuum should be drawn on the items and maintained. Recommended vacuum drying times, relative to oven temperature and pressure, are specified in Appendix F.

**NOTE:**

Unless approved by the procuring activity or NASA Engineering, formed lip seals and non-metallic convoluted diaphragms shall not be oven dried (heated).

### *14.3.3 Ambient Pressure Bakeout*

Parts and components with an internal surface area of $<0.4\text{m}^2$, can be placed in an oven and heated to dry. The oven shall be closed and constantly purged with inert test gas in accordance with Section 12 (a) and shall be heated. Part's temperature will be governed by the following criteria:

a. The minimum target drying temperature for all parts shall be 45º C.

b. The maximum drying temperature for parts containing metallic only parts is 120º C.

c. The maximum drying temperature for parts containing non-metallics shall be 69º C.

**NOTE:**

The details of the drying procedure (maximum temperature, hold time, etc.) shall be left to the discretion of the performing organization subject to the approval of NASA.

# 15. PROTECTION AND PACKAGING OF CLEANED ITEMS

## 15.1 General

a. Cleaning is a perishable condition; consequently, proper handling and packaging to preserve the surface cleanliness level is a critical process. All protective materials, devices, and closures shall be compatible with the system or component-critical surface in contact with the protective material.

b. Protective materials shall be designed to withstand the specified environment for the storage period and mode of delivery, including impact protection of critical surfaces.

c. Preservative and lubricant materials used inside the primary and secondary packaging on items that have been precision cleaned shall:

   1. Be compatible with the service media and in-service operating conditions.
   2. Not compromise cleanliness levels of the respective items.
   3. Be used sparingly (minimum amounts required to provide the needed protection of item surfaces) and only where absolutely necessary.

d. Installation of primary packaging films onto and around openings and other orifices of precision cleaned items or the enclosure of precision cleaned items into the inner bags (made of the primary packaging film) shall be performed in an environment equal to or cleaner than the environment in which the respective items were cleaned and certified.

e. Installation of metallic caps, plugs, blind flanges, and hubs onto and into openings or other orifices of precision cleaned items without the use of packaging films (e.g., blind flange or hub not used in conjunction with or as a protective barrier for packaging films) shall be performed in an environment equal to or cleaner than the environment in which the respective items were cleaned and certified. The cleanliness level of the caps, plugs etc. shall be at least equal to items they protect.

f. Installation of protective devices and secondary packaging films shall be performed within a time period and in an environment that prevents damage to primary packaging, potential contamination of precision cleaned surfaces, and visible contamination on any item surfaces and packaging films.

g. Any signs of visible contamination on packaging films prior to completed installation of secondary packaging films and protective barriers shall be cause for repeating clean level solvent sample collection and analysis, clean level verification and certification processes, and any precision cleaning processes deemed necessary to assure restoration of required cleanliness level.

h. Rubber, paper, non-metallic materials not listed in Table 4. Packaging Materials Thickness and Service Requirements 4, aluminum foil, or other non-approved materials shall not be used on precision cleaned surfaces.

## 15.2 Packaging Films

a. All plastic films used for precision packaging shall comply with the requirements of Table 4.

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

c. The cleanliness level of the inner wrap shall be at least equal to the item’s exposed, cleaned surfaces.

d. All parts that come in contact with oxygen, hydrogen peroxide, other oxidizers, or hypergols shall be protected with an inner bag or layers of a fluorohalocarbon film, such as Aclar 22A, or polyfluoroethylenepropylene (FEP) film conforming to requirements indicated and documents referenced in Table 4.

e. Other parts, components, subsystems, and systems (that do not come in contact with oxygen, hydrogen peroxide, other oxidizers, or hypergols) shall be protected with an inner bag or with layers of a polyamide film or a fluorohalocarbon film conforming to requirements indicated and documents referenced in Table 4. Polyamide films have a higher resistance to sloughing particles, while fluorocarbon or halocarbon films provide a better barrier to moisture vapor and gas permeability. If unique packaging requirements exist, such as flammability, electrostatic discharge, and/or hypergolic propellant compatibility, a plastic film other than polyethylene may be selected for use as an overwrap material.

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

g. All film procured clean shall be overwrapped with a second bag of clean, 152 μm (6 mils) thick polyethylene before packaging for shipment.

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

i. Plastic media in low humidity conditions can develop static charges that can attract ionic contaminates (e.g., dust, dirt, particulates). Precautions should be taken to minimize any secondary contamination transfer to critical surfaces.

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

k. The GC level does not require a cleanliness certification tag or sticker, since protective contamination control packaging is not required.

**Table 4. Packaging Materials Thickness and Service Requirements**

| Plastic Film | Thickness Range in Micrometers | Use |
|---|---|---|
| Polyethylene in accordance with A-A-3174 | 137 to 168<br>(5.4 to 6.6 mils) | Overwrap (secondary packaging), except may be used for inner wrap of items cleaned to level VC |
| Nylon 6 or equivalent polyamide | 43 to 58<br>(1.7 to 2.3 mils) | Precision (primary) packaging; not for liquid and gaseous oxygen, hydrogen peroxide, other oxidizer, or for hypergol service |
| Aclar 22A, per SAE-AMS 3649 or equivalent | 38 to 76<br>(1.5 to 3.0 mils) | Precision (primary) packaging; suitable for liquid and gaseous oxygen, hydrogen peroxide, other oxidizer, and hypergol service |
| Virgin PTFE FEP or equivalent polyfluoroethylenepropylene in accordance with SAE-AMS 3647 | 13 to 508<br>(0.5 to 20 mils) | Precision (primary) packaging; suitable for liquid and gaseous oxygen, hydrogen peroxide, other oxidizer, and for hypergol service |

### 15.3 Metallic Closures

a. Metallic closures, such as plates, blind hubs and flanges, threaded plugs, and caps, may be used instead of packaging films on item end and nozzle connections to protect precision cleaned surfaces from contamination. If and when used for this purpose, seals or gaskets shall be used to prevent entry of air or moisture into internal volumes and onto precision cleaned surfaces of items that are internally cleaned only (refer to Section 15.8.2 for further packaging details about these types of items).

b. For cases where the internal volume of a precision cleaned item (e.g., vessel, tank, pipe spool, valve, or other fluid component) is pressurized with an inert gas, metallic closures shall be used instead of packaging films to protect internal precision cleaned surfaces from damage and contamination.

c. To prevent electrolytic corrosion, metals dissimilar to the item flanges, hub connections, and threaded connections (e.g., stainless steel versus carbon steel) shall not be used where metal-to-metal contact can or will occur, including this type of contact with studs, bolts, nuts, clamps, washers, other fasteners, and spacers. Dissimilar metals may be used for metallic closures only where insulating spacers or dielectric couplings, gaskets, or seals are used properly and in a way to prevent contact between the dissimilar metals. Refer to MIL-STD-889 for corrosion and definition of dissimilar metals.

d. Gaskets or seal rings used with metallic closures shall be the same as those to be used when the precision cleaned item is installed for and placed into operational service, except that PTFE sheets may be used as gaskets for face-to-face sealing of flange and hub connections.

e. PTFE sheets used as gaskets for face-to-face sealing of flanges and hub connections shall be precut from a sheet of polytetrafluoroethylene of 1.57 mm (0.062 inch) minimum thickness.

f. When and where metallic plates are used instead of blind hubs and flanges, the plate thickness shall be no less than 3.18 mm (0.125 inch). Metallic plates shall not be used as substitutes for threaded cap and plug fittings.

g. The cleanliness level of gaskets, seals, and critical surfaces of metallic closures shall be at least equal to the level of cleanliness of the cleaned item being protected.

h. All threaded fittings and fasteners, including studs, bolts, nuts, and clamps, shall be installed and torqued or pre-loaded to provide seal/gasket loading for leak-tight sealing that prevents leakage of gas or moisture into or out of openings or orifices with attached metallic closures.

i. Use of packaging film is not required when and where metallic closures are used in accordance with this section. However, secondary packaging film may be used around these closures if extra safety precautions are desired or deemed necessary or to enclose certification card(s) in accordance with Section 15.8.6.

## 15.4 Protective Devices

a. When and where metallic closures are used in accordance with Section 15.3, additional protective devices are not required.

b. When packaging films are used in accordance with Section 15.2 to prevent contaminant entry onto precision cleaned critical surfaces, all openings or other orifices with an inside diameter or maximum edge-to-edge dimension greater than 38.1 mm (1.5 inch) shall be covered with wood, hardboard, plastic, or metallic barriers (shields).

c. If metallic shields are used, they shall be blind flanges, blind hubs, or plates as described in Section 15.3.

d. Insulating or dielectric spacer materials shall be used to prevent contact between dissimilar metals when metallic shields are used. Refer to MIL-STD-889 for corrosion and definition of dissimilar metals.

e. Overwrap materials consisting of a sufficient amount of packaging material to form a film cushion shall be used for heavy items or items having sharp points and edges that could potentially damage or puncture primary and secondary packaging film layers.

f. All protective shields and insulating materials shall be installed over the secondary packaging film.

g. Any and all protective devices (shields) not used in conjunction with packaging films to prevent contaminant entry onto precision cleaned surfaces shall be metallic closures that conform to requirements of Section 15.3, including material and installation requirements.

## 15.5 Dessicants

a. Desiccants used for packaging of precision cleaned components shall meet the requirements of MIL-D-3464 Type II (non-dusting). Even non-dusting desiccants may be a source of contamination for precision cleaned components; therefore, desiccants should not be used inside the inner bag or package.

b. Desiccants shall be packaged with a visual humidity indicator. Desiccant bag integrity should be verified before installation and after removal.

c. Smaller items, including fluid components that are less than 1.5 inch nominal size and items totally enclosed and sealed within inner and outer bags (made of primary and secondary packaging film materials), that have precision cleaned surfaces made of carbon steel or other materials susceptible to corrosion when in contact with moisture/water for indefinite periods of time shall be packaged with desiccants placed between the inner and outer bags (outside the inner bag and inside the outer bag).

## 15.6 Inert Gas Purging

a. Items where all of the following criteria apply shall be internally pressurized to 3 psig or higher pressure with an inert gas conforming to Section 12.0(b):

    1. Item has precision cleaned surfaces made of carbon steel or other materials prone to corrosion when in contact with moisture/water during extended time periods.
    2. Item is either placed into storage for an indefinite time period or is shipped to or from an RPT facility.
    3. Item is not packaged inside inner and outer bags or with desiccant as prescribed in Section 15.5.c.
    4. Item that is not IM&TE or AM&TE shall be packaged in accordance with Section 15.6.f.

b. Items internally pressurized shall each be equipped with no less than one gage, to provide continuous indication of internal pressure, and valves to provide a safe means to pressurize and vent (depressurize) the item.

c. Larger items, having internal volumes greater than $0.5 m^3$ shall not be pressurized to pressures above 10 psig. Maximum allowed pressure for smaller items, having internal volumes no greater than $0.5 m^3$, is 25 psig.

d. Prior to shipment of item or placement of item into storage, internal pressure shall be monitored for a time period of 12 hours or more to assure no detectable leakage of internal gas from the item.

e. On a case-by-case basis, items shall be pressurized in accordance with above requirements in Section 15.6.a, b, c, and d if unacceptable risk of moisture entry exists prior to installation and operational use of item, entry of air or moisture into the item will degrade its performance or operation.

f. For each IM&TE item packaged and totally enclosed within an inner bag (totally enclosed and sealed within primary packaging film), the outer bag (made of secondary packaging film) shall be purged with gaseous nitrogen or argon, conforming to requirements of Section 12.0(c) to assure an inert storage package.

## 15.7 Sealing

a. This section applies to cases where inner and outer bags are used to contain/enclose entire precision cleaned item(s) and where these bags are made from sheets of packaging film or are closed after precision cleaned items are placed inside the bags.

b. Material used for the inner and outer bags shall be packaging films conforming to requirements of Section 15.2 where primary packaging films are used for the inner bags and secondary packaging films are used for the outer bags.

c. Each inner and outer bag shall be made of only one film material.

d. For IM&TE and AM&TE, the bags shall be completely sealed to ensure the storage package is inert.

e. For items that are not IM&TE, the inner bag shall be completely sealed to prevent contaminant entry onto precision cleaned items and the outer bag shall be completely sealed to prevent moisture and visible contaminant entry onto the inner bag.

f. Bags shall be overwrapped and double-bagged to prevent damage during storage and handling.

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

h. If specific sealing procedures are not available, the recommendations of the manufacturer shall be followed for temperature setting and dwell time.

i. Fluorohalocarbon films, such as Aclar 22A, shall be sealed on all sides when fabricating bags.

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

k. Outer protective wrap (e.g., dimple wrap) may be applied outside the controlled area.

## 15.8 Detailed Requirements

### *15.8.1 Small Items*

a. Small items that have all surfaces precision cleaned shall be packaged in accordance with Section 15.2, sealed in accordance with Section 15.7, cushioned as applicable, bagged, and sealed.

b. Threaded fittings shall be double-bagged and may be placed in a polyethylene bubble bag. 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. Each compartment must be separable from the others by cutting without violating the integrity of the remaining compartments.

c. Each inner bag shall be placed in an outer bag of polyethylene, made of film material conforming to requirements and referenced documents in Table 4, with a certification card in accordance with Section 15.8.6.

d. The outer bag shall be sealed in accordance with Section 15.7.

### *15.8.2 Items Internally Cleaned Only*

a. Items cleaned internally only shall have all openings and other orifices leading to the internally cleaned surfaces sealed with plastic film in accordance with Section 15.2 or metallic closures in accordance with Section 15.3.

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

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

d. Each opening or other orifice of large items sealed and wrapped with packaging film per Section 15.2 and not sealed with metallic closures per Section 15.3, shall be overwrapped with polyethylene.

e. Openings and other orifices sealed and wrapped with packaging film shall be covered with protective devices in accordance with Section 15.4.

f. Identification shall be in accordance with Section 15.8.6.

### *15.8.3 Items with Flange or Hub Nozzle Connections*

a. Flange and hub connections on items that have only internally cleaned surfaces shall be sealed with packaging films in accordance with Section 15.2 or with metallic closures in accordance with Section 15.3.

b. When packaging films are used, protective devices shall be used as required by and in accordance with Section 15.4.

c. Marking and identification shall be in accordance with Section 15.8.6.

### *15.8.4 Electrical and Electronic Items*

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

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

c. Each inner bag shall be placed in an outer bag of polyethylene conforming to requirements and referenced documents in Table 4. Packaging Materials Thickness and Service Requirements 4, sealed in accordance with Section 15.7, and marked in accordance with Section 15.8.6.

d. Tamperproof decals shall be applied to the outer bag.

### *15.8.5 Hose and Tube Assemblies*

a. Hose and tube assemblies that have only internally cleaned surfaces shall be sealed with plastic film in accordance with Section 15.2 or with metallic closures on end openings/connections in accordance with Section 15.3.

b. When packaging films are used, protective devices shall be used as required by and in accordance with Section 15.4.

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

d. The entire hose or tube assembly may be overwrapped with polyethylene film as applicable.

### *15.8.6 Identification of Cleaned Items*

a. For precision cleaned items totally enclosed and sealed in bags, appropriate certification cards shall be placed between the inner and outer bags or layers (primary nd secondary packaging film layers) where practicable or as requested by the customer.

b. For cases where the precision cleaned items totally enclosed and sealed in bags are too small or of a configuration that does not enable placing the certification card between inner and outer bags, the certification card shall be enclosed and sealed in a separate plastic bag or between layers of packaging film, fully sealed around the enclosed card.

c. The separate bag or sealed film layers shall be securely taped to the outside of the outer bag containing the precision cleaned item(s).

d. For items that are internally cleaned only (see Section 15.8.2), the certification card shall be enclosed and sealed within a polyethylene bag or envelope.

e. The bag or envelope shall be securely attached to the item. If one or more of the openings or orifices are closed off with attached metallic closure(s) in accordance with Section 15.3, the certification card may be placed inside a polyethylene bag that is wrapped and taped around one of the metallic closures (see Section 15.3.i).

f. Certification cards shall be serviceable and of sufficient size to contain the following information at a minimum:

    1. Part description and work authorization number (e.g., work request/task number).
    2. Manufacturer’s serial number or other identification number (property or calibration control number).
    3. Cleanliness level and cleanliness inspection date.
    4. Acceptance stamps (QA or Quality Designee).
    5. Excepted Components shall be marked with “EXC”, if applicable (see 6. 9).

#### *15.8.7 Packaging Removal*

a. Removal of packaging film before installation of hardware into a system shall be performed such that all material is completely removed (i.e., no shreds, strips, or pieces of material will remain after packaging is removed).

b. Clean habits, where transfer/movement of contaminants to environments and hardware during processing and handling are prevented or limited to the maximum practicable extent, shall be followed.

c. Visible contamination on items cleaned to precision, UV, or VC levels shall be cause for rejection.

d. Visible evidence of an item damaged from transit, handling, packaging, or other causes shall be reason for rejection.

e. Cleanliness during assembly shall be maintained.

## 16. RECORDS AND FORMS

All records and forms shall be maintained in accordance with the latest version of NASA Procedural Requirements (NPR) 1441.1, NASA Records Management Program Requirements.

# Appendix A SOLVENT REQUIREMENTS

### Table A–1. Trichlorotrifluoroethane. Procurement Specification Requirements [1]

| Characteristics | Requirement |
|---|---|
| Chemical purity | 99.6% by wt. (min.) |
| Non-volatile residue | 0.5 mg/200 milliliters (max.) = (1.6 ppm w/w)[3] |
| Chloride (CL)[4] | 0.3 ppm (max.) |
| Moisture | 60 ppm (max.) |
| Alcohol | 0.3% by wt. (max.) [2] |

**NOTES:**

[1] Use limits apply to both new and reclaimed trichlorotrifluoroethane.

[2] Test for alcohol by ferrox test or infrared spectroscopy.

[3] W/W = Weight divided by weight

[4] Chloride ion characteristic is not required if the acidity per ASTM D2989 or equivalent is reported.

### Table A–2. HCFC-225G.
### ASAHIKLN AK-225G [1, 2]
### Procurement Specification Requirements [1]

| Characteristics | Requirement |
|---|---|
| Appearance | Clear colorless liquid |
| Purity | 99.5% (min.) |
| Non-Volatile Residue | 0.6 mg/200 milliliters (max) = (2 ppm w/w)[3] |
| Acidity (as HCI) | 1 ppm (max.) |
| Moisture | 100 ppm (max.) |
| Isomer Ratio (%) – 225ca | <2 |
| Isomer Ratio (%) – 225cb | >98 |
| Chloride (CL)[4] | <1 ppm |

**NOTES:**

[1] Use limits apply to both new and reclaimed dichloropentafluoropropane (HCFC-225G).

[2] HCFC-225G ca is 3, 3-Dichloro-1, 1, 1, 2, 2-pentafluoropropane and HCFC-225G cb is 1, 3-Dichloro-1, 1, 2, 2, 3-pentafluoropropane solvent.

[3] W/W = Weight divided by weight

[4] Chloride ion characteristic is not required if the acidity per ASTM D2989 or equivalent is reported.

### Table A–3. HCFC-225.
### ASAHIKLN AK-225 [1, 2]
### Procurement Specification Requirements [1]

| Characteristics | Requirement |
|---|---|
| Appearance | Clear colorless liquid |
| Purity | 99.5% (min.) |
| Non-Volatile Residue | 0.3 mg/200 milliliters (max) = (1 ppm w/w)[3] |
| Acidity (as HCI) | 1 ppm (max.) |
| Moisture | 100 ppm (max.) |
| Isomer Ratio (%) – 225ca | 45 ±5 |
| Isomer Ratio (%) – 225cb | 55 ±5 |
| Chloride (CL)[4] | <1 ppm |

**NOTES:**

[1] Use limits apply to both new and reclaimed dichloropentafluoropropane (HCFC-225).

[2] HCFC-225ca is 3, 3-Dichloro-1, 1, 1, 2, 2-pentafluoropropane and HCFC-225cb is 1, 3-Dichloro-1, 1, 2, 2, 3-pentafluoroprone.

[3] W/W = Weight divided by weight

[4] Chloride ion characteristic is not required if the acidity per ASTM D2989 or equivalent is reported.

### Table A–4. HFE-7100.
### Methoxy-Nonafluorobutane [1]
### Procurement Specification Requirements

| Characteristics | Requirement |
|---|---|
| Appearance | Clear colorless liquid |
| Purity | 99.5% (min.) |
| Non-Volatile Residue | 0.6 mg/200 milliliters (max) = (2 ppm w/w)[2] |
| Acidity (as HCI) | 1 ppm (max.) |
| Moisture | 100 ppm (max.) |
| Free Fluoride | <1 ppm |

**NOTES:**

[1] Use limits apply to both new and reclaimed methoxy-nonafluorobutane (HFE-7100).

[2] W/W = Weight divided by weight

### Table A–5. Vertrel MCA.
### Decafluoropentane (62%) and Trans-Dichloroethylene (38%) [1]
### Procurement Specification Requirements [1]

| Characteristics | Requirement |
|---|---|
| Appearance | Clear Colorless Liquid |
| Decafluoropentane (Vertrel XF) | 64 ± 4 (%) |
| Trans 1,2-Dichloroethylene (DCE) | 36 ± 4 (%) |
| Purity | 99.5% (min.) |
| Non-Volatile Residue | 0.9 mg/200 milliliters (max) = (3 ppm w/w) [2] |
| Acidity (equivalent to hydrochloric acid ppm by weight)[3] | 1 ppm (max.) |
| Moisture | 100 ppm (max.) |

**NOTES:**

[1] Use limits apply to both new and reclaimed Vertrel MCA.

[2] W/W = Weight divided by weight

[3] Test for acidity per ASTM D2989 or equivalent.

### Table A–6. Vertrel XF.
### 1, 1, 1, 2, 3, 4, 4, 5, 5, 5-Decafluoropentane [1]
### Procurement Specification Requirements

| Characteristics | Requirement |
|---|---|
| Appearance | Clear colorless liquid |
| Purity | 99.0% (min.) |
| Moisture [2] | <100 ppm |
| Acidity (equivalent hydrochloric acid ppm, max. by wt.) [3] | 1 ppm (max.) |
| Free Fluoride Content [4] | <10 ppm |
| Non-Volatile Residue [5] | 0.3 mg/200 milliliters (max) = (1 ppm w/w) [6] |

**NOTES:**

[1] Use limits apply to both new and reclaimed Vertrel XF.

[2] Test for moisture per ASTM D 3401.

[3] Test for acidity per ASTM D 2989.

[4] Test for free fluoride per ASTM D 3443.

[5] Test for NVR per ASTM D 2109 or Appendix B using a minimum sample volume of 100 ml.

[6] W/W = Weight divided by weight

### Table A–7. Solstice PF or PF-HP. Trans-1-chloro-3,3,3, trifluoropropene [1, 2] Procurement Specification Requirements [1]

| Characteristics | Requirement |
|---|---|
| Appearance | Clear Colorless Liquid |
| Purity | 99.0% (w/w) min. |
| NVR | 1mg /200ml or 2 ppm (w/w) max. |
| Acidity (as HCL) | 1 ppm (w/w) max. |
| Moisture | 100 ppm (w/w) max. |
| Free chloride ion[3] | 1 ppm (max.) |

**NOTE:**

[1] Requirements apply to new and reclaimed (distilled) solvent – the solvent shall contain no inhibitor, stabilizers or additives.

[2] Propellant, if required for purging or pressurization, shall be nitrogen conforming to MIL PRF-27401 Grade B or equivalent. HFO-1234ze (trans-1-3,3,3 –tetrafluorooprop-1-ene) may also be used as a propellant when mixed with Solstice PF (or Solstice PF-HP) at a 20% propellant ratio by weight during initial fill into the original container.

[3] Chloride ion characteristic is not required if the acidity is reported.

# Appendix B TEST METHODS

## B.1 Gravimetric NVR Analysis Method

The gravimetric NVR analysis method as referenced in ASTM F 331, Standard Test Method for Nonvolatile Residues of Solvent Extract from Aerospace Components (Using Flash Evaporator), shall be performed as follows:

a. Prior to performing the gravimetric analysis, the QC requirements in Table B-1 should be performed daily and recorded.

**Table B-1. QC Requirements**

| Control Type | Frequency | Control Limit | Comments |
|---|---|---|---|
| Mass Balance Check with Calibrated Class S Weights | Daily or Prior to Use | 1mg ± 0.1mg or 5mg ± 0. 2mg (1mg std. is preferred) | Mass Verification<br>Weigh to nearest 0.1mg |
| Blank Check (Al Pan vs. Al Pan) * | Daily or Prior to Use | < 0.1 mg (should read 0.0000g) | Zero Verification<br>Weigh to nearest 0.1mg |

b. Filter the verification solvent sample through a 10-micron pore size or less filter paper or membrane, compatible with the fluids being tested. Collect the filtered solvent into a cleaned container.

c. Evaporate a portion of the solvent sample to a 10–20 ml volume using a steam bath, a rotary evaporator at 50ºC (122ºF) with a vacuum of 10”-24” Hg, or a thermostatically controlled hot plate. If the test solvent used is perchlorethylene (tetrachloroethylene), a silicon-based oil bath must be employed with the rotary evaporator due to the high boiling point of perchlorethylene.

d. Transfer the sample to a clean constant weight (within 0.1 mg), tared weighing container, which was previously weighed to the nearest 0.1 mg. Rinse the sample container (e.g., beaker or flask) with approximately 20 ml of clean, filtered fluid and transfer the wash fluid to the weighing container (e.g., aluminum weighing pan).

e. Continue evaporation by placing weighing dish inside a constant-temperature oven at maximum temperature of 65°C (149ºF), or 3°C above boiling point of the solvent. Allow weighing dish to remain in oven until the fluid has just evaporated to dryness.

f. Remove the weighing dish from the oven and place in a desiccator to cool for 30 minutes. Remove the weighing container and weigh to the nearest 0.1mg.

g. Record the weight mg / volume analyzed (mg/200 mL for most analyses).

h. Perform a blank NVR on the filtered control solvent, and subtract the results from the NVR value obtained for the sample (f.).

i. Calculate the NVR as follows:

$$NVR = M_S - C_S$$

**Where:**

$M_S$ = Measured Sample NVR concentration from f.

$C_S$ = Control Sample (Solvent Blank NVR)

j. A correction (sensitivity) factor for hydrocarbons is required if HFE 7100 is used to perform a solvent flush for NVR analysis.

$$NVR = \{(M_S - C_S)\ (S_F)\}$$

**Where:**

$S_F$ = HFE 7100 sensitivity factor (3.0) for hydrocarbons (mineral oil)

$M_S$ = Measured sample NVR concentration (e.g., mg / 100ml or mg/ 200ml)

$C_S$ = Control Sample (Solvent Blank NVR)

**NOTE:**

The value of $S_F$ is dependent upon the type of residues likely to be left on hardware following a solvent flush and may vary from operation to operation. The $S_F$ value of 3.0 is based on mixed aliphatic hydrocarbons (mineral oil). For fluorocarbon oils, (e.g., Krytox) no sensitivity correction factor is required.

k. The requesting organization shall adjust NVR value based on the total amount of solvent used and the surface area sampled.

l. A NVR correction (sensitivity) factor is required if HFE 7100 is used to perform a solvent flush for NVR analysis (see Appendix B-1(i).

## B.2 Aqueous Ultrasonic Sampling and NVR Determination using Total Organic Carbon Analysis

This procedure defines the method for performing aqueous ultrasonic sampling and TOC NVR analysis of small parts. This method is limited to moderately sized hardware due to the sensitivity of the TOC analysis. This technique may also be used to quantify residue obtained from solvent flushes or extractions only after the solvent has been completely evaporated in the sampling pan.

**NOTE:**

Lower frequencies have been found to be most efficient in the removal of contamination; however, frequencies below 25 kilohertz (kHz) have been found to damage soft metals such as aluminum and silver.

### *B.2.1 Equipment*

The equipment unique to performing this procedure is as follows:

a. Ultrasonic (U/S) bath, 50 to 100 watts/gallons, 25 to 27 kilohertz

b. Stainless steel parts sampling pan, volumes 1, 2, 3, and 4 liters

c. Bracket to suspend parts sampling pan in U/S bath

d. A high-temperature (880 °C) combustion TCA (total carbon analyzer) with a sensitivity of ±0.2 ppm carbon (c) (mgC/L) and direct sample injection into combustion furnace

e. Carrier gas – oxygen or air, 1.0 ppm maximum total gaseous hydrocarbon (expressed as methane)

f. Potassium hydrogen phthalate, used to prepare calibration standards

g. Syringes, 200–500 microliter capacity, gastight

### *B.2.2 Preliminary Steps*

a. Set the U/S bath temperature at 52 ±2 °C and degas the bath for 10 minutes before use.

b. Set TCA to syringe mode and set the optimum parameters with the furnace temperature at 880 °C. Adjust TCA in accordance with the manufacturer's instruction.

c. Instrument calibration shall be performed daily using a 5ppm or lower hydrogen phthalate solution with DI water that meets the requirements in 7.5.1 A series of 200 micro-liter injections, five minimum shall be made until the percent relative standard deviation of the TC is less than 6 percent.

d. Clean the parts sampling pans. Conduct sampling procedure without parts to verify cleanliness of the pans. TCA results should be less than 1.0 ppm (1.0 mgC/L). If the total carbon reading is greater than 1.0 ppm, check the quality of the reagent water and/or the cleanliness of the parts sampling pan.

e. Record the TCA results on the parts sampling pan as blank sample ($TC_B$).

### *B.2.3 Sampling*

a. Place the parts with surface area of 0.1 to 0.2 $m^2$ in a clean parts sampling pan.

b. Measure quantity of reagent water required to cover the parts in the parts sampling pan.

c. Cover the parts sampling pan with foil and place it on a bracket in the U/S bath.

**NOTE:**

Reagent-water-to-parts-surface-area ratio shall not exceed 1000 mL/0.1 $m^2$; the ideal ratio is 500 mL/0.1 $m^2$.

d. Set water level in the U/S bath so it is above the water level in the parts sampling pan.

e. Sonicate parts in the U/S bath for 10 minutes. Perform the three following steps (f, g, and h) as soon as possible within the maximum time limit of 120 minutes.

f. Remove the parts sampling pan from the U/S bath and remove the cover. Swirl the parts sampling pan to mix the water.

g. Draw a 200-microliter sample of water from the parts sampling pan with a syringe.

h. Inject the 200-microliter sample of water into the TCA following the instrument operating instructions and record the TCA results.

i. Record the sample total carbon reading ($TC_S$).

### *B.2.4 Calculation*

a. Equivalent Nonvolatile Residue (Aqueous Ultrasonic Sampling)

$$NVR = \{(TC_S - TC_B)\ V_W\} / \{(S_F)\ A\}$$

**Where:**

NVR = Equivalent NVR (mg/$m^2$ or mg/0.1 $m^2$)

$TC_S$ = Total carbon value of sample (mgC/L or ppm)

$TC_B$ = Total carbon value of blank (mgC/L or ppm)

$V_W$ = Volume of water (L)

A = Surface area of parts ($m^2$)

$S_F$ = Sensitivity factor (mgC/mg contaminant) empirical constant derived from test of known contaminants

b. Sensitivity Factor (Aqueous Ultrasonic Sampling)

$$S_F = TC/S$$

**Where:**

$S_F$ = Sensitivity factor (mgC/mg of contaminant)
TC = Average total carbon value of the sample (mgC/L)

S = Contaminant solution concentration (mg/L)

Many contaminants are not soluble in water. Heating the water and the ultrasonic agitation may be required to adequately emulsify the contaminant.

**NOTE:**

Some contaminants are very difficult to emulsify directly. Some success has been achieved by applying a known amount of contaminant to a small, thin, lightweight coupon, such as shim stock or polytetrafluoroethylene (PTFE). Then the coupon is ultrasonically agitated in a known amount of heated water. The coupon is dried and reweighed. The difference in coupon weight is the amount of contaminant extracted into the water. The water sample is analyzed for TC, and an SF can then be calculated based on the known contaminant concentration and the measured TC.

## B.3 Infrared Spectrometric Transmission Method for Nonvolatile Residue Analysis

### *B.3.1 General*

This method involves evaporating an aliquot of solvent (AK225g, HFE 7100, etc.), or the entire sample volume and picking up the residue in tetrachloroethylene and analyzing the solution with an infrared spectrometer

### *B.3.2 Equipment*

a. Fourier Transform Infrared (FTIR) Spectrometer

b. Quartz cell, 20mm pathlength (10 mm optional)

c. Pharmaceutical grade mineral oil

d. Tetrachloroethylene, spectrometric grade

e. Temperature controlled oven (optional)

### *B.3.3 Calibration*

a. Before using this method, the FTIR spectrometer shall be initially calibrated.

b. Follow manufacturer's instructions for internal optical alignment if required, and optimal energy through put. Instrument parameters (number of scans, wave number resolution, gain ranging radius, etc.) should be adjusted as needed to optimize results.

c. Using tetrachloroethylene in a 20mm quartz cell, perform background (single beam) scan daily or before use between 3200 $cm^{-1}$ and 2600 $cm^{-1}$. The background spectrum will be used to develop absorbance spectra for the NVR calibration standards.

d. For a 50ml sample aliquot, calibrate the FTIR spectrometer by preparing mineral oil standards in tetrachloroethylene.

e. A minimum of five calibration points shall be obtained.

f. Final calibration concentrations shall range from 0.01mg/ml to an upper limit of 0.36mg/ml. The 0.02mg/ml mineral oil standard in tetrachloroethylene represents 0.5mg of NVR in a 200ml sample brought down to dryness and reconstituted with 7 ml of tetrachloroethylene.

g. Progressing from the lowest calibration standard to the highest standard, scan the various hydrocarbon blends in the 3200$cm^{-1}$ and 2600$cm^{-1}$ range using a 20mm quartz cell. If a representative aliquot or entire of the sample volume is analyzed, prepare equivalent calibration standards based on the total amount of solvent used (e.g., 50ml of a 200ml sample with an NVR of 1 mg/200ml = 0.25mgs. of NVR ml 0.25mgs. reconstituted with 7ml of tetrachloroethylene is 0.036 mg/ml. Therefore, an equivalent NVR (hydrocarbon) standard of 0.036 mg/ml would represent 1 mg/200ml from a 50 ml aliquot. The quartz cell should be flushed twice with tetrachloroethylene and a minimum of two times using a standard of the next highest concentration level when changing standards.

h. Use the IR spectra from the prepared NVR calibration standards to compute the least squares regression calibration coefficients. The correlation coefficient for the linear regression or quadratic model should be 0.990 or better. Either peak intensity or area can be modeled. The calibration curve should not be forced to go through zero.

### *B.3.4 Infrared Analysis Procedure*

a. Perform a background scan daily with tetrachloroethylene or before use between 3200 $cm^{-1}$ and 2600 $cm^{-1}$ . The single beam background spectra will be used to develop absorbance spectra for analyzing samples.

b. Following the initial calibration (Section B.3.3) and the background scan (a), analyze check standards daily or before sample analysis. The check standards shall represent

1mg/200ml and 4 mg/200ml. The check standards (mineral oil in tetrachloroethylene) should read within ±10%.

c. Filter the solvent sample (e.g., AK225g, HFE 7100, etc.) through a 10 micron pore size or less filter paper or membrane, compatible with the fluids being tested. Collect the filtered solvent into a cleaned container.

d. Evaporate the sample or a representative aliquot of the solvent sample to near dryness (3 to 5 ml) using a steam bath, a rotary evaporator at 50ºC (122ºF) with a vacuum of 10"-24" Hg, or a thermostatically controlled hot plate. Remove the beaker before dryness and place in an oven at a maximum temperature 65°C (149ºF), or 3°C above the boiling point of the solvent, or allow it to dry or with forced air (draft from the fume hood) flowing over the sample or with a nitrogen purge.

e. Allow the beaker or flask to cool and add 7mls of tetrachloroethylene to the residue.

f. Briefly swirl the solvent over the residue and transfer the solution to a 20mm quartz cell. Use care during transfer to avoid loss of sample due to spilling or overfilling of the cell.

g. Record a sample infrared absorption spectrum between 3200 to 2600cm$^{-1}$ using the same cell pathlength that was used to develop the calibration curve.

h. Determine the amount of NVR (mgs. of hydrocarbon) in the sample by using the least squares regression calibration curve (B.3.3). If the sample concentration is greater than the highest calibration standard, a dilution of the sample with tetrachloroethylene shall be made and the appropriate dilution factor applied.

$$\mathrm{NVR} = (M_S)\,(Vs)$$

**Where:**

$M_S$ = FTIR measured sample NVR concentration (e.g., mg/200 ml)

Vs = Tetrachloroethylene volume used to reconstitute the sample residue (e.g., 7 ml)

NVR = mg of NVR (hydrocarbon)

i. If a blank sample is submitted, perform a blank NVR on the filtered control solvent (steps c-h.) and subtract results from the NVR value obtained for the sample (h).

j. A hydrocarbon correction (sensitivity) factor is required if HFE 7100 is used to perform a solvent flush for NVR analysis (Appendix B-1, subsection i). Also, if applicable, adjust the NVR value based on the sample volume analyzed, and the concentration units reported (mgs per 200ml sample or mgs per 100ml sample volume).

k. The requesting organization shall adjust the NVR value as required, based on the total amount of solvent used, control solvent (background NVR), and surface area sampled.

## B.4 Microscopical Particle Population Analysis

### *B.4.1 Scope*

This analytical method covers the size distribution and quantity of particulate matter contamination removed from cleaned items and isolated on a membrane filter. This test method does not provide for sizing particles smaller than 5 µm.

### *B.4.2 Analysis*

a. Assemble a precision-cleaned filtration apparatus.

b. Using clean forceps with nonserrated tips, place a filter membrane (47-mm diameter with 0.4-µm to 1.0-µm pores) in position in the filter holder.

c. The filter membrane shall be compatible with the test fluid. Before insertion, the filter membrane may be rinsed with filtered test fluid to remove any adherent contamination.

d. Fill filter funnel approximately three-fourths full of test fluid and turn on vacuum pump.

e. Add the remaining test fluid to the filter funnel at a rate necessary to maintain the funnel more than half full until all of the test fluid has been added. Do not allow the test fluid to pour directly onto the filter membrane after filtration has started.

f. 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.

g. Retain the filtrate for analysis of the NVR in accordance with Appendix B, subsection B.1(a) and B.1(c).

h. Place the filter membrane under the microscope.

i. Direct a high-intensity light source of 5000 to 6000 candelas (cd) onto the filter membrane from an oblique position to obtain maximum definition for sizing and counting. High-intensity illumination is a critical requirement.

j. Use magnification of approximately 40-50 power for counting particles for level 150 conformance and greater and approximately 100 power for level 100 and less.

k. Count particles in accordance with the method of ASTM F312 or SAE ARP 598 except when the total number of particles of a given particle size range is to be between 1 and 154. Then the number of particles over the entire effective filtering area of the membrane shall be counted.

# Appendix C CLEANLINESS VERIFICATION USING THE TEST SPOOL METHOD

## C.1 Scope

This appendix provides guidance relating to performing cleanliness verification using the test spool sampling method. In a complex or large piping system, it may be difficult to determine how effective a field cleaning operation has been. A short flanged length of pipe (e.g., spool piece) at a location where the cleaning is likely to be least effective can be used for cleanliness verification. Multiple spool pieces should be used for long pipe sections or with complex configurations (e.g., branched sections). The spool piece can be removed from the system and analyzed for NVR or particulate verification.

## C.2 Equipment

a. The test spool shall be of the same material and same diameter as the system being cleaned.

b. Double isolation valves shall be installed at each end of the test spool before installation to allow removal without compromising the system's cleanliness integrity.

c. The isolation valves shall be compatible with the system being cleaned and sized appropriately to prevent any flow restriction of the process fluids.

d. The test spool shall have an interior surface area equal to or greater than $0.5m^2$.

## C.3 Operation

a. The test spool shall be cleaned to the appropriate cleanliness level per this standard before use.

b. The test spool shall be installed at the systems outlet port or at low points in the line before beginning the operation.

c. The test spool is to remain in place throughout the entire cleaning process and will be routed to the laboratory for analysis.

d. Immediate surrounding surfaces (test spool connection points) shall be flushed/wiped with validation fluid before removing the test spool to remove oils/contaminates.

e. All immediate surrounding surfaces (test spool connection points) shall be purge dried with filtered $GN_2$ until visibly dry.

f. Isolation valves shall be closed; the test spool shall be removed.

g. All open ports (system and test spool) shall be immediately sealed from outside contamination. When sealing open ports, the primary barrier must be certified to meet system cleanliness requirements.

h. The test spool shall be routed to the laboratory for analysis.

## C.4 Analysis Method of Test Spool

a. Sufficient quantity of validation fluid to perform the analysis shall be obtained.

b. The isolation valve at one end of the test spool shall be opened. 200ml per 0.1m$^2$ of the test solvent from Section 8 shall be poured through the open port into the test spool.

c. The isolation valve shall be closed and the test spool shall be agitated to ensure validation fluid is introduced evenly and has wet all surface areas.

d. The sample shall be decanted into a sample container, which shall be submitted to site lab and analyzed for acceptable NVR and/or particulate in accordance with this standard.

# Appendix D METHOD V, NVR AND PARTICLE DETERMINATION FOR IN SERVICE SYSTEMS

## D.1 Scope

This appendix provides a gas flow test method to evaluate a systems capability to deliver fluid that meets the specified cleanliness requirements (for in-service systems). This method may be used to evaluate a field system which is suspected to have been contaminated in use or during operational testing.

Gas samples shall be drawn from a flowing gas stream (not from a dead space in the system).

## D.2 Particle Determination

The gas flow test method for monitoring particle population and NVR remaining on critical surfaces shall be performed as follows.

a. Sampling of the component, subsystem, or system shall be performed at the specified point.

b. The sampling gas shall be drawn through a 47mm 1-µm or smaller filter membrane.

c. Nitrogen or helium that complies with the requirements in Table 4 shall be used as the sample gas.

d. Particle level determination shall be made using a minimum 4000 liter (142 scf) sample.

e. The minimum gas flow rate through the sampler while accumulating. The samples shall be 990 liters/minute (35 scfm).

f. A positive flow rate of at least 14 liters/minute (0.5 scfm) shall be maintained during installation and removal of the sampler.

g. Two consecutive successive samples taken 8 to 48 hours apart, shall demonstrate compliance with cleanliness requirements of this standard.

h. The particles on the filter membrane shall be counted using procedures described in this standard.

## D.3 NVR Determination

An NVR sample at the user interface point can be obtained by passing the sampling gas through a precision cleaned gas sampling device as shown in Figure D–1. Volume surface area requirements are met when sampling collection per Table D–1 is followed.

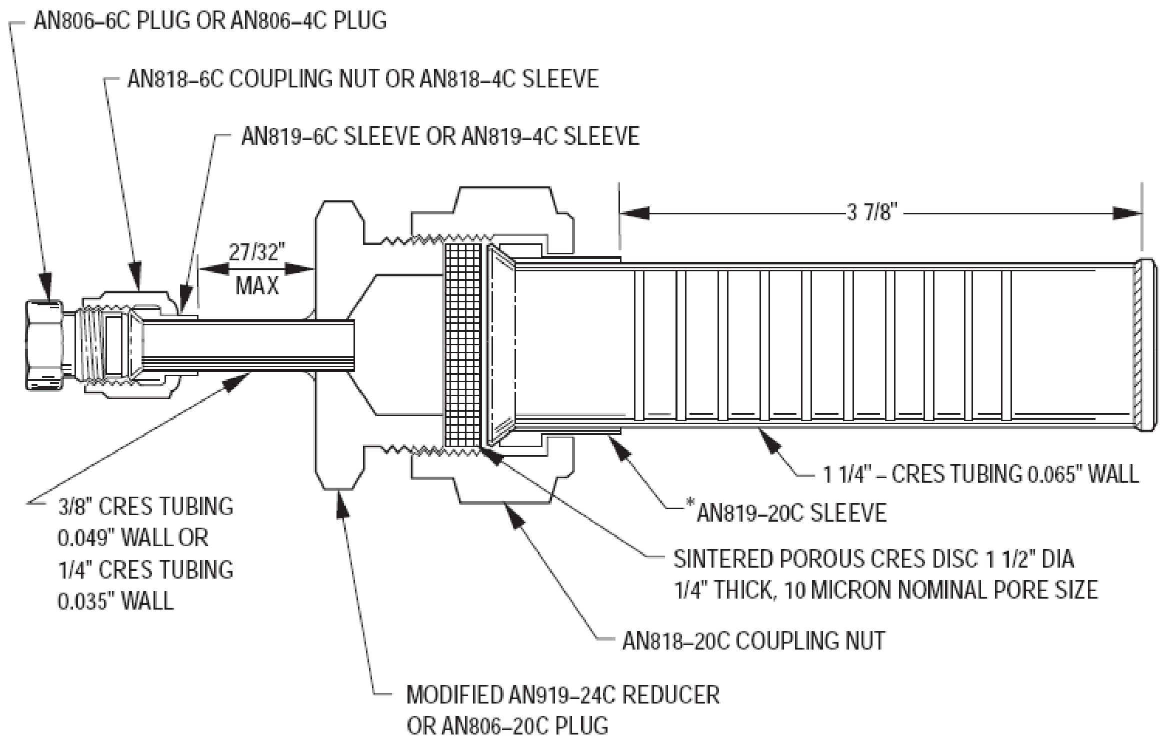


**Figure D–1. Gas Sampler for NVR Residue.**

**Table D–1. Sampling Time.**

| **Nitrogen** [1] | |
|---|---|
| Pressure Drop (psi) [2] | Sampling time |
| 200–499 | 2.5 min |
| > 500 | 1.2 min |
| **Helium** [3] | |
| Pressure Drop (psi) [2] | Sampling time |
| 200–299 | 2.5 min |
| > 500 | 1.2 min |

**NOTES:**

[1] $N_2$ is used as the sampling gas for oxidizer and nitrogen systems

[2] Pressure drop is defined as the pressure reading on the gauge at the sampling location when the sampler is connected and the valve is open.

[3] He is used as the sampling gas for hydrogen, helium and fuel systems

a. Do not add pressure line extensions between sampling port and the system being tested. Open the system valve to achieve a pressure drop reading above 500 psi for 1 minute. If a pressure drop of 500 psi cannot be obtained, refer to Table D–1 for the required sampling time. No sampling shall be conducted below a pressure drop of 200 psi.

b. Remove the sampler from the sample port and reinstall the AN plug in the inlet of the sampler and insert sampler into Teflon or Aclar bag that complies with Section 15. Pass the sampling gas through sampling device under the conditions listed in Table D–1.

c. Disassemble the NVR sampler and place the sintered stainless steel disc in Gooch crucible or a 47mm diameter filter holder/filtering apparatus.

d. Flush 200ml of a halogenated solvent (referenced in Section 7.3) through the sintered disc. Repeat twice using the same solvent.

e. Determine NVR using the gravimetric or infrared procedure described in Appendix B.

f. The extraction and analysis shall be repeated until results are less than 0.3mg or the results of successive analyses agree within 0.2mgs.

g. Two consecutive samples taken 8 to 48 hours apart, shall demonstrate compliance with the NVR requirements of this standard.

# Appendix E METHOD VII, WIPE SAMPLES FROM REPRESENTATIVE CRITICAL SURFACES

## E.1 Scope

This method consists of wiping the critical surfaces of the hardware with a cloth type wipe and analyzing the contamination picked up by the wipe. This method is used on hardware when the solvent flush method is not practical.

## E.2 Preparation of Sampling Wipes

a. Lint-free nylon or polyester wipes varying from 6 to 12 inches square. The ends of the wipe shall be double rolled (hemmed) or heat sealed.

b. Wipes shall be cleaned until each wipe has an NVR or hydrocarbon content less than 0.3mgs.

c. Each wipe will be placed in a cleaned aluminum foil and placed in an outer Teflon bag.

## E.3 Wipe Method

a. A clean pair of solvent resistant gloves (or a clean Teflon bag placed over a glove) shall be worn while handling the wipe.

b. Remove the wipe from the protective packaging and soak the wipe with a halogenated solvent per Section 7.3.

c. Critical surfaces shall be wiped while turning the wipe often to expose a clean area.

d. One to three square feet shall be sampled per wipe. Caution is necessary on cast items and metals such as aluminum not to rub hard enough to generate lint particles or to degrade treated surfaces.

e. The wipe shall then be rewrapped in the aluminum foil and placed in an outer inert bag (e.g., Teflon bag).

f. The package shall be labeled including area sampled and solvent used during sampling.

g. The wipe shall be extracted using 200ml of halogenated solvent per Section 7.3. Extraction may be performed using Soxhlet extraction (minimum of six extractions) or a soak leach method using agitation for a min. of 30 minutes.

h. Determine NVR using the gravimetric or infrared procedure described in Appendix B.

i. The extraction and analysis shall be repeated until results are less than 0.3mg or the results of successive analyses agree within 0.2mgs.

# Appendix F THERMAL VACUUM DRYING TIME (HOURS)

| VACUUM OVEN PRESSURE | | TEMPERATURE VS. HOURS OF DRYING TIME | | | | |
|---|---|---|---|---|---|---|
| **psia** | **torr** | **43 °C (110 °F)** | **54 °C (130 °F)** | **65 °C (150 °F)** | **76 °C (170 °F)** | **87 °C (190 °F)** |
| 2.9 | 150 | - | - | - | 0.9 | 0.75 |
| 2.4 | 125 | - | - | 1.3 | 0.8 | 0.75 |
| 1.9 | 100 | - | 4.8 | 1.2 | 0.75 | 0.75 |
| 1.4 | 75 | - | 2.0 | 0.8 | 0.75 | 0.75 |
| 0.93 | 50 | 3.4 | 1.1 | 0.75 | 0.75 | 0.75 |
| 0.44 | 25 | 0.9 | 0.75 | 0.75 | 0.75 | 0.75 |
| 0.29 | 15 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |

**NOTES:**

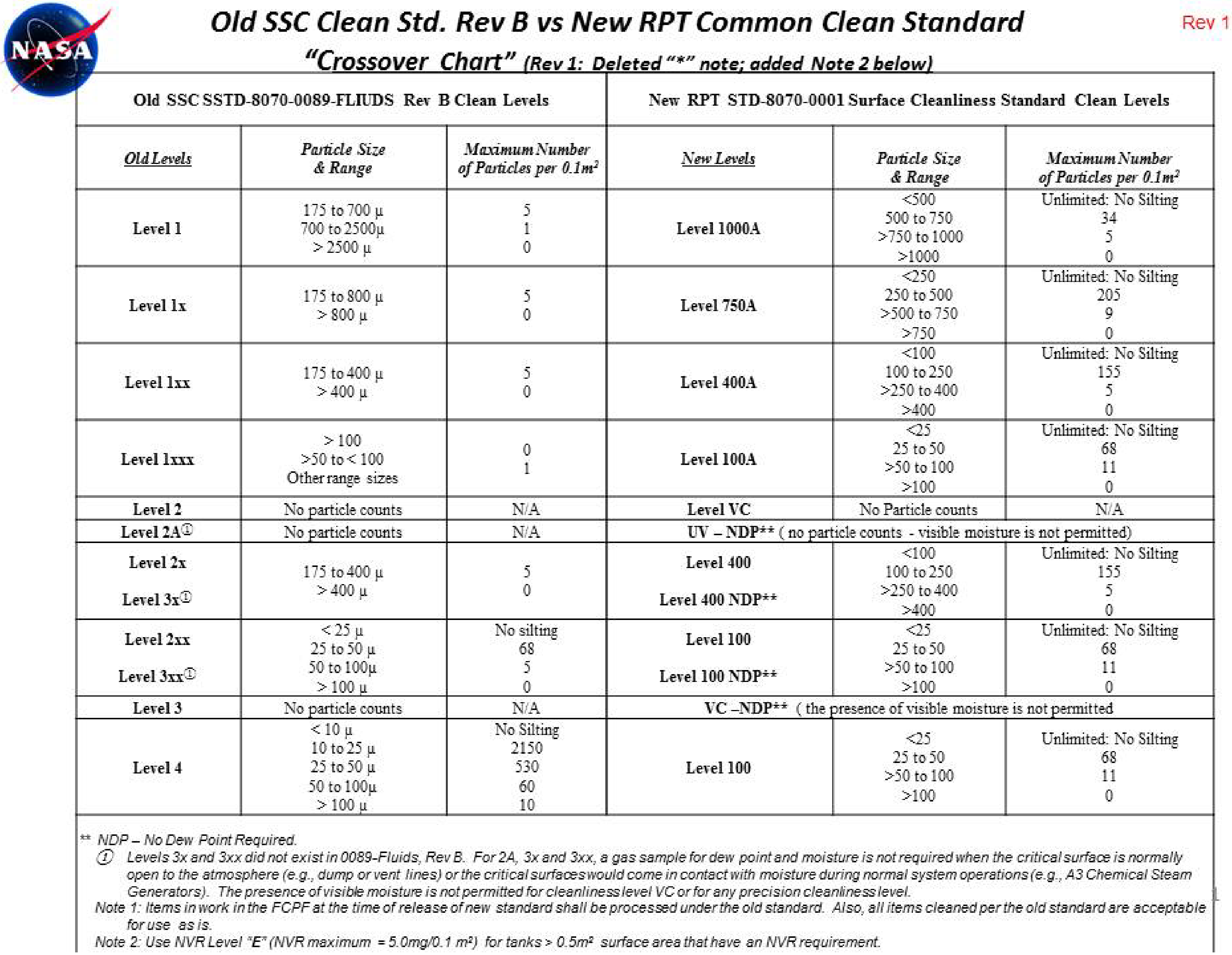
Time tolerance of ±5 mins

Pressure tolerance ±20 torr

Allowed temperature tolerance of ±3 ºC (±5 ºF)

When the parts have reached the desired temperature, a vacuum shall be drawn on the parts and maintained for the period specified. Once the parts have been dehydrated, the heat should be discontinued and the oven slowly back filled with the test gas.

# Appendix G CROSSOVER CHART, *FOR SSC USE ONLY*



## Old SSC Clean Std. Rev B vs New RPT Common Clean Standard

Rev 1

### "Crossover Chart" (Rev 1: Deleted "*" note; added Note 2 below)

| Old SSC SSTD-8070-0089-FLIUDS Rev B Clean Levels | | | New RPT STD-8070-0001 Surface Cleanliness Standard Clean Levels | | |
|---|---|---|---|---|---|
| *Old Levels* | *Particle Size & Range* | *Maximum Number of Particles per 0.1m²* | *New Levels* | *Particle Size & Range* | *Maximum Number of Particles per 0.1m²* |
| **Level 1** | 175 to 700 µ<br>700 to 2500µ<br>> 2500 µ | 5<br>1<br>0 | **Level 1000A** | <500<br>500 to 750<br>>750 to 1000<br>>1000 | Unlimited: No Silting<br>34<br>5<br>0 |
| **Level 1x** | 175 to 800 µ<br>> 800 µ | 5<br>0 | **Level 750A** | <250<br>250 to 500<br>>500 to 750<br>>750 | Unlimited: No Silting<br>205<br>9<br>0 |
| **Level 1xx** | 175 to 400 µ<br>> 400 µ | 5<br>0 | **Level 400A** | <100<br>100 to 250<br>>250 to 400<br>>400 | Unlimited: No Silting<br>155<br>5<br>0 |
| **Level 1xxx** | > 100<br>>50 to < 100<br>Other range sizes | 0<br>1 | **Level 100A** | <25<br>25 to 50<br>>50 to 100<br>>100 | Unlimited: No Silting<br>68<br>11<br>0 |
| **Level 2** | No particle counts | N/A | **Level VC** | No Particle counts | N/A |
| **Level 2A①** | No particle counts | N/A | **UV – NDP**** ( no particle counts - visible moisture is not permitted) | | |
| **Level 2x**<br>**Level 3x①** | 175 to 400 µ<br>> 400 µ | 5<br>0 | **Level 400**<br>**Level 400 NDP**** | <100<br>100 to 250<br>>250 to 400<br>>400 | Unlimited: No Silting<br>155<br>5<br>0 |
| **Level 2xx**<br>**Level 3xx①** | < 25 µ<br>25 to 50 µ<br>50 to 100µ<br>> 100 µ | No silting<br>68<br>5<br>0 | **Level 100**<br>**Level 100 NDP**** | <25<br>25 to 50<br>>50 to 100<br>>100 | Unlimited: No Silting<br>68<br>11<br>0 |
| **Level 3** | No particle counts | N/A | **VC –NDP**** ( the presence of visible moisture is not permitted | | |
| **Level 4** | < 10 µ<br>10 to 25 µ<br>25 to 50 µ<br>50 to 100µ<br>> 100 µ | No Silting<br>2150<br>530<br>60<br>10 | **Level 100** | <25<br>25 to 50<br>>50 to 100<br>>100 | Unlimited: No Silting<br>68<br>11<br>0 |

*** *NDP – No Dew Point Required.*

① *Levels 3x and 3xx did not exist in 0089-Fluids, Rev B. For 2A, 3x and 3xx, a gas sample for dew point and moisture is not required when the critical surface is normally open to the atmosphere (e.g., dump or vent lines) or the critical surfaces would come in contact with moisture during normal system operations (e.g., A3 Chemical Steam Generators). The presence of visible moisture is not permitted for cleanliness level VC or for any precision cleanliness level.*

*Note 1: Items in work in the FCPF at the time of release of new standard shall be processed under the old standard. Also, all items cleaned per the old standard are acceptable for use as is.*

*Note 2: Use NVR Level "E" (NVR maximum = 5.0mg/0.1 m²) for tanks > 0.5m² surface area that have an NVR requirement.*