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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

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Basic	Basic	10.25.2010	Initial Release, via RPT Program Office
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 ≤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 Hydralic. Added Appendix G, Crossover Chart for **SSC use only**.
Rev 1-1	Rev 1-1	4.30.2013	Administrative change to SSC Crossover Chart: removed "oxidizer" and "oxygen" from *Note at bottom of chart.
Rev 2	Rev 2	5.15.2013	Administrative change to SSC Cross Over chart to clarify NVR requirements. Deleted Note "* Use Level "**A**" for all Oxidizer lines, parts, components (NVR maximum = 1.0 mg/ 0.1 $m^{2)}$. Use Level "**E**" for Oxygen tanks > 0.5m^2 surface area (NVR maximum = 5.0mg/0.1 $m^{2)}$." Added "Note 2: Use Level "**E**" (NVR maximum = 5.0mg/0.1 m^2) for tanks > 0.5m^2 surface area."

NOTES:

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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.

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 QA (quality assurance) 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 Material Safety Data Sheet (MSDS) material 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 environment, 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 are in compliance 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 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 SP-5076	Contamination Control Guidelines Handbook
NASA STD 6001	Flammability, Odor, Off-gassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion

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 6368	Standard Specification for Vapor-Degreasing Grade and General Grade normal-Propyl Bromide
ASTM D 5486	Standard Specification for Pressure-Sensitive Tape for Packaging, Box Closure, and Sealing
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 E 2042	Standard Practices for Cleanliness and Maintaining Controlled Areas and Clean Rooms

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	millilters
M_S	Measured Sample NVR concentration
MSDS	Material Safety Data Sheet
MSFC	Marshall Space Flight Center
MIL	Military
NASA	National Aeronautics and Space Administration
NVR	Nonvolatile Residue
N2H4	Hydrazine
N2O4	Dinitrogen Tetroxide
PCTFE	Polychlorotrifluoroethylene
PFEP	Polyfluoroethylene-propylene
ppm	parts per million
PVC	Polyvinyl Chloride
QA	Quality Assurance
SA	Surface Area
SAE	Society of Automotive Engineers
scf	standard cubic feet
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). IM&TE is instrument measurement and test equipment that is calibrated by a calibration laboratory (e.g., pressure gages, flow meters, balances, volt meters, etc.).

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 (UV spectrum 3200-3800 angstroms).

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 in which precautions are employed to reduce contaminants in the air, producing a controlled environment for verification, assembly, and packing of cleaned items.

Commercial Clean: without gross contamination. 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.

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

Drying: reducing moisture or dewpoint 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 room 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.

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): items 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 dewpoint.

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 hydrocarbons, NVR and total hydrocarbon content are considered equivalent; therefore, analytical methods that determine total hydrocarbon (e.g., gravimetrics, Fourier Transform Infrared (FTIR), and TOC) may be used to determine 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 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 cleaning process 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: the cleaning process normally used to achieve cleanliness level VC.

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.

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."

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 1A. 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 5 to 15 >15 to 25 >25	Unlimited * 19 4 0	A	1.0	GC	Freedom from manufacturing residue, dirt, oil, grease, etc.
50	<15 15 to 25 >25 to 50 >50	Unlimited * 17 8 0	B	2.0	VC	The absence of all particulate and non-particulate matter visible to the normal unaided eye or corrected-vision eye; commercially cleaned.
100	<25 25 to 50 >50 to 100 >100	Unlimited * 68 11 0	C	3.0	UV	Visually clean and inspected with ultraviolet light; requires precision cleaning methods
150	<50 50 to 100 >100 to 150 >150	Unlimited * 47 5 0	D	4.0	● NVR & Moisture Requirements Critical surfaces with NVR requirements will meet: Level "A" NVR for all oxidizer tanks ≤0.5m^2. Level "B" for N_2O_4 tanks >0.5m^2. Level "E" for O_2 tanks >0.5m^2 ● Dewpoint & Moisture Content -54° C (-65 °F) 24 ppm for lines, parts, and components -40 °C (-40 °F) 128 ppm for tanks and vessels Dewpoint & 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 ● **NOTES** Allowable particulate and NVR are based on 0.1 m^2 (1.08 ft^2) * Silting is not permitted	
200	<50 50 to 100 >100 to 200 >200	Unlimited * 154 16 0	E	5.0		
250	<100 100 to 200 >200 to 250 >250	Unlimited * 39 3 0	F	7.0		
300	<100 100 to 250 >250 to 300 >300	Unlimited * 93 3 0	G	10.0		
400	<100 100 to 250 >250 to 400 >400	Unlimited * 155 5 0				
500	<100 100 to 250 >250 to 500 >500	Unlimited * 1073 27 0				
750	<250 250 to 500 >500 to 750 >750	Unlimited * 205 9 0				
1000	<500 500 to 750 >750 to 1000 >1000	Unlimited * 34 5 0				

Table 1B Visible Contamination Levels	
Level	**Definition**
GC	Freedom from manufacturing residue, dirt, oil, grease, etc. – Level GC is similar to level VC but differs in the following significant areas: • 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. • Inspection is not as rigorous as VC in that clumps or agglomerations of contamination are removed instead of individual particles. • Heat-sealed bagging protection is not required, but normal protection is required for handling, shipping, and storage. • The GC level should be specified for hardware that is not sensitive to contamination and is easily and quickly cleaned or re-cleaned.
VC	The absence of all particulate and non-particulate matter visible to the normal unaided eye or corrected-vision eye; commercially cleaned.
UV	Visually clean and inspected with ultraviolet light; requires precision cleaning methods.

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.
3. Some propulsion systems, such as hypergolic systems, may require cleanliness levels more stringent than those defined in Tables 1A and 1B for system performance or safety. When more stringent cleanliness levels than those shown in Table 1 are required, they shall be specified on the engineering drawing or specification in accordance with IEST-STD-CC1246, or tailored from IEST-STD-CC1246, with cleaning, inspection, and packaging in accordance with this document.
4. The cleanliness levels specified in RPT site specific cleanliness standards (e.g. MSFC 164 or SSTD-8070-0089 –FLUIDS, etc.) will remain in effect for items cleaned prior to the approval date of the RPT Surface Cleanliness Standard of Fluid Systems.
5. Cleanliness levels listed in site specific cleanliness standards shall commence for items cleaned "on or after" the approval date of this standard.

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 800A NDP is the same cleanliness level as 800A except the dew point and moisture requirement is absent (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).

Table 2. Surface Cleanliness Requirements

Fluid	Facility Item Description	Cleanliness Level ① ③④
LOX/GOX	Metallic and/or PTFE and 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 including IPA	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 or 750A or 1000A
GN_2	LH barges	1000
Hydraulic	All items	100 or 100A

NOTES:

① Depending on the site specific requirements, more stringent cleanliness levels are acceptable. An absolute filter 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 the cleanliness levels differ as shown in Table 2, 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.

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

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

f. 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 an absolute filter 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 6.4.3.

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 Piping

In 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 where the cleaning is likely to be least effective. The spool piece can be removed for cleanliness verification upon completion (see verification method IV in Table 3, Spool Piece Test Method for Pipes and Fluid Transmission Lines).

5.5 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 can 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 a concern regarding the effectiveness of the cleaning 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 the 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 the items to be cleaned, 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. The 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. The records shall indicate the 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 the 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 the final or precision-cleaning operation using an appropriate test fluid at the 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 the 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 the removal of components or instrumentation shall be visibly clean of contamination before the 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 the 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 requirements or upon approval from the 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. Nitric acid solutions are effective for removing free iron and other metallic contamination, but are not effective against scale and heavy corrosion deposits,

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 will 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 the 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 mechanical methods or other chemical methods is 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, such as aluminum and zinc. Types of alkaline cleaners 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 permissible for systems or components that are required to be cleaned in place because of size and configuration (e.g., fluid transmission lines, large pipes, tanks, vessels, etc.). For all other systems or components, the provisions of Section 6.4 must be satisfied before field cleaning is allowed.

6.8.1 Preparation Before Field Cleaning

a. Before performing cleaning, all cognizant organizations shall be advised of the 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 or 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.

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 and 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 7.7.1 or Section 7.7.2) 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

The 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 the 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 12.0a or 12.0b 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 that meet cleanliness requirements do not need to be re-verified when contamination associated with field activities is completely accessible and can be removed by handwiping or purging (e.g., removal of loose, randomly 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 materials and packaging films shall comply with the 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 the 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. 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 Halogenated Solvents

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 the appropriate Material 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® and verified to ensure solvent removal in accordance with Section 13.0 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®)

a. Perfluorobutylmethylether (HFE-7100®) may be used to perform NVR or particulate analysis as a rinsing agent to remove Vertrel MCA® from items with an NVR requirement. HFE-7100® shall **not** be used for flushing hydraulic components or systems or with MMH or N_2H_4**.**

b. Exception: HFE-7100 may be used as a cleaning or test solvent if the removal of MMH from the item or system is verified to be less than 5 ppm. An NVR correction sensitivity factor is required to correct for the efficiency of HFE 7100 to remove non-volatile (hydrocarbon-based residue) from critical surfaces. See appendix B-1 for NVR correction factor. 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 or N_2H_4, 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 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 normal-Propyl Bromide (Ensolv®)

a. normal-Propyl Bromide (n-propyl bromide) use is limited to NVR and/or particulate analysis for single items with simple geometry (e.g. open pipes and lines) and are physically isolated from the fluid system and other components.

b. It shall **not** be used for hydrazine-based (MMH, UDMH, or N_2H_4) service items or for NVR and/or particulate analysis for components, assemblies, systems, or other items (e.g., reflanged seal rings, IM&TE). The solvent must meet the NVR and particulate level of the systems being verified. Normal-propyl-bromide (Ensolv®) does **not** meet the liquid oxygen compatibility requirements of NASA-STD-6001. Verify solvent removal in accordance with Section 13. For procurement specification requirements, refer to ASTM D 6368.

c. normal-Propyl Bromide (nPB) shall not be used on titanium or parts containing titanium.

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 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 used to sample or rinse tanks and vessels that have an NVR requirement shall have no more than 3 mg NVR per 100 ml of fluid.

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

e. When the control (blank) 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 that 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

Test samples can be obtained by flushing or spraying significant surfaces with certified halogenated, alcohol solvents and hydraulic fluids that comply with the requirements in Section 7. All solvents used for NVR determination must meet the requirements in Sections 7.1 or 7.3. To calculate the NVR, the control solvent sample is subtracted from the solvent verification sample. The requesting organization is responsible for making this NVR adjustment. Subtraction of the control solvent from the test solvent is not allowed for particulate analysis.

8.3 Solvent Volume Required For Cleanliness Verification

8.3.1 Items with Surface Area Less Than 0.1m^2

a. Small components consist of a sufficient number to make up 0.1 m^2 surface area. The 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 that all parts in the lot be cleaned using the same basic process.

b. A 200-ml sample shall be collected and analyzed.

c. In cases where all critical surfaces can be sampled with 100 ml or less of test fluid, a 100-ml sample shall be taken and analyzed to represent 0.1 m^2.

d. For IM&TE and AM&TE with surface areas less than 0.01m^2, solvent volumes less than 100ml may be used. Details of the cleaning process procedure shall be left to the discretion of the performing organization.

e. The process shall not be detrimental to the items being cleaned.

f. Process requirements, (cleaning steps, verification procedures, and drying requirements) shall be approved by the procuring organization and/or the performing organizations Quality Assurance.

8.3.2 Items with Surface Area Between 0.1 and 0.5 m^2

a. Significant surfaces having an area between 0.1 m^2 and 0.5 m^2 require 200 ml of sampling fluid per 0.1 m^2.

b. All sample fluid shall be collected and a 200-ml representative aliquot shall be taken from the total fluid collected and analyzed.

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

a. Significant surfaces having an area greater than 0.5 m^2 shall be flushed with 100 ml of sampling fluid per 0.1 m^2.

b. All sample fluid must be collected and a 100 ml representative sample shall be taken from the total fluid collected and analyzed.

9. VISUAL CLEANING CERTIFICATION

9.1 Visual Cleanliness

The Visual Cleanliness category includes GC, VC, and UV (see Sections 4.2and 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. 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 10 percent of the internal significant surface area of systems or components.

b. Furthermore, flash rust is not acceptable if it prevents the system or component from meeting 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 for NVR). 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 7.5.1is 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. 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 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 – NVR and Particulate for In Service Systems	Gas Flow Through (1) with Sintered Porous Disc for NVR (2) Membrane Filter for Particle Count	Particle Count & Infrared NVR
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 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.

10.5 Method V – NVR and Particle Determination for In-Service Systems

a. A gas flow test shall be performed to evaluate a systems capability to deliver fluid that meets the specified cleanliness requirements (for in-service systems). Test method is specified in Appendix D.

b. This method shall not be used to:
   1. Certify a new system.
   2. Certify the cleanliness of components.
   3. Recertify any component or system that has been decertified.
   4. Recertify any component or system that is maintained cleaned.

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 0.1 m^2 (one square foot) with a certified clean, solvent-soaked, lint-free nylon or polyester wipe.

b. The ends of the wipe shall be double hemmed or heat sealed.

c. After wiping the area to be verified, each wipe shall be flushed with approximately 200 ml of solvent and analyzed for NVR. Surfaces > 0.4 m^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.) shall 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 in7.5.1 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 to 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

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 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 120^{o}C (248°F).

d. If non-metallics are present, the temperature of the drying gas shall not exceed 60^{o}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 45^{o}C (113°F).

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

e. If non-metallics are present, the temperature of the drying gas shall not exceed 60°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 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 43º (110º F).

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

c. The maximum target temperature for drying metallic parts shall be 120 ºC (248º 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).

14.3.2 Ambient Pressure Bakeout

Parts and components with an internal surface area of $<0.4m^2$, 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 120 ºC.

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 approval of the procurement and NASA engineering authority 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.

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, 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, that 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 (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 (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 (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 (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 are 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. Fl**a**nge 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 Section15.8.6.

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, 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 and secondary packaging film layers) where practicable.

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/Quality Designee).

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

Records and forms required by this standard shall be maintained as specified.

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.)
Chloride ion	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 trichlorotrifluroethane.

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

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

Characteristics	Requirement
Appearance	Clear colorless liquid
Purity	99.5% (min.)
Residue	2 ppm (max.)
Acidity (as HCI)	1 ppm (max.)
Moisture	100 ppm (max.)
Isomer Ratio (%) – 225ca	<2
Isomer Ratio (%) – 225cb	>98
Chloride (CL)	<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.

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

Characteristics	Requirement
Appearance	Clear colorless liquid
Purity	99.5% (min.)
Residue	2 ppm (max.)
Acidity (as HCI)	1 ppm (max.)
Moisture	100 ppm (max.)
Isomer Ratio (%) – 225ca	45 ±5
Isomer Ratio (%) – 225cb	55 ±5
Chloride (CL)	<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.

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

Characteristics	Requirement
Appearance	Clear colorless liquid
Purity	99.5% (min.)
Residue	2 ppm (max.)
Acidity (as HCI)	1 ppm (max.)
Moisture	100 ppm (max.)
Free Fluoride	<1 ppm

NOTE:

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

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.)
Residue	3 ppm (max.)
Acidity (as HCI)	1 ppm (max.)
Moisture	100 ppm (max.)

NOTE:

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

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
Nonvolatile Residue [5]	2 ppm (max)

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.

Appendix B TEST METHODS

B.1 Gravimetric NVR Analysis Method

The gravimetric NVR analysis method shall be performed as follows:

a. Filter the 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.

b. Evaporate a portion of the solvent sample to a 10–20 ml volume using a steam bath or rotary evaporator 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.

c. 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).

d. Continue evaporation by placing the weighing dish inside a constant-temperature oven at a maximum temperature of 110 °C. Allow the weighing dish to remain inside the oven until the fluid has just evaporated to dryness.

e. 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.

f. Record the weight as mg/200 mL for most analyses

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

h. 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)

i. 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.

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

k. Users may opt to analyze 100ml of the 200 ml sample to determine the gravimetric NVR. Consequently, adjust the NVR test results by applying a 2X correction factor when reporting NVR per 200ml. Also, 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 the 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

e. 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 the TCA to syringe mode and set the optimum parameters with the furnace temperature at 880 °C. Adjust the 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 the sampling procedure without parts to verify the cleanliness of the pans. The 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 the surface area of 0.1 to 0.2 m^2 in a clean parts sampling pan.

b. Measure the 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 the level of water 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 20 mm quartz cell, perform a 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 calibration standards in (d, e and f below).

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

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

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

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 20 mm 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., 50 ml of a 200 ml sample with an NVR of 1 mg/200 ml = 0.25 mgs. of NVR ml 0.25 mgs. reconstituted with 7 ml of tetrachloroethylene is 0.036 mg/ml. Therefore, an equivalent NVR (hydrocarbon) standard of 0.036 mg/ml would represent 1 mg/200 ml 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 spectra from Sections D, E and F 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 cannot have a y intercept of zero, and it 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.2.3) and the background scan (a), analyze check standards daily or before sample analysis. The check standards shall represent

1mg/200 ml 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 or rotary evaporator or a thermostatically controlled hot plate. Remove the beaker before dryness and place in an oven at a maximum temperature 110 °C 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 7 mls of tetrachloroethylene to the residue.

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

g. Record a sample infrared absorption spectrum between 3200 to 2600 cm^{-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.2.3). 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.

$$NVR = (M_S)\ (Vs)$$

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 through h.) and subtract the 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(i). If applicable, adjust the NVR value based on the sample volume analyzed, and the concentration units reported (mgs per 200 ml sample or mgs per 100 ml 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 the 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 the filter funnel approximately three-fourths full of test fluid and turn on the 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 0(a) and 0(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 a magnification of approximately 40 to 50 power for counting particles for conformance to level 150 and greater and approximately 100 power for level 100 and less.

k. Count the 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 GN2 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. 200 ml per 0.1 m^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

a. 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 is intended to evaluate a field system which is suspected to have been contaminated in use or during operational testing. This method should not be used to certify a new system cleaned in the field.

b. 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/min (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.

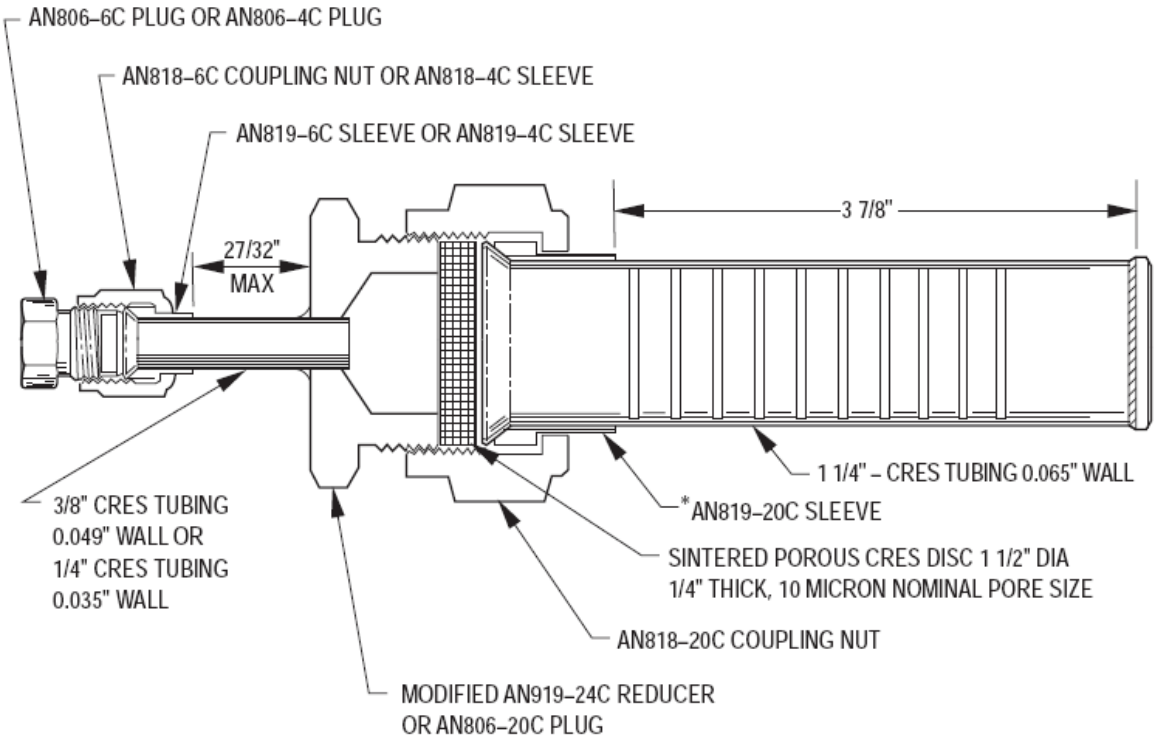

Figure D–1. Gas Sampler for NVR Residue.

Table D–1. Sampling Time.

Nitrogen [1]	
Pressure Drop (psi) [2]	Sampling time
200–499	12 min
> 500	5 min
Helium [3]	
Pressure Drop (psi) [2]	Sampling time
200–299	10 min
> 500	4 min

NOTE:

[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 Section15. Pass the sampling gas through the 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 the NVR using the gravimetric or infrared procedure described in Appendix B.

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

g. Two consecutive samples taken 8 to 48 hrs 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 0.3 mgs.

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. The 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 the area sampled and the solvent used during sampling

g. The wipe shall be extracted using 200ml of halogenated solvent per Section7.3. 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 the NVR using the gravimetric or infrared procedure described in Appendix B.

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

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

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

Rev 1

Old SSC SSTD-8070-0089-FLUDS 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	5	Level 1000A	<500	Unlimited: No Silting
	700 to 2500µ	1		500 to 750	34
	> 2500 µ	0		>750 to 1000	5
				>1000	0
Level 1x	175 to 800 µ	5	Level 750A	<250	Unlimited: No Silting
	> 800 µ	0		250 to 500	205
				>500 to 750	9
				>750	0
Level 1xx	175 to 400 µ	5	Level 400A	<100	Unlimited: No Silting
	> 400 µ	0		100 to 250	155
				>250 to 400	5
				>400	0
Level 1xxx	> 100	0	Level 100A	<25	Unlimited: No Silting
	>50 to < 100	1		25 to 50	68
	Other range sizes			>50 to 100	11
				>100	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	175 to 400 µ	5	Level 400	<100	Unlimited: No Silting
	> 400 µ	0		100 to 250	155
Level 3x①			Level 400 NDP**	>250 to 400	5
				>400	0
Level 2xx	< 25 µ	No silting	Level 100	<25	Unlimited: No Silting
	25 to 50 µ	68		25 to 50	68
	50 to 100µ	5		>50 to 100	11
Level 3xx①	> 100 µ	0	Level 100 NDP**	>100	0
Level 3	No particle counts	N/A	VC –NDP** (the presence of visible moisture is not permitted		
	< 10 µ	No Silting			
	10 to 25 µ	2150			
	25 to 50 µ	530			
Level 4	50 to 100µ	60	Level 100	<25	Unlimited: No Silting
	> 100 µ	10		25 to 50	68
				>50 to 100	11
				>100	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 surface 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.