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KSC-C-123J
JULY 17, 2009

Supersedes
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September 25, 1995
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SURFACE CLEANLINESS OF GROUND SUPPORT EQUIPMENT FLUID SYSTEMS, SPECIFICATION FOR

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SURFACE CLEANLINESS OF GROUND SUPPORT EQUIPMENT FLUID SYSTEMS, SPECIFICATION FOR

Approved by:

Patrick A. Simpkins, D.B.A.
Director, Engineering Directorate

This Revision Supersedes All Previous Editions of This Document

JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

A	surface area
ACS	American Chemical Society
AMS	Aerospace Material Specifications
ARP	Aerospace Recommended Practice
ASTM	American Society for Testing and Materials
C	carbon
CC	Cleaning Contractor
cd	candela
CFR	Code of Federal Regulations
CO	Contracting Officer
DOD	Department of Defense
DOT	Department of Transportation
EPA	Environmental Protection Agency
FED	federal
FEP	fluoroethylenepropylene
ft^2	square foot
ft/s	foot per second
GC	generally clean
GP	General Publication
GSE	ground support equipment
HEPA	high-efficiency particulate air
IEST	Institute of Envionmental Sciences and Technology
in	inch
IR	infrared
ISO	International Organization for Standardization
JSC	Lyndon B. Johnson Space Center
kPa	kilopascal
KSC	John F. Kennedy Space Center
KTI	Kennedy Technical Instruction

L	liter
m	meter
m^2	square meter
mg	milligram
mg/L	milligram per liter
MIL	military
mL	milliliter
mm	millimeter
MPa	megapascal
M&PE	Materials and Processes Engineer
m/s	meter per second
MSDS	Material Safety Data Sheet
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NE	Enngineering Directorate
NHB	NASA handbook
NIST	National Institute of Standards and Technology
NVR	nonvolatile residue
no.	number
NVR	nonvolatile residue
ODS	ozone-depleting substance
PCTFE	polychlorotrifluoroethylene
ppm	part per million
PRF	performance
psi	pound per square inch
psig	pound per square inch gage
PTFE	polytetrafluoroethylene
s	second
S	contaminant solution concentration
SAE	Society of Automotive Engineers
SF	sensitivity factor

SF_A	sensitivity factor at a known area A
SPEC	specification
STD	standard
TC	total carbon value
TCA	total carbon analyzer, trichloroethane
TC_B	total carbon value of blank
TC_S	total carbon value of sample
TOC	total organic carbon
TOC_B	total organic carbon value of blank
TOC_S	total organic carbon value of sample
TF	trichlorotrifloroethane
U/S	ultrasonic
UV	ultraviolet, visually clean plus ultraviolet
V	volume
VC	visibly clean
V_W	volume of water
µg/L	microgram per liter
µm	micrometer
U/S	ultrasonic
UV	visibly clean plus ultraviolet
>	greater than
<	less than
°C	degree Celsius
°F	degree Fahrenheit

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SURFACE CLEANLINESS OF GROUND SUPPORT EQUIPMENT FLUID SYSTEMS, SPECIFICATION FOR

1. SCOPE

This specification establishes surface cleanliness levels, processing, handling, cleaning, test methods, packaging, protection, and inspection procedures for determining surface cleanliness for critical surfaces of ground support equipment (GSE) at the John F. Kennedy Space Center (KSC), including parts, components, assemblies, subsystems, and systems or other related equipment in contact with any fluid medium.

NOTE

The industrial gas transmission and distribution pipeline at KSC is not considered GSE and, due to the inherent length, is beyond the intended scope of this document.

1.1 Applicability

This specification applies to GSE at KSC, including GSE that interfaces with flight hardware associated with launch vehicles and spacecraft. In cases where program, project, or customer-specified requirements impose additional cleanliness or process requirements, process changes and supplemental procedures may be implemented. Additional or modified cleanliness/contamination control requirements shall be authorized through the appropriate work requests or associated engineering documents. In cases of conflict between program or project requirements and the requirements of this document, program or project requirements take precedence.

1.2 Requirements

1.2.1 General

All parts, components, assemblies, subsystems, systems, or related equipment requiring cleaning shall be cleaned to the specified cleanliness level and inspected in accordance with this specification.

1.2.2 Request for Cleaning

Work requests for cleaning in accordance with the requirements of this specification shall specify the following:

a. Title, number, and date of this specification

b. Cleanliness level and testing procedure required

c. Whether preproduction approval is required (see 3.6.3)

d. Whether functional testing is required on items disassembled for cleaning (see 4.2.5)

e. Whether special preservation, packaging, packing, and marking are required beyond the requirements of section 3.

1.2.3 Quality Assurance

Quality assurance provisions for inspection and testing for the acceptance of parts, components, assemblies, subsystems, systems, and other related equipment that have been cleaned to a specific level of cleanliness shall be as specified in section 4.

1.2.4 Environmental, Health, and Safety

This specification allows the use of materials, processes, and equipment that may be hazardous, toxic, and/or detrimental to the environment. This specification does not purport to address all of the environmental, health, or safety problems associated with the use of these materials, processes, and equipment. It is the responsibility of the user of this specification to review pertinent Material Safety Data Sheets (MSDS), material specifications and work instructions to ensure safety of personnel and protection of the environment and facilities in fulfilling the requirements of this specification. All materials and processes required to fulfill the requirements of this specification are subject to applicable Federal, State, and local environment; health and safety regulations; standards; codes; and operating procedures (e.g., work instructions). It is the responsibility of the performing organization to determine and establish the appropriate environmental, health, and safety practices that are in compliance with all applicable regulations. Questions regarding these activities, including air emissions, spills, solid and hazardous waste inventory, storage, removal, disposal, discharges, and waste minimization (e.g., recycling), shall be referred to the cognizant personnel within the performing organization.

1.2.5 Hazardous Materials

It is the user's responsibility to store all hazardous materials and inform the local emergency planning organization as to the quantity on hand and the storage location. Records shall be maintained by each user as to the weight of hazardous material used and what happened to the material [consumed in the product, released to the environment (spilled, air emission, land discharge, water discharge, underground injection) used for energy onsite, used for energy offsite, recycled offsite, recycled onsite, treated offsite, treated onsite].

1.2.6 Waste Minimization (Recycling)

It is the user's responsibility to implement waste reduction practices. Materials, especially test fluids, shall be recycled where applicable. Test fluids shall be considered as in-process recyclable materials as long as the nonvolatile residue (NVR) level does not exceed 200 milligrams per

liter (mg/L). Test fluids with NVR levels in excess of 200 mg/L and recycling still-bottom residues shall be made available for other reuse/recycling activities or disposed of in accordance with applicable Federal, State, and local regulations.

1.2.7 Training

Cleaning or disassembly operations on precision components shall be performed only by competent personnel who have been trained and certified to perform these functions. The performing organization or contractor shall ensure that all personnel responsible for contamination control functions are trained as required to ensure proficiency within their assigned task. The processing organization or contractor shall establish personnel certification with traceable documentation.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement, with the exception of any conflict with Federal law.

2.1 Governmental

2.1.1 Specifications

Code of Federal Regulations (CFR)

29 CFR 1910	Occupational Safety and Health Standards
40 CFR	Protection of Environment
49 CFR 171-180	Pipeline and Hazardous Materials Safety Administration, Department of Transportation

(Application for copies of the Code of Federal Regulations should be addressed to the Superintendent of Documents, Government Printing Office, North Capitol and H Streets N.W., Washington, DC 20401.)

Federal

A-A-1689	Tape, Pressure-Sensitive Adhesive, Plastic Film
A-A-3174	Plastic Sheet Polyolefin
A-A-51693	Alcohol, Dehydrated, USP

A-A-59503	Nitrogen, Technical

John F. Kennedy Space Center (KSC), NASA

80K57369	Panel Assembly, High Intensity Water Impingement Cleaning
GP-1098	KSC Ground Operations Safety Plan
KTI-5212	Material Selection List for Plastic Films, Foams, and Adhesive Tapes

Lyndon B. Johnson Space Center (JSC), NASA

JSC-SPEC-C-20	Water, High Purity, Specification for
SE-S-0073	Space Shuttle Specification: Fluid Procurement and Use Control
CxP 70156	Constellation Program Fluid Procurement and Use Control Specification

(Copies of specification, standards, drawings, and publications required by suppliers in connection with a specified procurement functions should be obtained from the procuring activity or as directed by the cognizant Contracting Officer (CO).)

Military (Department of Defense [DOD])

MIL-C-81302	Cleaning, Compound, Solvent, Trichlorotrifluoroethane
MIL-E-17555	Electronic and Electrical Equipment, Accessories, and Provisioning Items, (Repair Parts): Packaging of
MIL-PRF-27401	Performance Specification Propellant Pressurizing Agent, Nitrogen
MIL-PRF-27407	Propellant, Pressurizing Agent, Helium
MIL-STD-129	Military Standard, Marking for Shipment and Storage
MIL-STD-889	Military Standard, Dissimilar Metals

MIL-STD-2073/1	Department of Defense, Standard Practice for Military Packaging
MIL-T-81533	1, 1, 1 Trichloroethane (Methyl Chloroform) Inhibited, Vapor Degreasing

National Aeronautics and Space Administration (NASA)

NASA-STD-6001	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion

2.1.2 Non-Governmental

American Chemical Society (ACS)

Reagent Chemicals, American Chemical Society Specifications

(Application for copies should be addressed to the American Chemical Society, 1155 16th Street, N.W., Washington, DC 20036.)

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 A 967	Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts
ASTM D 1193	Standard Specification for Reagent Water
ASTM D 4080	Standard Specification for Trichloroethylene, Technical and Vapor-Degreasing Grade
ASTM D 4081	Standard Specification for Drycleaning-Grade Perchloroethylene
ASTM D 4376	Standard Specification for Vapor-Degreasing Grade Perchloroethylene
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 Residue of Solvent Extract From Aerospace Components (Using Flash Evaporator)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

Institute of Environmental Sciences and Technology

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

(Application for copies should be addressed to IEST, Arlington Place One, 2340 South Arlington Heights Road, Suite 100, Arlington Heights, IL 60005-4516.)

International Organization for Standardization (ISO)

ISO 14644-1	Cleanrooms and Associated Controlled 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
ISO 14952-2	Space Systems – Surface Cleanliness of Fluid Systems Part 2: Cleanliness Levels
ISO 9001	Quality Management Systems – Requirements

Society of Automotive Engineers (SAE) Aerospace Materials Specification (AMS)

SAE-AMS-2700	Passivation of Corrosion Resistant Steels
SAE-AMS 3647	Polyfluoroethylene Propylene Film and Sheet
SAE-AMS 3649	Film, Polychlorotrifluoroethylene (PCTFE) Unplasticized

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

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

SAE-ARP-599	Aerospace – Dynamic Test Method for Determining the Relative Degree of Cleanliness of the Downstream Side of Filter Elements

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

3. REQUIREMENTS

3.1 Classification of Cleanliness Levels

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

3.2 Non Precision Cleanliness Levels

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

VC (visibly clean) is the absence of all particulate and nonparticulate matter visible to the normal unaided (except corrected vision) eye. Particulate is identified as matter of size with observable length, width, and/or thickness. Nonparticulate matter is normally a film or residue without definite dimension. Scale free discoloration due to surface treatments (i.e., passivation, anodizing, etching) or thermal processes (i.e., welding, heat treatments) is permitted. Level VC is commonly referred to as commercially clean.

3.3 Precision Cleanliness Levels

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

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

Table 1. Fluid Surface Cleanliness Levels

(Table 1A) Particulate Matter Contamination Levels			(Table 1B) NVR Contamination Levels		(Table 1C) Visible Contamination Levels	
Level	**Particle Size Range μm (micrometer)**	**Maximum Number of Particles per 0.1 m²**	**Level**	**Maximum NVR (mg/0.1 m²)**	**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 nonparticulate 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		**Notes** Allowable particulate and NVR are based on 0.1 m² (1 ft²) Dewpoint and moisture can be waived if the critical surface is normally opened to the atmosphere (Test Method III, A.3.3) * 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		
500	<100 100 to 250 >250 to 500 >500	Unlimited * 1073 27 0	H	15.0		
750	<250 250 to 500 >500 to 750 >750	Unlimited * 205 9 0	J	25.0		
1000	<500 500 to 750 >750 to 1000 >1000	Unlimited * 34 5 0				

3.4 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 200 refers to size and count limits on particulate contamination only.

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

c. Level 200B refers to size and count limits on particulate contamination and NVR limits.

d. Level 200A is a more stringent cleaning level than level 300B for both particulate matter and NVR.

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

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

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

3.5 Test Methods

The cleanliness level test methods are summarized in Table 2. Determination of a component or system's cleanliness level shall be made by using Test Method I or II. Procedures for test methods I, II, III, and IV are provided in Appendix A, A.3.1through A.3.4.

3.6 Cleaning

3.6.1 General

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

Table 2. Cleanliness Level Test Methods

Test Method	Sampling Technique	Analysis Method
Method I (A.3.1) - Liquid Flush Test for Particle Population and Representative NVR Remaining on Critical Surfaces of Items Cleaned in a Controlled Environment	Flush with or immerse in test fluid	Filtration, manual particle count, NVR analysis
Method II (A.3.2) – Liquid Flow Test for Particle Population and Representative NVR Remaining on Critical Surfaces of Items Cleaned in the Field	Flow-through with test fluid	Filtration, manual particle count, NVR analysis
Method III (A.3.3) – Gas Flow Test for Moisture Remaining on Critical Surfaces After Cleaning	Purge with test gas	Dewpoint analysis
Method IV (A.3.4) – Liquid or Gas Flow Test for Specified Service Requirements	Discharge service fluid under normal operating conditions	Filtration, manual particle count, NVR analysis, dewpoint analysis

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

3.6.2 Decontamination

All systems, subsystems, components, and equipment that have been exposed to toxic propellants or hazardous materials shall be decontaminated to the required level of safe handling prior to initial cleaning operations. Under no circumstances shall propellant-contaminated systems, subsystems, or components be cleaned or transported directly to a cleaning facility prior to decontamination. Decontamination shall be accomplished by the use of established and proven methods for the removal and neutralization of propellant residues in place or removed to an area specifically designated for decontamination operations. Decontaminated items shall be clearly and legibly marked to indicate that they have been decontaminated. No items shall be accepted for cleaning without proof of decontamination.

3.6.3 Preproduction Cleaning and Preservation Process Approval

Unless otherwise specified in the contract or order, the performing activity or contractor's facility may be inspected by the cognizant quality surveillance organization prior to performing any cleaning under this specification. The Contracting Officer (CO) is authorized to stop the Clean-

ing Contractor (CC) from performing any cleaning under this specification if noncompliance with the requirements of this specification and approved procedures are observed or suspected. The cleaning facility may be reinspected on an annual basis at the discretion of the CO. The following items shall be inspected and reviewed:

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

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

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

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

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

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

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

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

3.6.4 Component Cleaning and Functional Testing

Components shall be assembled using cleaned parts that have been inspected and functionally tested in accordance with 4.2. Conformance to the applicable cleanliness level, other than levels GC, VC, and UV, shall be determined by the test fluid-flush procedure (Test Method I, A.3.1) for individual parts. A component assembled from clean parts in cleanroom facilities shall be certified to the cleanliness level of the component parts. Acceptance inspection by analysis of test fluid flow-through flush (Test Method II, A.3.2) of assembled components is prohibited except in the following cases.

3.6.4.1 Hydraulic Components

Hydraulic components may be sampled by Test Method II (A.3.2) for particulate population analysis utilizing hydraulic fluid, provided the component has been assembled using clean parts that have been inspected in accordance with 4.2.1 and 4.2.2. When specified, functional testing in accordance with 4.2.5 shall be performed following cleaning and inspection. Hydraulic fluid used for particulate population analysis and functional testing shall be as specified by the procuring activity.

3.6.4.2 Components Designed for Flow-Through Testing

Components specifically designed so neither lubricated surfaces nor soft goods that can be degraded by test fluids are exposed to fluid-flow paths through the components may be sampled by Test Method II (A.3.2). Flow-through components shall be evaluated for areas of entrapment and for actuation of moving parts, e.g., poppets, during cleaning. Consideration should also be given to proper drying methods for assembled items (see A.1.6).

3.6.5 Cleanroom and Workstation Requirements

Cleanroom facilities and work stations used for precision cleaning, cleanliness verification, assembly, and packaging of cleaned items shall meet the requirements of ISO 14644-1 and 14644-2. The cleanroom level shall be consistent with the cleanliness level requirements of the cleaned item.

3.6.6 Rough Cleaning

All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall undergo rough cleaning prior to precision cleaning. Rough cleaning is used to achieve level VC clean articles. Rough cleaning removes contaminants such as weld scale, heat treat scale, corrosion, oxide films, oils, grease, shop soil, fuel, and carbon deposits. The cleanliness level achieved by rough cleaning does not normally require verification beyond visual inspection. (Wipe test, water break test, ultraviolet inspection, special lights, and mirrors are considered aids to visual inspection.) Rough cleaning is considered a normal shop process and usually does not require special environmental controls, packaging, handling, or storage beyond accepted good practice.

Appendix B provides nonmandatory supplemental guidance information relating to establishing rough cleaning procedures.

3.6.7 Precision Cleaning

This method is used to achieve a level of product cleanliness greater than the level detected by visual means and requiring cleanliness verification by particle analysis and nonvolatile residue analysis as specified. Articles should be cleaned to level VC prior to precision cleaning. Precision cleaning is performed in a controlled environment and is intended to remove particles, films, biological forms, and other forms of contaminants that are usually not visible but which could

degrade the product or process. The level of precision cleanliness shall be verified and evidence of inspection and acceptance shall be provided. Precision-cleaned articles shall be packaged immediately after verification of cleanliness or suitably protected prior to leaving the controlled environment. Precision-cleaning solutions or material shall not react with, combine with, etch, or otherwise cause immediate or latent degradation of the item being cleaned. Precision-cleaning fluids shall be filtered and controlled. Their cleanliness level shall be verified as being sufficient to achieve the specified product cleanliness as specified by section 4.

3.6.8 Field Cleaning

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

NOTE

The industrial gas transmission and distribution pipeline at KSC is not considered GSE and, due to the inherent length, is beyond the intended scope of this document.

3.6.8.1 Preparation Prior to Field Cleaning

3.6.8.1.1 Approvals

Prior to the beginning of the cleaning processes, all cognizant activities or onsite agencies having jurisdiction shall be advised of the scheduled procedures, and the necessary appropriate approvals and permits shall be obtained.

3.6.8.1.2 Decontamination

Decontamination shall be performed in accordance with 3.6.2.

3.6.8.1.3 Component Removal

All subsystems, systems, or other related field equipment components that would entrap fluids or be harmed if subjected to the cleaning process shall be removed prior to cleaning. These components shall be cleaned and tested in accordance with 3.6.4. All removed components shall be replaced by temporary hardware. Decontamination of the subsystem, system, or other related field equipment may be accomplished, as applicable, prior to removal.

3.6.8.1.4 Installation and Marking of Temporary Hardware

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

is to be cleaned. Temporary hardware and all surfaces near openings resulting from the removal of components shall be visibly clean of contamination, such as dirt, scale, and grease, prior to the installation of temporary hardware. All temporary hardware installed in, on, or attached to an item to be cleaned shall be legibly marked or otherwise identified as temporary hardware to ensure its removal from the item prior to final acceptance by the CO.

3.6.8.1.5 Validation of System Integrity

Unless otherwise specified, the integrity of the subsystem, system, or other related field equipment shall be validated by a pressure test using water, pneumatics (nitrogen, compressed air, etc.), or a solvent after the installation of all temporary hardware and prior to the beginning of the cleaning process if corrosive or hazardous fluids are to follow. The system integrity test pressure shall be at least 110 percent of the maximum (anticipated) cleaning process working pressure, and it shall be held for a minimum of 5 minutes. Under no circumstances shall the working pressure of the original subsystem, system, or other related field equipment be exceeded without prior written approval of the CO.

3.6.8.1.6 Rough Cleaning

Rough cleaning shall be performed in accordance with 3.6.6.

3.6.8.2 Mechanical Cleaning

Mechanical cleaning shall be used only when contaminants so generated can be removed and when physical damage to the item being cleaned shall not occur. Appendix B provides nonmandatory supplemental guidance information relating to mechanical cleaning methods.

3.6.8.3 Cleaning by Closed Loop Circulation of Solution and Closed Loop Cleaning Equipment

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

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

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

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

c. Circulating pumps, valves, and other components of sufficient size and capacity to minimize pressure losses in the cleaning system and capable of maintaining the

required flow rates. Cleaning fluids shall be flowed at a minimum of 1.25 meters per second (m/s) to ensure satisfactory cleaning of the subsystems, systems, or other related equipment.

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

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

3.6.8.4 Cleaning by Solution Spraying

Items, such as storage vessels or large-diameter pipes, having a size or configuration that cannot be cleaned by circulating a fluid through the item, shall be cleaned by the use of spray equipment, such as rotating or transversing spray wands and rotating-head spray machines. Spray equipment shall be capable of delivering process solutions to provide a spray pattern that forcibly impinges process solutions onto and completely wets the entire interior surface of the item being cleaned.

3.7 TEST FLUIDS

3.7.1 General

The test fluid shall meet the following requirements:

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

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

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

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

3.7.2 Compatibility

Test fluids must be compatible with the item being verified or rinsed and shall not cause immediate or latent degradation (e.g., leaching of plasticizers, swelling of softgoods or hardware corrosion). The performing organization or contractor must also ensure that verification and rinsing

processes employing dissimilar fluids do not degrade hardware. Compatibility of nonmetallic materials with the applicable test fluid shall be determined prior to testing. Permission to remove nonmetallic materials prior to testing shall be granted at the discretion of the CO. Halogenated solvents shall not be used on titanium alloys. Trichlorotrifloroethane (TF) (Freon) shall be limited in use to controlled processes that have been approved by the CO.

3.7.3 Solvents

The solvents approved for use as test fluids are presented in Table 3, with the maximum allowable NVR levels shown for specific test fluid applications. In some cases the maximum allowable NVR level of the test fluid is less than the procurement specification value; therefore, it may be necessary to distill the solvent to obtain the required quality (NVR level) of solvent.

3.7.4 Aqueous-Based Fluids

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

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

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

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

3.7.5 Hydraulic Fluid

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

3.8 DRYING AND TESTING GAS

Nitrogen gas for drying and testing of precision-cleaned items shall conform to MIL-PRF-27401, type I, grade A, or A-A-59503, type I, class 1, grade B, and shall be prefiltered as close to the end case as practical to the applicable cleanliness level. Helium gas conforming to MIL-PRF-27407 is also acceptable for drying and testing.

Table 3 Solvents, Maximum Allowable Nonvolatile Residue

Solvent/Specification and Grade Type	Maximum Allowable NVR	
	Procurement Specification (mg/L)	Test Fluid (mg/L)
Trichlorotrifluoroethane (CFC 113) ODS		
MIL-C-81302, Type I	1.57	10
MIL-C-81302, Type II	3.14	10
Perchloroethylene		
ASTM D 4081	40.6	10
ASTM D 4376	162.4	10
ACS Spectrometric Grade	8.1	10
Isopropyl alcohol (3)		
SE-S-0073	50	20
ACS Reagent Grade	3.9	10
Ethyl alcohol (3)		
A-A-51693	0.1	10
	0.3	10
1,1,1, Trichloroethane (TCA) ODS (1)		
MIL-T-81533,	13.3	10
ACS, anhydrous	4.0	10
Vertrel MCA (1) (2) SE-S-0073	10	10
Vertrel XF SE-S-0073	10	10
HCFC-225 ca/cb (1) SE-S-0073	10	10
HCFC-225G ca/cb (1) SE-S-0073	10	10
Methoxy-nonafluorobutane HFE 7100 SE-S-0073	10	10

Notes

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

3.9 PROTECTION OF CLEANED SURFACES

3.9.1 Environmental Control

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

3.9.2 Protection Materials

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

3.9.2.1 Packaging Films

All plastic films used for precision packaging shall comply with the requirements of Table 4. Acceptance inspection for conformance to the requirements of Table 4 shall be in accordance with 4.2.6. Cleanliness level of inner wrap shall at least be equal to exposed cleaned surfaces of the item. Unless otherwise specified, cleanliness of outer wrap shall be visibly clean in accordance with 4.2.6.3.

Selection of a specific film shall be dictated by compatibility with the specified service medium. All parts that come in contact with liquid and gaseous oxygen in service shall be protected with an inner bag or layers of a fluorohalocarbon film, such as Aclar 22A film conforming to SAE-AMS-3649 or polyfluoroethylenepropylene film conforming to SAE-AMS 3647. Other parts, components, subsystems, and systems shall be protected with an inner bag or layers of a polyamide film or a fluorohalocarbon film. Polyamide films have a higher resistance to sloughing particles, while fluorohalocarbon 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 from KTI-5212 for use as an overwrap material. 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. All film procured clean shall be overwrapped with a second bag of clean, 152 μm (6 mils), antistatic polyethylene prior to packaging for shipment. Roll stock shall be wound on clean cores made from nondusted plastic or metal.

3.9.2.2 Packaging Tape

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

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, 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 packaging, not for liquid and gaseous oxygen and hypergol service
Aclar 22A per SAE-AMS-3649	38 to 76 (1.5 to 3.0 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service
Teflon FEP or equivalent polyfluoroethylenepropylene in accordance with SAE-AMS 3647	13 to 508 (0.5 to 20 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service

3.9.2.3 Metallic Closures

When metallic closure plates are specified to seal flanged items, the materials shall be precut and drilled aluminum alloy or stainless steel of 3.18 millimeters (mm) [0.125 inch (in)] minimum thickness. To prevent electrolytic corrosion, metals dissimilar to item flanges shall not come in contact with the flange. Refer to MIL-STD-889 for definition of dissimilar metals.

All metallic closures shall be separated from the flanged item with gaskets. Gaskets shall be precut from a minimum of two layers of plastic film conforming to 3.9.2.1 or from a sheet of polytetrafluoroethylene of 1.57 mm (0.062 in) minimum thickness. The cleanliness level of metallic closures and gaskets shall be at least equal to the level of cleanliness of the cleaned item being protected.

3.9.2.4 Plastic Closures

When specified, sheet or plate plastic closures may be used to seal flanged items. Plastic closures, such as caps and plugs, shall not be used to seal openings of items with precision-cleaned internal surfaces. The insertion and removal of plastic closures generate particles that can invalidate the level of cleanliness of the precision-cleaned surfaces.

3.9.2.5 Protective Shields

Flanged items sealed with plastic film in accordance with 3.9.2.1 may be covered with cardboard or wooden shields to maintain the cleanliness integrity of sealed components.

3.9.2.6 Preservatives

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

3.9.2.7 Desiccants

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

3.9.2.8 Tamperproof Decal

When specified, a tamperproof decal shall be applied in such a manner that the decal is destroyed when the package or closure is opened.

3.9.3 Packaging of Cleaned Items

3.9.3.1 Cutting

When clean plastic film is to be cut, stainless steel chrome-plated or nickel-plated scissors shall be used. The scissors cut shall be started, and the scissors shall be pushed carefully through the film. Sawing and hacking actions resulting from opening and closing the scissors shall be avoided to prevent the generation of particles. Razor blades or other single-blade-type instruments shall not be used to cut plastic film.

3.9.3.2 Purging

Prior to final sealing of the plastic film bag containing the clean component, the plastic film bag should be purged with filtered gaseous nitrogen in accordance with MIL-PRF-27401, type I, grade A, or A-A-59503, type I, class I, grade B when required.

3.9.3.3 Sealing

An all-purpose impulse sealer shall be used to produce effective seals with plastic films. If specific sealing procedures are not available, the recommendations of the manufacturer shall be followed for temperature setting and dwell time. Fluorohalocarbon films such as Aclar 22A shall be sealed on all sides when fabricating bags. Fluorohalocarbon films shall not be center folded. Center folding may generate particles since fluorohalocarbon films tend to be brittle.

3.9.3.4 Detailed Requirements

3.9.3.4.1 Small Items

Small items that have all surfaces precision cleaned shall be packaged in accordance with 3.9.2.1, sealed in accordance with 3.9.3.2, cushioned as applicable, bagged, and sealed. 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. Each inner bag shall be placed in an outer bag of polyethylene with a tag in accordance with 3.9.4. The outer bag shall be sealed in accordance with 3.9.3.3.

3.9.3.4.2 Items Internally Cleaned Only

Items cleaned internally only shall have all fittings and orifices leading to the internally cleaned surfaces sealed with plastic film in accordance with 3.9.2.1. The plastic film shall be secured in place with tape conforming to A-A-1689. The adhesive backing on the tape shall not come in contact with the body of the item whenever possible. Tamperproof decals shall be applied to the sealed fittings or other orifices in accordance with 3.9.2.7. The sealed fittings or other orifices may be cushioned with protective film as applicable. Small items that have been cleaned and sealed shall be placed in an outer bag of polyethylene and sealed in accordance with 3.9.3.3. Each sealed fitting or other orifice of large items shall be overwrapped with polyethylene. Identification shall be in accordance with 3.9.4.

3.9.3.4.3 Flanged Items

Flanged items that have only internally cleaned surfaces shall be sealed with gaskets and closures conforming to 3.9.2.2 or 3.9.2.3. A cleaned gasket shall be placed over the flange face followed by placing the closure over the gasket. Attachment hardware shall be inserted through all the flange holes and shall be tightened to the recommended torque value for the type and size of the attachment bolt used. The completed closure shall be overwrapped with polyethylene and secured with tape conforming to A-A-1689. Whenever possible, the adhesive backing of the tape shall not come in contact with the body of the item. Tamperproof decals shall be applied to the sealed overwrapping in accordance with 3.9.2.7. Marking shall be in accordance with 3.9.4.

3.9.3.4.4 Electrical and Electronic Items

Electrical and electronic items that require testing after cleaning shall be packaged in an inner bag sealed in a manner that shall permit access to test points, such as leads and connectors, without violating the integrity of the inner bag. Exposed items, such as leads and connectors, shall be cushioned as required. Each inner bag shall be placed in an outer bag of polyethylene, sealed, and marked in accordance with 3.9.4. Tamperproof decals shall be applied to the outer bag in accordance with 3.9.2.7.

3.9.3.4.5 Hose and Tube Assemblies

Hose and tube assemblies that have only internally cleaned surfaces shall be sealed with plastic film in accordance with 3.9.2.1. The plastic film shall be secured in place with tape conforming to A-A-1689. If practical, the adhesive backing on the tape shall not come in contact with the body of the item. The entire hose or tube assembly may be overwrapped with polyethylene film as applicable.

3.9.4 Identification of Cleaned Items

Appropriate certification tags shall be placed between the inner and outer bags or layers of protective packaging film where practical. Where the tag cannot be placed between the inner and outer packaging film, the tag shall be enclosed in a plastic bag or between layers of plastic film

and securely taped to the outside of the package. Tags shall be serviceable and of sufficient size to contain the following information:

a. Part or identification number

b. Contractor identification

c. Cleanliness level and number and revision of this specification

d. Date of cleaning

e. Manufacturer's serial number

f. Acceptance stamps

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The cognizant cleaning organization shall be responsible for the performance of all inspection and testing requirements specified herein. Unless otherwise specified in the contract or order, the supplier may use his own or any other inspection and testing facilities and services that are acceptable to the CO. Inspection and test records shall be kept complete and, upon request, made available to the CO in accordance with the provisions of the contract or order. The CO reserves the right to perform any or all of the inspections and tests set forth in this specification to ensure that the end item conforms to all specified requirements.

4.2 Acceptance Inspection

Unless otherwise specified by the CO, acceptance inspection shall be performed as specified herein.

4.2.1 Visual Inspection

Visual inspection shall be performed to verify visible cleanliness levels (GC, VC, and UV). The surfaces of all items that will contact the service medium shall be visually inspected for the presence of moisture, corrosion, scale, dirt, grease, and other foreign matter. An external light source or borescope may be required to examine internal surfaces. Items having limited accessibility for visual inspection shall be accepted or rejected on the basis of the quality assurance inspections of 4.2.2, 4.2.3, and 4.2.4. The presence of visible contamination, which discloses a particle population greater than the level specified, shall be cause for rejection. Discoloration of a surface due to welding and passivation shall be permitted provided no weld scale or other contaminants remain. Discoloration of a surface due to flash rust shall be permitted provided it does not prevent the system or component from meeting cleanliness requirements.

4.2.2 Acidity and Alkalinity Test

All surfaces that have been cleaned shall be tested for acidity and alkalinity with pH paper while the surfaces are wet from the final water rinse. Dry surfaces of completed items shall be wetted with a few drops of ASTM D 1193 type II reagent water to permit testing as required. Test for neutral pH as indicated on pH paper or verify that the conductivity of the rinse water is less than 5 micromhos.

4.2.3 Acceptance Inspection of Items Cleaned in a Controlled Environment

Items cleaned in a controlled environment, except those processed to level VC and/or level UV, shall be tested for conformance to the applicable cleanliness level by the test fluid-flush procedure (Appendix A, A.1).

4.2.4 Acceptance Inspection of Items Cleaned in the Field

Items, such as tubing, piping, and vessels cleaned in the field, shall be tested for conformance to the applicable cleanliness level using either Test Method I (A.3.1) or Test Method II (A.3.2). Testing procedures are determined by the configuration of the item being cleaned and by the method of dispensing the test fluid.

4.2.5 Acceptance Inspection of Items by Functional Test

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

4.2.5.1 Calibrated Instrumentation

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

4.2.5.2 Hydrostatic Testing

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

4.2.5.3 Component Testing

Functional components, such as valves, solenoid valves, regulators, actuators, and cylinders, shall be assembled using clean parts in accordance with 3.6.4 and shall be functionally tested with gaseous nitrogen conforming to MIL-PRF-27401, type 1, grade A, or A-A-59503, type 1, class 1, grade B, prefiltered as close to the endcase as practical to the applicable cleanliness level, unless otherwise specified. The component will be tested at the specified conditions.

4.2.6 Acceptance Inspection of Packaging Materials

4.2.6.1 Environmental Control

All quality assurance operations shall be accomplished within a cleanroom conforming to ISO 14644-1 and ISO 14644-2, which is consistent with or cleaner than the packaging material being inspected. Care shall be taken not to contaminate the packaging materials, which should be stored in an area with proper cleanliness ratings.

4.2.6.2 Sampling

Packaging materials shall be examined and tested to determine compliance with the cleanliness requirements of 3.9.2.1. All the plastic film of one type, one size, and one configuration, such as tubing, flat roll stock, sheet, and fabricated bags offered by one manufacturer at one time, shall be considered one lot.

4.2.6.3 Visual Inspection

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

4.2.6.4 Thickness of Packaging Film

The thickness of plastic films used for precision packaging shall conform to the limits specified in Table 4. Thickness measurements shall be made with a micrometer caliper having a flat anvil and capable of being read to the nearest 2.5 μm (0.0001 in).

4.2.6.5 Verification of Cleanliness Level

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

4.2.6.5.1 Minimum Critical Surface Area for Test

The minimum interior critical surface area for verification of cleanliness level shall be 0.1 m^2. Sampling shall be according to 4.2.6.2, except that additional sample material from the offered lot shall be used when necessary to make 0.1 m^2.

4.2.6.5.2 Sample Preparation

Fabricated bags shall be sealed across the open end. Tubular packaging material shall be fabricated into a bag by cutting off, with properly cleaned tools, a length conforming to the requirements of 4.2.6.5.1 and sealing both ends. Flat roll sheet and stock shall be fabricated into a bag by cutting out a section with an area conforming to the requirements of 4.2.6.5.1, folding the section, and sealing the section as necessary. The cutting technique shall be in accordance with 3.9.3.1. The sealing technique shall be in accordance with 3.9.3.3. All items shall be handled in a

manner that minimizes exposure of the interior critical surfaces to airborne particles. One corner of the completely sealed test bag shall be cut off so that an opening of a maximum of 19 mm (0.75 in) in length is created.

4.2.6.5.3 Optional Roll Sample Preparation

Using a sharp, single-bladed instrument, two or more layers of the film roll shall be cut through. Without separating the layers, the film shall be heat sealed on all four sides. One corner shall be cut off per 4.2.6.5.2.

4.2.6.6 Rinsing Procedures

Test fluid that conforms to the cleanliness level of 3.7.1 shall be used as the test fluid in the ratio of 100 mL of fluid per 0.1 m^2 of critical surface area. The following rinsing procedure shall be used:

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

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

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

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

e. Analyze the test fluid for particulate population and NVR in conformance with A.1.4.

4.3 Recleaning Operational Systems

Systems that have successfully passed the specified quality assurance tests for initial acceptance and have been placed in operation shall be recleaned only when analysis of operational fluids shows that the delivered fluid does not meet specified requirements. Operational systems that are delivering fluids of an acceptable level of cleanliness shall be recleaned only at the discretion of the CO.

4.3.1 Surveying of Operational System

Contamination usually increases in areas of fluid stagnation and restricted flow, such as dead ends, sharp tubing bends, orifices, abrupt changes in component internal diameter or filters. Systems containing such configurations may be surveyed by removing one or more restrictive items, such as tubing containing a right-angle bend or a filter, and testing these items for particle population and NVR in accordance with 4.2.3. Three operations (component assembly, installing a component in a system, and removing a component from a system) all generate contamination that may cause the component to fail the original certified component cleanliness level.

4.3.2 Testing of Operational System

To test an operational system for the cleanliness of the fluid delivered, testing shall be performed in accordance with Test Method IV (Appendix A, A.3.4).

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging

Preservation and packaging of materials shall be in accordance with 3.9.

5.2 Packing

Cushioning material used to pack packaged precision-cleaned items shall be nonflammable and noncontaminating in nature. Cushioning materials, such as excelsior, shredded newspaper, and similar materials that generate large numbers of particles and fibers, are not acceptable.

5.2.1 Onsite Transportation of Small Items

Small, packaged precision-cleaned items shall be removed from the cleanroom and packed as required. Cushioning material shall be used to immobilize the item and prevent damage to the packaging. When a number of small, individually packaged items are packed, cushioning material shall be used to separate and to immobilize the individually packaged items.

5.2.2 Onsite Transportation of Large Items

Large or heavy items protected in accordance with 3.9 shall be placed on skids or pallets designed to support and protect the items from damage during handling. All items shall be secured to the skids or pallets by bolts, suitably tensioned and cushioned steel straps, tie down rods, or lumber hold downs. Cushioning shall be placed between the item and all support points and the base of the skid or dolly to prevent physical damage to the item.

5.2.3 Offsite Shipment

Packing of precision-cleaned items for offsite shipment shall be in accordance with level A or B of MIL-STD-2073/1 or MIL-E-17555 as applicable to the type of item being packed. Level A packing shall be used when storage conditions are indeterminate and may involve outdoor storage. Level B packing shall be used when handling under cover and warehouse storage are probable.

5.3 Marking for Shipment

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

6. NOTES

6.1 Intended Use

This specification establishes the cleanliness levels and cleaning, protection, and inspection procedures for surfaces of parts, components, assemblies, subsystems, systems, or other related equipment in contact with service media of launch vehicles, spacecraft, and associated ground support equipment.

6.2 Definitions

accuracy. how close the measured value is to the "true" value.

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.

blank. the result for an analytical sample of the test fluid prior to use in performing a cleanliness verification test.

component. an article that is normally a combination of parts, subassemblies, or assemblies and is a self-contained element within complete operating equipment.

condensable hydrocarbon. a hydrocarbon capable of going from a gaseous to a liquid or solid state at ambient temperature and prevailing pressure.

contracting officer (CO). cognizant officer or representative individual overseeing a specific design, system, or procurement. The CO requests work from the Cleaning Contractor (CC).

controlled environment. area, such as a cleanroom, in which factors such as humidity, temperature, particle matter, and contamination are precisely controlled.

critical surface. any surface of an item that contacts the critical service medium (liquid oxygen, pneumatic gases, etc.). A critical surface is subject to the cleaning procedures and cleanliness requirements of this specification.

dewar. a double-walled vessel with the annular space between the walls evacuated to provide insulation.

dewpoint. the temperature at which condensation of water vapor takes place at prevailing pressure (usually atmospheric pressure).

English-to-metric Conversion. for the purposes of this specification, the following approximate conversions shall be applicable:

a. Surface Area

0.1 square meter (m^2) = 1.0 square foot (ft^2)

b. Temperature

Temperature in degrees Celsius:

$T^C = 5/9\ (T^F - 32\ °F)$

Where: T^C = degree Celsius (°C)

T^F = degree Fahrenheit (°F)

c. Pressure

1.0 pound per square inch (psi) = 6.895 kilopascal (kPa)

d. Velocity

1.0 foot per second (ft/s) = 0.3048 meter per second (m/s)

fiber. a nonmetallic, flexible particle having a length-to-width ratio of 10 to 1 or greater.

field cleaning. the processes of rough cleaning and precision cleaning of large components and systems that cannot be processed in a controlled environment (such as a cleanroom).

fluid. for the purpose of this specification, a gas or a liquid.

generally clean (GC). freedom from manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination. GC is the only cleanliness level that does not require items to be packaged.

high-efficiency particulate air (HEPA) filter. a filter that is at least 99.97-percent efficient by volume on 0.3-micron particles.

hydrocarbon. an organic compound consisting exclusively of the elements of carbon and hydrogen.

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

micrometer. one micrometer (micron) is equivalent to 0.001 millimeter, 0.000001 meter, 0.0000394 inch, or 0.0394 mil. (One mil is equal to 0.001 inch.)

nonvolatile residue (NVR). soluble or suspended material and insoluble particulate matter remaining after temperature-controlled evaporation of a filtered volatile liquid.

oxidizer. a chemical that initiates or promotes combustion in materials, thereby causing fire either of itself or through release of oxygen or other gases; a substance that gives up oxygen readily or otherwise supports combustion. For the purposes of this specification gaseous oxygen and breathing air shall be considered oxidizers.

part. one piece of two or more pieces joined together in such a way that it is not normally disassembled without destruction of the designed use. Fittings, O-rings, and poppets are normally considered parts of a valve.

particle. unit of matter with observable length, width, and thickness and is usually measured by its largest dimension in micrometers. Also see fiber.

parts per million (ppm) by weight. an absolute weight relationship expressed on an equivalent basis in any weight unit. The user may employ a weight unit that is convenient. One ppm may be 1 gram per million grams, 1 pound per million pounds, 1 milligram per liter (approximately), etc.

passivation. process by which a corrosive-resistant layer is formed on a metal surface by submersing the surface in an acid solution.

pH. a value taken to represent the acidity or alkalinity of an aqueous solution. It is defined as the logarithm of the reciprocal of the hydrogen ion concentration of a solution. The pH is measured over the nominal range of 0 to 14. A pH reading below 7 is acidic, pH 7 is neutral, and pH above 7 is alkaline.

pickling. chemical or electrochemical process by which surface oxides are removed from metals.

precision cleaning. a cleaning process used to achieve cleanliness levels more stringent than level VC.

repeatability. reproducibility to acceptable level of precision.

rough cleaning. the cleaning process normally used to achieve cleanliness level VC.

silting. an accumulation of particles (approximately 2 to 20 μm) of sufficient quantity to cause a haze or obscuring of any portion of a grid line or any portion of the grid of a filter membrane when viewed visually or under 40-power maximum magnification.

still-bottom residue. the concentrated liquid that remains in distillation equipment after the distillation process is complete.

subsystem. two or more assemblies joined together to perform a definite function. A subsystem should be capable of independent operation when interconnected into a system.

system. a series of subsystems joined together to perform a definite function.

test fluid. either a liquid solvent or an aqueous solution that is utilized to determine fluid system wetted-surface cleanliness level.

validate/validation. the process or method of proving that an item subsystem or system does meet the specified requirements (for example, to validate the integrity of the system).

verify/verification. the process or method to establish the truth, accuracy, or reality of the cleanliness level of a cleaned item (for example, to verify the cleanliness level of a system).

visibly clean (VC). the absence of all particulate and nonparticulate matter visible to the normal unaided (except corrected vision) eye. Level VC is commonly referred to as commercially clean.

visibly clean plus ultraviolet (UV). visibly clean (VC) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 angstroms wavelength (3.2×10^{-7} to 3.8×10^{-7} meters). This level requires precision-cleaning methods but no particle count.

volatile hydrocarbon. hydrocarbon capable of going from liquid or solid to a gaseous state at ambient temperature and prevailing pressure.

volatile liquid. evaporates at ambient temperature or vaporizes readily; liquid with a high vapor pressure or low boiling point.

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APPENDIX A. SAMPLING, ANALYTICAL, AND DRYING PRACTICES

A.1 CONTROLLED ENVIRONMENT

A.1.1 Test Fluids

NOTE

A cleaning fluid may be used as a test fluid as long as it meets the criteria of Table 3. Validation performed in series with cleaning without draining the cleaning fluid is acceptable.

A.1.2 Test Fluid Volume Cleanliness Verification

For items cleaned in a controlled environment, all critical surface areas shall be sampled with test fluid unless specified otherwise. The standard test sample for cleanliness verification shall be 500 milliliters (mL) of test fluid to ensure all critical surfaces are flushed. The 500-mL sample of test fluid shall be representative of total critical surface area; however, for analytical purposes, the 500-mL sample shall represent a minimum surface area of 0.1 m^2 to a maximum of 0.5 m^2, with 100 mL being representative of 0.1 m^2 of actual surface area. In cases where all critical surfaces can be sampled with 100 mL of test fluid and the analytical method requires 100 mL or less of test fluid, a 100-mL sample of test fluid shall be allowed to represent 0.1 m^2 of critical surface area if approved by the CO.

A.1.3 Test Fluid-Flush Procedure (Solvent)

The fluid flush procedure shall be as follows:

a. Ascertain the test procedure and total volume of test fluid necessary to flush the cleaned item or items in accordance with Test Method I (A.3.1).

b. Flush all critical surfaces uniformly with the test fluid. Tubing, piping, and hoses shall be flushed in accordance with either Test Method I (A.3.1) or Test Method II (A.3.2). Where flushing does not reach all interior surfaces, the test fluid shall be introduced and the small item shall be manually shaken or rolled until all interior surfaces are wetted. Large, difficult-to-flush items may be positioned so that the vessel can be filled from the bottom and overflowed from the top.

c. Catch the test fluid in a precision-cleaned container.

d. Immediately upon the completion of step c, dry the tested items in accordance with the applicable cleaning procedure.

e. Some analytical methods specify other test procedures (see A.3).

A.1.4 Analysis of Test Sample (Solvent)

When a solvent is utilized as the test fluid, the test sample shall be analyzed for particle population and NVR by the following recognized analytical methods. Other analytical methods may be used that have demonstrated accuracy and repeatability and their use is approved by the CO.

A.1.4.1 Particle Population Analysis (Solvent-Flush)

The solvent-flush sample shall be analyzed for particle population as follows.

A.1.4.1.1 Microscopic Particle Population

Particle analysis shall conform to ASTM F 312, SAE-ARP-598, or SAE-ARP-599. The sample preparation and analysis procedure shall be as follows:

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

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

d. 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.

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

f. Retain the filtrate for analysis of the NVR in accordance with A.1.4.2.

g. Place the filter membrane under the microscope.

h. 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.

i. 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.

j. Count the particles in accordance with the method of ASTM F 312 except that when the total number of particles of a given particle size range is to be between 1 and 154, the number of particles over the entire effective filtering area of the membrane shall be counted.

A.1.4.1.2 Particle Population Analysis (Automatic Particle Counters)

Automatic liquidborne particle counters may be used for final verification of cleanliness of the end product, provided the individual counters have demonstrated accuracy and repeatability, which correlates with accepted analytical methods, and their use is approved by the CO.

A.1.4.2 NVR Analysis (Solvent-Flush)

The solvent-flush samples that have been filtered in accordance with A.1.4.1.1 shall be analyzed for NVR by methods that have demonstrated accuracy and repeatability (which correlate with accepted analytical methods). The use of the solvents shall be approved by the Materials and Processes Engineer (M&PE) prior to use. The following paragraphs describe three accepted methods.

A.1.4.2.1 Gravimetric NVR Analysis Method

Perform the gravimetric NVR analysis in accordance with ASTM F 331 or a similar method that will allow the evaporated test fluid to be recovered and recycled. If the test fluid used is perchlorethylene, a silicon-based oil bath must be employed with the rotary evaporator due to the high boiling point of perchlorethylene. The gravimetric NVR analysis method shall be performed as follows:

a. Degrease an evaporation flask by washing it three times with alcohol and three times with the test fluid. Transfer the 500 mL of filtrate from A.1.4.1.1 into the clean, degreased flask.

b. Evaporate the 500-mL sample to a volume small enough to be contained in a tared weighing dish, minus 20 to 30 mL.

c. After cooling, transfer the sample to a clean constant weight (within 0.1 mg), tared weighing dish. Wash the flask three times with a total volume of approximately 20 mL of clean, filtered fluid and transfer the wash fluid to the weighing dish.

d. Continue evaporation by placing the weighing dish inside a constant temperature oven at a maximum temperature of 110 degree Celsius (°C). Allow the weighing dish to remain inside the oven until the fluid has just evaporated to dryness. A thermostatically controlled hot plate may be substituted for the oven.

e. Remove the weighing dish from the oven and place in a desiccator to cool for 30 minutes.

f. After cooling, remove the weighing dish from the desiccator, weigh the dish to the nearest 0.1 mg, and record the weight.

g. A blank is determined on the filtered fluid, and the results are subtracted from the NVR value obtained for the sample.

A.1.4.2.2 Solvent Purity Meter

The solvent purity meter shall be Model SP-1000, as manufactured by the Virtis Co., Gardiner, New York, or equivalent, that has demonstrated accuracy and repeatability, which correlates with accepted analytical methods, and is approved by the CO.

A.1.4.2.3 Infrared Spectrophotometric NVR Analysis Method

Infrared (IR) spectrophotometric NVR analysis of solvent samples may be used if the following apply:

a. The method quantifies hydrocarbons and other contaminants that are reactive with liquid oxygen.

b. The analysis method has demonstrated accuracy and repeatability and the method is approved by the CO.

A.1.5 Analysis of Test Fluid-Flush Sample (Aqeuous-Based)

The aqueous-based fluid-flush samples shall be analyzed for particle population and NVR as follows.

A.1.5.1 Particle Population Analysis (Aqueous)

The particle analyses of A.1.4.1 may be used for final verification of cleanliness of the end product, provided the sampling and analysis methods have demonstrated accuracy and repeatability, which correlates with accepted analytical methods, and their use is approved by the CO.

A.1.5.2 NVR Analysis (Aqueous)

Aqueous NVR sampling and analysis methods may be used for the final verification of cleanliness of the end product, provided the methods have demonstrated accuracy and repeatability (which correlate with accepted analytical methods) and their use is approved by the M&PE. Two accepted methods are outlined in A.4 and A.5.

A.1.6 Drying

After testing for particle population and NVR, all components and parts shall be dried.

A.1.6.1 Purge Drying

All components and parts rinsed shall be dried by a purge of filtered test gas in accordance with 3.8. The critical internal surfaces of small vessels, hoses, and tube assemblies shall also be purge dried. If the critical internal surfaces cannot be inspected visually, analyses in accordance with A.1.6.1.1 shall be performed. Component parts may be dried with heated air drivers equipped with high-efficiency particulate air (HEPA) filters.

A.1.6.1.1 Dewpoint Analysis

All items rinsed with reagent water that cannot be visually inspected (100 percent) shall be tested by Test Method III (A.3.3) for surface moisture.

A.1.6.2 Vacuum Drying

Intricate parts with features (such as wire mesh filter elements and fine threaded holes) shall be placed in a clean vacuum oven, which shall be purged with test gas, the parts shall be heated, and then the oven shall be evacuated until the parts dry. Recommended vacuum drying practices are discussed in A.5.

A.2 Field Cleaning

A.2.1 Test Fluids

Test fluids shall be in accordance with 3.7.

NOTE

A cleaning fluid may be used as a test fluid as long as it meets the criteria of Table 3. Validation performed in series with cleaning without draining the cleaning fluid is acceptable.

A.2.2 Test fluid Volume for Cleanliness Verification

For items cleaned in the field, all critical surface areas shall be sampled with test fluid unless specified otherwise. The standard test sample for cleanliness verification shall be 500 mL of test fluid to ensure all critical surfaces are flushed. The 500-mL sample of test fluid shall be representative of total critical surface area; however, for analytical purposes, the 500-mL sample shall represent a minimum surface area of 0.1 m^2 to a maximum of 0.5 m^2.

A.2.3 Particle Population Analysis

Each sample shall be tested for particle population in accordance with the procedure of A.1.4.1. Particle population per 0.1 m^2 shall be determined on the basis of the proportional critical surface area. The 100 mL represents 0.1 m^2; ratio of particle population per representative surface area converted to particle population per 0.1 m^2.

A.2.4 NVR analysis

The NVR shall be determined in accordance with A.1.4.2. NVR per 0.1 m^2 shall be determined on the basis of the proportional critical surface area.

A.2.5 Drying

All items cleaned in the field shall be dried in accordance with A.1.6.

A.2.6 Maintaining Cleanliness

The cleaning organization is responsible for maintaining the cleanliness of items and systems cleaned in the field until it is received or accepted by the contracting officer.

A.2.6.1 Test Gas Purge

Items, such as vessels, pipe and tubing systems, and pipe, tubing, and flex hose assemblies, shall be maintained under the test gas purge of 13.8 kPa to 34.5 kPa (2 to 5 pounds per square inch gage [psig]) until all ports, orifices, and fittings are sealed. Test gas shall be in accordance with 3.8.

A.2.6.2 Temporary Hardware Replacement

Temporary hardware installed in subsystems, systems, and related field equipment for cleaning (refer to 3.6.8.1.3 through 3.6.8.1.5) shall be replaced with clean functional components after the subsystem, system, or related field equipment has been verified clean. Procedures and practices shall be established to maintain system cleanliness. Adjacent, external system, and structural surfaces will be cleaned to level GC prior to replacement. Where practical, the hardware replacement shall be performed in a controlled environment, which can be provided by a portable cleanroom (tent) or similar structure.

A.2.6.3 Component Replacement

Replacement of functional components in clean systems shall be in accordance with A.2.6.2.

A.3 Cleanliness Level Test Method

A.3.1 Test Method I

Liquid flush test for particle population and NVR remaining on critical surfaces of items cleaned in a controlled environment shall be performed in the following manner:

a. All items, except those processed to level VC, level UV, and/or rough clean requirements, must be sampled.

b. Parts having a surface area greater than 0.5 m^2 may be sampled during a continuous flush cleaning operation. The collected sample shall contain test fluid that has contacted all critical surface areas. The sample shall be contained in, or transferred to, one suitable precision cleaned sample container, but only 500 mL (standard test sample volume) of the collected sample will be used for cleanliness level verification. The 500-mL sample of test fluid shall be representative of total critical surface area; however, for analytical purposes, the 500-mL sample shall represent 0.5 m^2 of actual surface area, with 100 mL being representative of 0.1 m^2 of actual surface area.

c. Parts having a surface area less than 0.5 m^2 but greater than 0.1 m^2 may be sampled during a continuous flush cleaning operation. The collected sample shall be 500 mL and shall represent the entire surface area of the part, with 100 mL being representative of 0.1 m^2 of actual surface area.

d. Small components, fittings, soft goods, etc., (items small enough to fit inside an 800-mL beaker) shall be individually dipped and agitated in 500 mL of test fluid. Small components should be combined into batches having a total surface area of at least 0.1 m^2.

e. Significant areas of components too large to dip, such as flanges or valves, shall be flushed and sampled.

f. Individual components, such as drums, having an area greater than 0.5 m^2 must be flush sampled with 100-mL maximum of test fluid for each 0.1 m^2 of significant surface area. The test fluid shall be collected in or transferred to a single container, agitated, and sampled to obtain 500 mL (total sample) from top, center, and bottom of the original test fluid sample for analysis. Discard excess test fluid (sample is representative of 0.5 m^2). When cleaning by continuously impinging the entire interior surface of a component with test fluid, a 500 mL sample may be collected from a low point drain by opening the port during flow. If the component contains multiple low point ports, each port must be sampled separately.

g. Small containers with less than 0.5 m^2 internal surface area, such as hoke cylinders and dewars, must be sampled by using 500 mL of test fluid. Agitate the con-

tainer to cover all significant surfaces with sample medium; then drain the test fluid from the container for analysis.

A.3.1.1 Example 1: Internal Surface Area = 0.5 m^2 (5 ft^2)

A component with an internal surface area of 0.5 m^2 (5 ft^2) is rinsed with 500 mL of test fluid. The 500 mL of test fluid is analyzed. After evaporation and subtraction of the test fluid's background NVR, 4.5 mg of NVR remains. The NVR per unit area is the mass of the NVR divided by the critical surface area: 4.5 mg / 0.5 m^2 (4.5 mg / 5 ft^2) = 9 mg / m^2 (0.9 mg / ft^2).

A.3.1.2 Example 2: Internal Surface Area < 0.5 m^2 (5 ft^2)

A component with an internal surface area of 0.4 m^2 (4ft^2) is rinsed with 500 ml of test fluid. The 500 mL of test fluid is analyzed. After evaporation and subtraction of the test fluid's background NVR, 5.2 mg of NVR remains. The NVR per unit area is the mass of the NVR divided by the critical surface area: 5.2 mg / 0.4 m^2 (5.2 mg / 4 ft^2) = 13 mg / m^2 (1.3 mg / ft^2).

A.3.1.3 Example 3: Internal Surface Area > 0.5 m^2 (5 ft^2)

A component with an internal surface area of 0.8 m^2 (8 ft^2) is rinsed with test fluid that has contacted all critical surfaces. The 500 mL of the test fluid, which is the standard test sample volume and considered representative of the entire surface area, is analyzed. After evaporation and subtraction of the test fluid's background NVR, 4 mg of NVR remains. The NVR per unit area is the mass of the NVR divided by the maximum area that the sample of test fluid represents: 4 mg / 0.5 m^2 (4 mg / 5 ft^2) = 9 mg / m^2 (0.9 mg / ft^2).

A.3.2 Test Method II

Liquid flow test for monitoring particle population and NVR remaining on critical surfaces of items cleaned in the field shall be performed in the following manner:

a. Flow test fluid in accordance with 4.2.3.1 through the item at a minimum average velocity of 1.25 m/s (4 ft/s).

b. Catch a test fluid sample in a precision-cleaned container.

A.3.3 Test Method III

The gas flow test for moisture remaining on a critical surface after cleaning shall be performed in the following manner:

a. The cleaned item shall be purged with test gas. The test gas shall be nitrogen conforming to 3.8.

b. The item shall be purged for a sufficient time to ensure all of the residual air and vapor have been expelled from the item. Hold (stop) the purge flow for sufficient

time to allow entrapped moisture to diffuse or permeate into the static purge gas. Begin monitoring for moisture in the purge gas at the item's discharge port. Resume purge gas flow.

c. The dewpoint of the effluent test gas shall be monitored by a suitable instrument. The method or instrument used in the dewpoint method shall be capable of detecting to a level of less than 20-ppm moisture. Manufacturer's directions shall be followed for the operation of a specific instrument. Effluent gas moisture content shall be 24 parts per million (ppm) (dewpoint = -54 °C [-65 °F]) for individual components or 128 ppm (dewpoint = -40 °C [-40 °F]) for systems, unless specified otherwise.

d. If the effluent gas moisture content exceeds the allowable limit, continue purging the item periodically repeating b. and c. until the test requirement is met.

A.3.4 Test Method IV

The liquid or gas flow test to evaluate a systems capability to deliver fluid that meets specified requirements shall be performed in the following manner.

a. Sampling of the system shall be performed at the system's designed point of delivery under normal system operating conditions. Fluid samples shall be drawn under the systems design operating conditions from the flowing stream, not from a dead space in the system.

b. If the fluid is a gas that is normally found in the atmosphere, the sampling may be conducted while discharging the system gas or test gas to the atmosphere. However, if the fluid is a hazardous material or liquid, the fluid discharge shall be routed to the fluid deservicing or return system.

c. The following fluid sample sizes are recommended:

(1) Liquid system - 500 mL to 1.0 L

(2) Pressurized gas system - 1.0 L (Hoke cylinder)

(3) Low pressure gas system - (minimum) 30-L bomb

(4) System purge gas for particulate filtration - 1.0 standard cubic meter.

A.4 AQUEOUS ULTRASONIC SAMPLING AND TOTAL ORGANIC CARBON (TOC) NONVOLATILE RESIDUE (NVR) ANALYSIS

This procedure defines the method of performing aqueous ultrasonic sampling and TOC NVR analysis of small parts.

NOTE

This procedure shall be implemented under the supervision of the CO.

A.4.1 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. Parts sampling pan (stainless steel) Volumes 1, 2, 3, and 4 liter

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

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

e. Syringe (TCA sample), 200 microliter or variable 500 microliter

A.4.2 Procedure

A.4.2.1 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. Calibrate the TCA in accordance with the manufacturer's instruction.

c. 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.

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

A.4.2.2 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 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 (TCs).

A.4.2.3 Calculation

a. Equivalent Nonvolatile Residue (Aqueous Ultrasonic Sampling)

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

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)
SF = Sensitivity factor (mgC/mg contaminant) empirical constant derived from text of known contaminants

b. Sensitivity Factor (Aqueous Ultrasonic Sampling)

$$SF = TC/S$$

Where:

SF	=	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.

A.5 Vacuum Drying

This procedure describes a suggested method for vacuum drying of intricate parts that are likely to retain entrapped moisture or solvent when dried by normal purging methods. It is the CC's responsibility to ensure the final dryness of the parts.

A.5.1 EQUIPMENT

a. Vacuum oven – Minimum temperature control range of 43 °C (110 °F) to 121 °C (250 °F) with a tolerance of ±3 °C (±5 °F) or better

b. Purge (test) gas – In accordance with 3.8

c. Thermocouple – Independent temperature monitoring of parts

A.5.2 PARTS HEATING

Component parts shall be placed in the vacuum oven with the thermocouple attached to the largest part. The oven shall be closed and purged with inert test gas in accordance with 3.8 and then shall be heated to the desired vacuum drying temperature. Parts temperature should be governed by the following criteria:

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

b. The maximum target drying temperature for parts containing nonmetallics shall be 63 °C (145 °F). Caution: some plastics may soften at temperatures below 63 °C (145 °F). If plastic properties are unknown, contact M&PE for approval.

c. The maximum target temperature for drying metallic parts shall be 121 °C (250 °F).

A.5.3 Thermal Vacuum Drying Time

Once the thermocouple monitor indicates the parts have reached the desired temperature, a vacuum should be drawn on the parts and maintained until parts are free from moisture or solvent. Recommended vacuum drying times, relative to oven temperature and pressure, are specified in Table 5. Once all moisture or solvent has been removed, the heat should be discontinued and the oven slowly back-filled with test gas in accordance with 3.8. Note: If at the end of the heating cycle there is still evidence of liquid, the vacuum drying time may be extended at the CC's discretion, or another heating cycle may be initiated. At no time shall the temperature for parts containing nonmetallic materials exceed the requirements of A.5.2, Step b, unless approved by M&PE.

Table 5. Recommended Vacuum Drying Time (Hours)

Vacuum Oven Pressure*		Target Temperature**				
psia	torr	43 °C (110 °F)	54 °C (130 °F)	63 °C (145 °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

* Allowed operational tolerance of +10 torr (+0.2 psia). Vacuum pressures less than listed values are not permitted.

** For all parts, there shall be an allowable operational tolerance of ±3 °C (±5 °F) from the target temperature.

APPENDIX B. NONMANDATORY SUPPLEMENTAL GUIDANCE FOR ESTABLISHING ROUGH CLEANING PROCESSES

NOTE

All systems, subsystems, components, and equipment that have been exposed to toxic propellants or hazardous materials shall be decontaminated to the required level of safe handling prior to initial cleaning operations (see 3.6.2).

B.1 Rough Cleaning

Rough cleaning is used to achieve level VC clean articles. Rough cleaning removes contaminants such as weld scale, heat treat scale, corrosion, oxide films, oils, grease, shop soil, fuel, and carbon deposits. The cleanliness level achieved by rough cleaning does not normally require verification beyond visual inspection. (Wipe test, waterbreak test, ultraviolet inspection, special lights, and mirrors are considered aids to visual inspection.) Rough cleaning is considered a normal shop process and usually does not require special environmental controls, packaging, handling, or storage beyond accepted good practice.

B.2 Rough Cleaning Types

Chemical cleaning agents must be compatible with the material composition of the item being cleaned, taking the following compatibility issues into consideration, as applicable: corrosion; stress corrosion cracking, embrittlement, leaching, masking of crack-like indications, residue, crazing (nonmetallics), reversion (nonmetallics), and hydrolisis (nonmetallics), in order to prevent excessive attack or latent degradation. The following cleaners or their equivalents may be used for removing gross forms of contamination.

B.2.1 Acid Cleaners

Acid cleaners are used to remove the 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.

B.2.2 Alkaline Cleaners

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

B.2.3 Degreasers (Organic and Aqueous-Based Solvents)

Degreasers are used to remove some forms of organic contamination; e.g., oils, grease, and hydrocarbon fuels.

B.2.4 Mild Alkaline Cleaners and Detergents

Mild alkaline cleaners and detergents are used for the removal of organic and inorganic contamination; e.g., oils, fats, shop soil, and grease. Mild alkaline cleaners and detergents include inhibited alkaline cleaners (mild alkaline cleaner), soaps, and detergents.

B.2.5 Tap Water and Reagent Water

Tap water or reagent water is used to remove the residual material left by cleaning solutions, and reagent water will be used as a final flushing or rinsing medium.

B.2.6 Neutralizing and Passivating Solutions

Neutralizing and passivating solutions are used as a supplementary treatment to acid, alkaline, and mechanical cleaning. The neutralizing and passivating solutions prevent corrosion and acid etching. Use nitrate, phosphate, alkali with nitrate or phosphate to neutralize; use nitric acid solutions to passivate. Guidelines for passivation are provided in ASTM A967 (superseding AMS-QQ-P-35), ASTM A 380, and SAE-AMS-2700.

B.2.7 Mechanical Cleaning

Mechanical cleaning removes contamination by abrasive action. Mechanical cleaning methods include wire brushing, shot peening, shot blasting (wet and dry), grit blasting, abrasive blasting (wet and dry), aluminum oxide, abrasive-coated papers and cloths, tumbling, and grinding. This method shall be used only when contaminants generated by the process can be removed and when physical damage to the item being cleaned shall not occur. Corrosion-resistant steel surfaces shall be cleaned by brushing with a corrosion-resistant steel brush, grinding, or using abrasive material. Abrasive materials used on corrosion-resistant steel surfaces shall contain no ferrous or ferric materials. The use of the same corrosion-resistant steel brush for corrosion-resistant steels and carbon steels shall not be permitted. All loose dirt, scale, and other debris shall be completely removed from the item by vacuum cleaning, brushing, blowing, or flushing with clean water.

NOTE

Mechanical cleaning often leaves foreign deposits that may require additional cleaning for removal. Compatibility of dissimilar metals is an important consideration when selecting a mechanical cleaning method.

B.3 Rough Cleaning Processes

Table 6. Selection Chart for Rough Cleaning Processes

NOTE:
"X" denotes a recommended process for the surface condition indicated, and steps will normally be accomplished in consecutive order from left to right.

Material	Surface Condition	Rough Cleaning Processes											
		Mechanical Descale/Clean	Degrease	Alkaline Clean	Tap Water Rinse	Detergent Clean	Tap Water Rinse	Acid Pickle	Tap Water Rinse	Passivate	Tap Water Rinse	Reagent Water Rinse	Drying
Aluminum	Bare or machined free of heat oxidation		X	X							X	X	X
	Conversion or chemical film coating		X			X	X					X	X
	Weld scale, corrosion, or heat oxidation	X	X	X							X	X	X
Copper, brass, bronze	Bare or machined free of heat oxidation		X	X							X	X	X
	Conversion or chemical film coating		X			X	X					X	X
	Weld scale, corrosion, or heat oxidation		X	X	X			X			X	X	X
Stainless steel*	Free of scale		X	X	X			X	X	X	X	X	X
	Weld scale, corrosion, or heat oxidation	X	X	X	X			X	X	X	X	X	X
Carbon steel	Free of scale		X	X	X					X	X	X	X
	Weld scale, corrosion, or heat oxidation	X	X	X	X			X	X	X	X	X	X
Titanium	Bare or machined	X	X*	X	X			X	X			X	X
	Conversion or chemical film coated		X	X	X			X	X			X	X
Nonmetallic parts	As received					X					X	X	X
Electroplated parts and dissimilar metals	As received		X	X							X	X	X

*Do not use halogenated solvents.

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3. DOCUMENT TITLE
Surface Cleanliness of Ground Support Equipment Fluid Systems, Specification for

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

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