METRIC/INCH-POUND

KSC-C-123H
September 25, 1995
Supersedes
KSC-C-123G
August 4, 1994

SURFACE CLEANLINESS OF FLUID SYSTEMS, SPECIFICATION FOR

National Aeronautics and
Space Administration

John F. Kennedy Space Center

TRANSMITTAL SHEET

TO:	DATE
Distribution	September 5, 2000

MATERIAL TRANSMITTED

Change Notice 6

KSC-C-123H, Surface Cleanliness of Fluid Systems, Specification for

K.J. Payne
Director of Spaceport Engineering
and Technology

FILING INSTRUCTIONS

Remove pages 23 and 24 and replace with the attached.

TRANSMITTAL SHEET

TO:	DATE
Distribution	October 26, 1999

MATERIAL TRANSMITTED

Change Notice 5

KSC-C-123H, Surface Cleanliness of Fluid Systems, Specification for

K.J. Payne
Director of Logistics Operations

FILING INSTRUCTIONS

Remove pages 3, 4, 11, 12, 19, and 20 and replace with the attached.

TRANSMITTAL SHEET

TO:	DATE
Distribution	June 18, 1999

MATERIAL TRANSMITTED

Change Notice 4

KSC-C-123H, Surface Cleanliness of Fluid Systems, Specification for

K. Payne

K.J. Payne
Director of Logistics Operations

FILING INSTRUCTIONS

Remove page 11 and replace with the attached. Note that this document was converted from WordPerfect to Microsoft Word which accounts for format changes.

TRANSMITTAL SHEET

TO:	DATE
Distribution	March 30, 1999

MATERIAL TRANSMITTED

Change Notice 3

KSC-C-123H, Surface Cleanliness of Fluid Systems, Specification for

K. J. Payne
Director of Logistics Operations

FILING INSTRUCTIONS

Remove pages 4, 5, 11, 12, 17, 18, 21, and 22 and replace with the attached. Note that this document was converted from WordPerfect to Microsoft Word which accounts for format changes.

TRANSMITTAL SHEET

TO:	DATE
Distribution	December 1, 1997

MATERIAL TRANSMITTED

KSC-C-123H, Change 2 *Surface Cleanliness of Fluid Systems, Specification for*

A. D. Montgomery
Director of Logistics Operations

FILING INSTRUCTIONS

Remove pages 11 (Change 1) and 12 and replace with the attached.

TRANSMITTAL SHEET

TO:	DATE
Distribution	April 14, 1997

MATERIAL TRANSMITTED

Change Notice 1

KSC-C-123H, Surface Cleanliness of Fluid Systems, Specification for

A. Montgomery
Director of Logistics Operations

FILING INSTRUCTIONS

Remove pages 11 and 12 and replace with the attached.

KSC-C-123H
September 25, 1995

SURFACE CLEANLINESS OF FLUID SYSTEMS, SPECIFICATION FOR

Approved By:

John R. Lyon
Director of Logistics Operations

JOHN F. KENNEDY SPACE CENTER, NASA

P1/WP51/KSC-123H.DOC

METRIC/INCH-POUND

KSC-C-123H
September 25, 1995
Supersedes
KSC-C-123G
August 4, 1994

SURFACE CLEANLINESS OF FLUID SYSTEMS, SPECIFICATION FOR

National Aeronautics and
Space Administration

John F. Kennedy Space Center

KSC FORM 16-12 (REV. 7/92)

TABLE OF CONTENTS

Section	Title	Page
1.	SCOPE	1
1.1	Classification	1
1.2	Method of Specifying Product Cleanliness Levels	1
1.3	Test Methods	1
1.4	English-to-Metric Conversion	3
2.	APPLICABLE DOCUMENTS	4
2.1	Governmental	4
2.1.1	Specifications	4
2.1.2	Standards	5
2.1.3	Other Documents	5
2.1.4	Code of Federal Regulations (CFR)	6
2.2	Non-Governmental	7
3.	REQUIREMENTS	8
3.1	General	8
3.2	Environmental, Health, and Safety Considerations	8
3.2.1	Hazardous Materials	8
3.2.2	Waste Minimization (Recycling)	8
3.2.3	Regulations	9
3.3	Preproduction Cleaning and Preservation Process Approval	9
3.4	Component Cleaning and Functional Testing	10
3.4.1	Hydraulic Components	10
3.4.2	Components Designed for Flow-Through Sampling	10
3.5	Cleanroom and Work Station Requirements	10
3.6	Materials	11
3.6.1	Test Fluids	11
3.6.1.1	Solvents	11
3.6.1.2	Aqueous-Based Fluids	12
3.6.1.3	Hydraulic Fluid	12
3.6.2	Precision-Clean Packaging Films	12
3.6.2.1	Polyethylene	12
3.6.2.2	Polyamide	12
3.6.2.3	Fluorohalocarbon	12

TABLE OF CONTENTS (cont)

Section	Title	Page
3.6.2.4	Fluorocarbon	12
3.6.3	Packaging Tape	12
3.6.4	Drying and Testing Gas	12
3.7	Rough Cleaning	13
3.8	Precision Cleaning	13
3.9	Field Cleaning	13
3.9.1	Preparation Prior to Field Cleaning	13
3.9.1.1	Approvals	13
3.9.1.2	Decontamination	13
3.9.1.3	Component Removal	14
3.9.1.4	Installation of Temporary Hardware	14
3.9.1.5	Marking of Temporary Hardware	14
3.9.1.6	Validation of System Integrity Prior to Cleaning	14
3.9.1.7	Rough Cleaning	14
3.9.2	Mechanical Cleaning	15
3.9.3	Field Cleaning Equipment	15
3.9.3.1	Closed-Loop Cleaning Equipment	15
3.9.3.2	Spray Equipment	15
3.9.4	Cleaning by Closed-Loop Circulation of Solution	16
3.9.5	Cleaning by Solution Spraying	16
3.10	Protection of Cleaned Surfaces	16
3.10.1	Environmental Control	16
3.10.2	Protection Materials	16
3.10.2.1	Packaging Films	16
3.10.2.2	Metallic Closures	17
3.10.2.3	Plastic Closures	18
3.10.2.4	Protective Shields	18
3.10.2.5	Preservatives	18
3.10.2.6	Desiccants	18
3.10.2.7	Tamperproof Decal	18
3.10.3	Packaging of Cleaned Items	18
3.10.3.1	Cutting	18
3.10.3.2	Purging	18
3.10.3.3	Sealing	18
3.10.3.4	Detailed Requirements	19
3.11	Identification of Cleaned Items	19

TABLE OF CONTENTS (cont)

Section	Title	Page
4.	QUALITY ASSURANCE PROVISIONS	20
4.1	Responsibility for Inspection	20
4.2	Acceptance Inspection	21
4.2.1	Visual Inspection	21
4.2.2	Acidity and Alkalinity Test	21
4.2.3	Acceptance Inspection of Items Cleaned in a Controlled Environment	21
4.2.3.1	Test Fluids	21
4.2.3.2	Test Fluid Volume for Analysis	22
4.2.3.3	Test Fluid-Flush Procedure (Solvent)	22
4.2.3.4	Analysis of Test Fluid-Flush Sample (Solvent)	23
4.2.3.5	Analysis of Aqueous-Based Fluid-Flush Sample	24
4.2.3.6	Drying	24
4.2.4	Acceptance Inspection of Items Cleaned in the Field	24
4.2.4.1	Test Fluids	25
4.2.4.2	Ratio of Testing Fluid Volume to Critical Surface Area	25
4.2.4.3	Particle Population Analysis	25
4.2.4.4	NVR Analysis	25
4.2.4.5	Drying	25
4.2.4.6	Maintaining Cleanliness	25
4.2.5	Acceptance Inspection of Packaging Materials	26
4.2.5.1	Environmental Control	26
4.2.5.2	Sampling	26
4.2.5.3	Visual Inspection	26
4.2.5.4	Thickness of Packaging Film	26
4.2.5.5	Verification of Cleanliness Level	26
4.2.5.6	Rinsing Procedures	27
4.2.6	Acceptance Inspection of Items by Functional Test	27
4.2.6.1	Calibrated Instrumentation	27
4.2.6.2	Hydrostatic Testing	27
4.2.6.3	Component Testing	27
4.3	Recleaning Operational Systems	28
4.3.1	Surveying Operational System	28
4.3.2	Testing of Operational System	28

TABLE OF CONTENTS (cont)

Section	Title	Page
5.	PREPARATION FOR DELIVERY	28
5.1	Preservation and Packaging	28
5.2	Packing	28
5.2.1	Onsite Transportation of Small Items	28
5.2.2	Onsite Transportation of Large Items	29
5.2.3	Offsite Shipment	29
5.3	Marking for Shipment	29
6.	NOTES	29
6.1	Intended Use	29
6.2	Ordering Data	29
6.3	Definitions	30
APPENDIX A	SAMPLING, ANALYTICAL, AND DRYING PRACTICES	A-1
APPENDIX B	ROUGH CLEANING PROCESSES	B-1

ABBREVIATIONS AND ACRONYMS

A	surface area
ACS	American Chemical Society
AMS	Aerospace Material Specifications
ASTM	American Society for Testing and Materials
BAIR	breathing air
CC	Cleaning Contractor
cd	candela
CF	correlation factor
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
in	inch
IR	infrared
JSC	Lyndon B. Johnson Space Center
kPa	kilopascal
KSC	John F. Kennedy Space Center
L	liter
m	meter
m^2	square meter
mg	milligram
mg/L	milligram per liter
MIL	military
min	minute
mL	milliliter
mm	millimeter
MPa	megapascal
m/s	meter per second
MSFC	George C. Marshall Space Flight Center
N/A	not allowed
NASA	National Aeronautics and Space Administration
NHB	NASA handbook
NIST	National Institute of Standards and Technology
nm	nanometer

ABBREVIATIONS AND ACRONYMS (cont)

no.	number
NVR	nonvolatile residue
ODS	ozone depleting substance
OSHA	Occupational Safety and Health Administration
PCTFE	polychlorotrifluoroethylene
PFEP	polyfluoroethylene-propylene
ppm	part per million
psi	pound per square inch
psig	pound per square inch gage
RGW	reagent grade water
s	second
SAE	Society of Automotive Engineers
SPEC	specification
STD	standard
T	sample time
TCA	total carbon analyzer, trichloroethane
TCE	trichloroethylene
TOC	total organic carbon
U/S	ultrasonic
UV	ultraviolet, visually clean plus ultraviolet
V	volume
VC	visually clean
µg/L	microgram per liter
µm	micrometer
>	greater than
<	less than
°C	degree Celsius
°F	degree Fahrenheit

SURFACE CLEANLINESS OF FLUID SYSTEMS, SPECIFICATION FOR

1. SCOPE

This specification establishes surface cleanliness levels, test methods, cleaning and packaging requirements, and protection and inspection procedures for determining surface cleanliness. These surfaces pertain to parts, components, assemblies, subsystems, and systems in contact with any fluid medium.

1.1 Classification. - Cleanliness levels are listed in table 1.

1.2 Method of Specifying Product Cleanliness Levels. - Product cleanliness levels shall be determined by program and system requirements which shall be specified as in the following examples:

a. KSC-C-123 level 200 refers to limits on particulate matter contamination only.

b. KSC-C-123 level 200B refers to limits on particulate matter and non-volatile residue (NVR) contamination.

c. KSC-C-123 level B refers to limits on NVR only.

d. KSC-C-123 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 (example: a component cleaned to KSC-C-123 level 200A may be used in a system application requiring cleanliness level 250A or some less stringent cleanliness level).

1.3 Test Methods. - Cleanliness level test methods are as follows:

Method	Description
I	Liquid flush test for particle population and NVR remaining on critical surfaces of items normally cleaned in a controlled environment (previously test method A) (applicable for small parts, vessels, and surface areas)

Table 1. Classification of Surface Cleanliness Levels

(Table 1-A) Particulate Matter Contamination Levels			(Table 1-B) NVR Contamination Levels		(Table 1-C) Visible Contamination Levels	
Level	Particle Size Range (micrometer)	Maximum Number of Particles per 0.1 m^2 *	Level	Maximum Quantity of NVR (mg. per 0.1 m^2)	Level	Definition
25	<5 5 to 15 >15 to 25 >25	Unlimited 19 4 0	A	1.0	GC	Freedom from manufacturing residue, dirt, oil, grease, etc.
50	<15 15 to 25 >25 to 50 >50	Unlimited 17 8 0	B	2.0		
100	<25 25 to 50 >50 to 100 >100	Unlimited 68 11 0	C	3.0		
150	<50 50 to 100 >100 to 150 >150	Unlimited 47 5 0	D	4.0	VC	The absence of all particulate and nonparticulate matter visible to the normal unaided eye or corrected-vision eye.
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	UV	Visually clean and inspected with ultraviolet light.
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				

* No silting permitted

II Liquid flow test for monitoring particle population and NVR remaining on critical surfaces of items normally cleaned in the field (previously test method B) (applicable for hoses, tubing, subsystems, and systems)

III Gas flow test for moisture remaining on critical surface after cleaning (originally test method D) (applicable for vessels, subsystems, and systems)

IV Liquid or gas flow test to evaluate systems capability to deliver fluid that meets specified requirements (applicable for inservice systems)

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.

1.4 English-to-Metric Conversion. - For the purposes of this specification, the following approximate conversions shall be applicable:

Surface Area

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

Temperature

Temperature in degree Celsius:

$$T^C = 5/9\ (T^F - 32\ °F)$$

Where: T^C = degree Celsius (°C)
T^F = degree Fahrenheit (°F)

Pressure

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

Velocity

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

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.

2.1 Governmental.

2.1.1 Specifications.

John F. Kennedy Space Center (KSC), NASA

80K57369	Panel Assembly, High Intensity Water Impingement Cleaning

Lyndon B. Johnson Space Center (JSC), NASA

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

George C. Marshall Space Flight Center (MSFC), NASA

MSFC-SPEC-364	Helium

Federal

A-A-3174	Federal Supply Service Commercial Item Description, Plastic Sheet, Polyolefin
BB-N-411	Nitrogen, Technical
O-T-236	Tetrachloroethylene (Perchloroethylene), Technical
A-A-1689B	Commercial Item Description Tape, Pressure-Sensitive Adhesive (Plastic Film)
TT-I-735	Isopropyl Alcohol

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-P-27401	Propellant, Pressurizing Agent, Nitrogen
MIL-T-81533	1, 1, 1 Trichloroethane (Methyl Chloroform)

2.1.2 Standards.

Federal

FED-STD-209	Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones

Military

MIL-STD-129	Marking for Shipment and Storage
MIL-STD-889	Dissimilar Metals
MIL-STD-1201	Ethyl Alcohol (Ethanol), Technical and Denatured Grades
MIL-STD-2073-1	DOD Materiel Procedures for Development and Application of Packaging Requirements

2.1.3 Other Documents.

National Aeronautics and Space Administration (NASA)

NHB 5300.4(1C)	Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components and Services
NHB 8060.1	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Proce-

	dures for Materials in Environments That Support Combustion

John F. Kennedy Space Center (KSC), NASA

GP-1098	KSC Ground Operations Safety Plan

2.1.4 Code of Federal Regulations (CFR).

29 CFR 1910	Occupational Safety and Health Standards
40 CFR 50-87	Environmental Protection Agency Clean Air Act Regulations
40 CFR 104-149	Environmental Protection Agency Clean Water Act Regulations
40 CFR 141-143	Environmental Protection Agency Safe Drinking Water Act Regulations
40 CFR 260-263	Environmental Protection Agency Hazardous Waste Regulations
40 CFR 355-372	Emergency Planning and Community Right-to-Know Reporting
49 CFR 171-180	Department of Transportation Hazardous Materials Regulations

[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.]

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

2.2 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 A380	Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment, and Systems
ASTM D1193	Standard Specification for Reagent Water
ASTM D4080	Standard Specification for Trichloroethylene, Technical and Vapor-Degreasing Grade
ASTM F312	Standard Methods for Microscopical Sizing and Counting Particles From Aerospace Fluids on Membrane Filters
ASTM F331	Standard Test Method for Nonvolatile Residue of Halogenated Solvent Extract from Aerospace Components (Using Rotary Flash Evaporator)

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

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

AMS 3647	Film and Sheet, Polyfluoroethylene-propylene (PFEP)
AMS 3649	Film, Polychlorotrifluoroethylene (PCTFE) Unplasticized

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

3. REQUIREMENTS

3.1 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. 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 herein. Subsystems and systems may require disassembly to permit cleaning. Any part or component that might be damaged during cleaning shall be removed before cleaning and cleaned as a separate item. Cleaning or disassembly operations on precision components shall be performed only by competent personnel who have been trained and certified to perform these functions.

3.2 Environmental, Health, and Safety Considerations. - 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 determine and establish the appropriate environmental, health, and safety practices that are in compliance with applicable Federal, state, and local regulations.

3.2.1 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 on site, used for energy off site, recycled off site, recycled on site, treated off site, treated on site].

3.2.2 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 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.

3.2.3 Regulations. - The following list of current Federal regulations may be applicable to the cleaning operations performed in accordance with this specification:

a. 29 CFR 1910

b. 40 CFR 50-87

c. 40 CFR 104-149

d. 40 CFR 141-143

e. 40 CFR 260-263

f. 40 CFR 355-372

g. 49 CFR 171-180

3.3 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 [NASA, Systems Assurance Office (RM-SAO-B)] prior to performing any cleaning under this specification. The Contracting Officer (CO) is authorized to stop the Cleaning 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.

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

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

3.4.1 Hydraulic Components. - Hydraulic components may be sampled by test method II for particulate population analysis utilizing hydraulic fluid, provided the component has been assembled using clean parts that have been inspected in accordance with 4.2.1 and 4.2.2. When specified, functional testing 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.

3.4.2 Components Designed for Flow-Through Sampling. - 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.

3.5 Cleanroom and Work Station Requirements. - Cleanroom facilities and work stations used for precision cleaning, cleanliness verification, assembly, and packaging of cleaned items shall meet the requirements of FED-STD-209. The cleanroom level shall be consistent with the cleanliness level requirements of the cleaned item.

3.6 Materials. - Unless otherwise specified, test solvents and packaging films shall be as specified herein.

3.6.1 Test Fluids.

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

Table 2. Solvents, Maximum Allowable Nonvolatile Residue

Solvent/Specification and Grade Type	Maximum Allowable NVR		
		Test Fluid	
	Procurement Specification (mg/L)	General Use (mg/L)	Oxidizer (mg/L)
Trichlorotrifluoroethane (CFC 113) ODS			
MIL-C-81302, Type I	1.57	10	10
MIL-C-81302, Type II	3.14	10	10
Perchloroethylene			
O-T-236, Grade A	40.6	10	10
O-T-236, Grade B	162.4	10	10
ACS Spectrometric Grade	8.1	10	10
Isopropyl alcohol			
TT-I-735, Grade A and B	20	20	N/A
ACS Reagent Grade	3.9	10	N/A
Ethyl alcohol			
MIL-STD-1201, Type I	0.1	10	N/A
MIL-STD-1201, Type II	0.3	10	N/A
1,1,1, Trichloroethane (TCA) ODS (1)			
MIL-T-81533,	13.3	10	10
ACS, anhydrous	4.0	10	10
Vertrel MCA (1) (2)	10	10	10
HCFC-225 ca/cb (1)	10	10	10
Perfluorobutylmethylether 3M HFE 7100	10	10	10

Note:
N/A = Not allowed
ODS = Ozone depleting substances which 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.

3.6.1.2 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 NHB 8060.1, Test 13A.

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 microsiemens) and the pH of the rinse water shall be between 5.0 and 8.0.

3.6.1.3 Hydraulic Fluid. - Use of hydraulic fluid is limited to only particle population analysis and functional testing of hydraulic systems and components.

3.6.2 Precision-Clean Packaging Films.

3.6.2.1 Polyethylene. - Polyethylene film shall meet the requirements of A-A-3174 and 3.10.2.1.

3.6.2.2 Polyamide. - Polyamide films, such as Nylon 6, shall meet the requirements of 3.10.2.1.

3.6.2.3 Fluorohalocarbon. - Fluorohalocarbon films, such as Aclar 22A, 22C, and 33C, shall conform to 3.10.2.1.

3.6.2.4 Fluorocarbon. - Fluorocarbon films, such as Teflon FEP, shall conform to AMS 3647B and 3.10.2.1.

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

3.6.4 Drying and Testing Gas. - Nitrogen gas for drying and testing of precision-cleaned items shall conform to MIL-P-27401, type I, grade A, or BB-N-411, type I, class 1, grade B, and shall be prefiltered as close to the endcase as practical to the applicable cleanliness level. Helium gas conforming to MSFC-SPEC-364 is also acceptable for drying and testing.

3.7 Rough Cleaning. - All critical surfaces of systems and individual component parts shall be free of corrosion, dirt, grease, scale, or other foreign matter prior to the final precision-cleaning process. Typical process solutions for achieving these conditions are identified in appendix B.

3.8 Precision Cleaning. - This method is used to achieve a level of product cleanliness greater than the level often 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.

3.9 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, such as pickling and passivating, shall be accomplished prior to installation. Equipment and materials used should be compatible with the system and noncontaminating.

3.9.1 Preparation Prior to Field Cleaning.

3.9.1.1 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.

3.9.1.2 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 devoted to 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.

3.9.1.3 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 3.4. 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.

3.9.1.4 Installation 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.

3.9.1.5 Marking 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.

3.9.1.6 Validation of System Integrity Prior to Cleaning. - 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.

3.9.1.7 Rough Cleaning. - All critical surfaces of subsystems, systems, storage vessels, or other items in the field shall be cleaned to remove corrosion, dirt, grease, scale, or other foreign matter prior to precision cleaning.

3.9.2 Mechanical Cleaning. - This method shall be used only when contaminants so generated can be removed and when physical damage to the item being cleaned shall not occur. Mechanical cleaning may be accomplished by brushing, shot peening, grit blasting, tumbling, or grinding. 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.

3.9.3 Field Cleaning Equipment.

3.9.3.1 Closed-Loop Cleaning Equipment. - 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.

3.9.3.2 Spray Equipment. - In addition to the equipment specified in 3.9.3.1, spray equipment, such as spray wands and rotating-head spray machines, shall be required for impinging process solutions onto and wetting all internal surfaces of large items, such as storage vessels or large-diameter pipes that cannot be cleaned by closed-loop circulation. 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. Rotating or transversing spray wands shall be used.

3.9.4 Cleaning by Closed-Loop Circulation of Solution. - 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. Equipment for use in closed-loop circulation shall meet the requirements of 3.9.3.1.

3.9.5 Cleaning by Solution Spraying. - Items having a size or configuration that cannot be cleaned by circulating a fluid through the item shall be cleaned by the use of spray equipment. Equipment for use in solution spraying shall meet the requirements of 3.9.3.2.

3.10 Protection of Cleaned Surfaces.

3.10.1 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.

3.10.2 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.

3.10.2.1 Packaging Films. - All plastic films used for precision packaging shall comply with the requirements of table 3. Acceptance inspection for conformance to the requirements of table 3 shall be in accordance with 4.2.5. 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 4.2.5.3.

Table 3. 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, 22C, 33C, or equivalent fluorohalocarbon film	38 to 76 (1.5 to 3.0 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service
Teflon FEP or equivalent poly-fluoroethylenepropylene in accordance with AMS 3647	13 to 508 (0.5 to 20 mils)	Precision packaging, suitable for liquid and gaseous oxygen and hypergol service

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, 22C, and 33C, or polyfluoroethylenepropylene film conforming to 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 the KSC Plastic Film List (http://www-msd.ksc.nasa.gov/msd/nasa-only/esd-docs/films_web_.pdf) 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 micrometers (μm) (6 mils), antistatic polyethylene prior to packaging for shipment. Roll stock shall be wound on clean cores made from nondusting plastic or metal.

3.10.2.2 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 3.10.2.1 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.

3.10.2.3 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.

3.10.2.4 Protective Shields. - Flanged items sealed with plastic film in accordance with 3.10.2.1 may be covered with cardboard or wooden shields to maintain the cleanliness integrity of sealed components.

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

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

3.10.2.7 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.

3.10.3 Packaging of Cleaned Items.

3.10.3.1 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.

3.10.3.2 Purging. - Prior to final sealing of the plastic film bag containing the clean component, the plastic film bag shall be purged with filtered gaseous nitrogen in accordance with MIL-P-27401, type I, grade A, or BB-N-411, type I, class I, grade B.

3.10.3.3 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, 22C, and 33C 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.

3.10.3.4 Detailed Requirements.

3.10.3.4.1 Small Items. - Small items that have all surfaces precision cleaned shall be packaged in accordance with 3.10.2.1, sealed in accordance with 3.10.3.2, 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 0-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 3.11. The outer bag shall be sealed in accordance with 3.10.3.3.

3.10.3.4.2 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 3.10.2.1. The plastic film shall be secured in place with tape conforming to A-A-1689B. 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 3.10.2.7. 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 3.10.3.3. Each sealed fitting or other orifice of large items shall be overwrapped with polyethylene. Identification shall be in accordance with 3.11.

3.10.3.4.3 Flanged Items. - Flanged items that have only internally cleaned surfaces shall be sealed with gaskets and closures conforming to 3.10.2.2 or 3.10.2.3. 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-1689B. 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 3.10.2.7. Marking shall be in accordance with 3.11.

3.10.3.4.4 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 3.11. Tamper-proof decals shall be applied to the outer bag in accordance with 3.10.2.7.

3.10.3.4.5 Hose and Tube Assemblies. - Hose and tube assemblies that have only internally cleaned surfaces shall be sealed with plastic film in accordance with 3.10.2.1. The plastic film shall be secured in place with tape conforming to A-A-1689B. 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.

3.11 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

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection. - The cognizant cleaning organization is 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. - 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.

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 D1193 type II reagent water to permit testing as required. When tested, the pH shall range from 5 to 8.

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, 4.2.3.1 to 4.2.4.4.

4.2.3.1 Test Fluids. - The test fluids shall not react with, combine with, etch, or otherwise cause immediate or latent degradation with the item being tested and shall be selected from those specified in 3.6.1, unless otherwise approved by the M&PE. The test fluid shall meet the following requirements:

a. The test fluid shall be filtered of particulate greater than 1.0 μm and shall not exceed NVR levels specified in table 2. 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 prior to use.

CAUTION

Halogenated solvents shall not be used on titanium alloys. Trichlorotrifloroethane (Freon TF) shall be limited in use to controlled processes that have been approved by the CO.

4.2.3.2 Test Fluid Volume for Analysis. - The standard test sample shall be 500 milliliters (mL) of test fluid to ensure all critical surfaces are flushed. The 500-mL sample of test fluid shall represent a minimum surface area of 0.1 m^2 to a maximum of 0.5 m^2. The test fluid volume required for analysis shall be dependent upon the analytical method employed. 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.

4.2.3.3 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 (see appendix A).

b. Flush all critical surfaces uniformly with the test fluid. Tubing, piping, and hoses shall be flushed in accordance with either test method I or test method II (see appendix A). 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 appendix A).

4.2.3.4 Analysis of Test Fluid-Flush 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 which have demonstrated accuracy and repeatability and their use is approved by the CO.

4.2.3.4.1 Particle Population Analysis (Solvent-Flush). - The solvent-flush sample shall be analyzed for particle population as follows:

4.2.3.4.1.1 Microscopical Particle Population. - Particle analysis shall conform to ASTM F312. A sample preparation and analysis procedure is provided in appendix A.

4.2.3.4.1.2 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.

4.2.3.4.2 NVR Analysis (Solvent-Flush). - The solvent-flush samples that have been filtered in accordance with 4.2.3.4.1.1 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 M&PE prior to use. The following paragraphs describe three accepted methods.

4.2.3.4.2.1 Gravimetric NVR Analysis Method. - The filtered solvent sample shall be evaporated to determine the NVR content in accordance with ASTM F331 as discussed in appendix A.

4.2.3.4.2.2 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.

4.2.3.4.2.3 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 which are reactive with liquid oxygen.

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

4.2.3.5 Analysis of Aqueous-Based Fluid-Flush Sample. - The aqueous-based fluid-flush samples shall be analyzed for particle population and NVR as follows.

4.2.3.5.1 Particle Population Analysis (Aqueous). - The particle analyses of 4.2.3.4.1 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.

4.2.3.5.2 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 appendix A.

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

4.2.3.6.1 Purge Drying. - All components and parts rinsed shall be dried by a purge of filtered test gas in accordance with 3.6.4. 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 4.2.3.6.1.1 shall be performed. Component parts may be dried with heated air drivers equipped with HEPA filters.

4.2.3.6.1.1 Dewpoint Analysis. - All items rinsed with reagent water which cannot be visually inspected (100 percent) shall be tested by test method III (see appendix A) for surface moisture.

4.2.3.6.2 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 evacuated until dry. Recommended vacuum drying practices are discussed in appendix A.

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 or test method II (as described in appendix A). Testing procedures are determined by the configuration of the item being cleaned and by the method of dispensing the test fluid.

4.2.4.1 Test Fluids. - The test fluids shall be in accordance with 4.2.3.1.

CAUTION

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.

4.2.4.2 Ratio of Testing Fluid Volume to Critical Surface Area. - All critical surface areas shall be sampled with test fluid unless specified otherwise. 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.

4.2.4.3 Particle Population Analysis. - Each sample shall be tested for particle population in accordance with the procedure of 4.2.3.4.1. Particle population per 0.1 m^2 shall be determined on the basis of the proportional critical surface area.

4.2.4.4 NVR Analysis. - The NVR shall be determined in accordance with 4.2.3.4.2. NVR per 0.1 m^2 shall be determined on the basis of the proportional critical surface area.

4.2.4.5 Drying. - All items cleaned in the field shall be dried in accordance with 4.2.3.6.

4.2.4.6 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 organization.

4.2.4.6.1 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 3.6.4.

4.2.4.6.2 Temporary Hardware Replacement. - Temporary hardware installed in subsystems, systems, and related field equipment for cleaning (refer to 3.9.1.3 through 3.9.1.5) 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.

4.2.4.6.3 Component Replacement. - Replacement of functional components in clean systems shall be in accordance with 4.2.4.6.2.

4.2.5 Acceptance Inspection of Packaging Materials.

4.2.5.1 Environmental Control. - All quality assurance operations shall be accomplished within a cleanroom conforming to FED-STD-209, 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.

4.2.5.2 Sampling. - Packaging materials shall be examined and tested to determine compliance with the cleanliness requirements of 3.10.2.1. 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.

4.2.5.3 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.

4.2.5.4 Thickness of Packaging Film. - The thickness of plastic films used for precision packaging shall conform to the limits specified in table 3. 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).

4.2.5.5 Verification of Cleanliness Level. - All plastic films of one lot shall have the cleanliness level verified prior to use.

4.2.5.5.1 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 4.2.5.2, except that additional sample material from the offered lot shall be used when necessary to make 0.1 m^2.

4.2.5.5.2 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 4.2.5.5.1 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 4.2.5.5.1,

folding the section, and sealing the section as necessary. The cutting technique shall be in accordance with 3.10.3.1. The sealing technique shall be in accordance with 3.10.3.3. 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.

4.2.5.6 Rinsing Procedures. - Test fluid that conforms to the cleanliness level of 4.2.3.1 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 (s), 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 4.2.3.4.

4.2.6 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.

4.2.6.1 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).

4.2.6.2 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.

4.2.6.3 Component Testing. - Functional components, such as valves, solenoid valves, regulators, actuators, and cylinders, shall be assembled using clean parts in accordance with 3.4 and shall be functionally tested with gaseous nitrogen

conforming to 3.6.4 unless otherwise specified. The component will be tested at the specified conditions.

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 show 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 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, filters, etc. 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).

5. PREPARATION FOR DELIVERY

5.1 Preservation and Packaging. - Preservation and packaging of cleaned items shall be in accordance with 3.10.

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, shall not be 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 3.10 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, tiedown rods, or lumber holddowns. 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 Ordering Data. - Procurement documents 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 3.3)

d. Whether functional testing is required on items disassembled for cleaning (see 3.4)

e. Whether special preservation, packaging, packing, and marking are required beyond the requirements of section 5

6.3 Definitions.

a. Accuracy. Accuracy is how close the measured value is to the "true" value.

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

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

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

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

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

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

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

i. Fiber. A fiber is a nonmetallic, flexible structure having a length-to-width ratio of 10 to 1 or greater.

j. Field Cleaning. The processes of rough cleaning and precision cleaning of large components and systems which cannot be processed in a controlled environment such as a cleanroom.

k. Fluid. For the purpose of this specification, a fluid is defined as a gas or liquid.

l. Generally Clean (GC). Generally clean (GC) is freedom from manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. This level shall not be designated for hardware that is sensitive to contamination.

m. High-Efficiency Particulate Air (HEPA) Filter. A HEPA filter is a filter that is at least 99.97-percent efficient by volume on 0.3-micron particles.

n. Hydrocarbon. A hydrocarbon is an organic compound consisting exclusively of the elements of carbon and hydrogen.

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

p. 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.)

q. Nonvolatile Residue. Nonvolatile residue is soluble or suspended material and insoluble particulate matter remaining after temperature-controlled evaporation of a filtered volatile liquid.

r. Oxidizer. Oxidizers are commodities, such as liquid oxygen and nitrogen tetroxide, which when combined with fuels (liquid hydrogen and hydrazine respectively) constitute the propellants for rocket engines. For the purposes of this specification gaseous oxygen and breathing air shall be considered oxidizers.

s. Part. A part is one piece of two or more pieces joined together in such a way that it is not normally disassembled without destruction of the designed use. Fittings, 0-rings, and poppets are normally considered parts of a valve.

t. Particle. A particle is a unit of matter with observable length, width, and thickness and is usually measured by its largest dimension in micrometers.

u. 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.

v. Passivation. Passivation is the process by which a corrosive-resistant layer is bonded to a metal surface by submersing the surface in an acid solution.

w. 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.

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

y. Precision Cleaning. Precision cleaning is a cleaning process used to achieve cleanliness levels more stringent than level VC.

z. Repeatability. Repeatability is reproducibility to acceptable level of precision.

aa. Rough Cleaning. Rough cleaning is the cleaning process normally used to achieve cleanliness level VC.

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

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

ad. System. A system is a series of subsystems joined together to perform a definite function.

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

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

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

ah. Visually Clean (VC). Visually clean is the absence of all particulate and nonparticulate matter visible to the normal unaided (except corrected vision) eye. Particulate is identified as matter of miniature size with observable length, width, and thickness. Nonparticulate is normally a film matter without definite dimension. This level, with the exception of the orbiter payload (cargo) bay, payload canister, and payloads, requires precision-cleaning methods but no particle count. Level VC is commonly referred to as commercially clean.

ai. Visually Clean Plus Ultraviolet (UV). UV is visually clean (VC) and inspected with the aid of an ultraviolet light (black light) of 3200 to 3800 angstroms wavelength (3.2×10^{-7} to 3.8×10^{-7} meters). This level requires precision-cleaning methods but no particle count. Fluorescents indicate possible hydrocarbon contamination. If recleaning fails to remove fluorescent indications, an investigation should be made to determine if the item material is naturally fluorescent.

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

NOTICE. The Government drawings, specifications, and/or data are prepared for the official use by, or on the behalf of, the United States Government. The Government neither warrants these Government drawings, specifications, or other data, nor assumes any responsibility or obligation, for their use for purposes other than the Government project for which they were prepared and/or provided by the Government, or an activity directly related thereto. The fact that the Government may have formulated, furnished, or in any way supplied the said drawings,

specifications, or other data is not to be regarded, by implication or otherwise, as licensing in any manner the holder or any other person or corporation, nor conveying the right or permission, to manufacture, use, or sell any patented invention that may relate thereto.

Custodian:

NASA - John F. Kennedy Space Center
Kennedy Space Center, FL 32899

Preparing Activity:

John F. Kennedy Space Center
Materials Science Division
Logistics Operations Directorate

APPENDIX A

SAMPLING, ANALYTICAL, AND DRYING PRACTICES

A.1 SCOPE

This appendix provides the sampling and analytical methods recommended to verify cleanliness levels, as well as component drying practices.

A.2 CLEANLINESS LEVEL TEST METHODS

A.2.1 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 surface area greater than 0.5 m^2 must be flushed with 100-mL maximum per 0.1 m^2 of significant surface area. However, the test sample volume shall be 500 mL and any excess shall be discarded. For parts having an area less than 0.5 m^2, but greater than 0.1 m^2, a 500-mL sample is considered representative of the actual surface area of the part being sampled.

c. 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.

d. Significant areas of large components, flanges, valves, etc. (items too large to dip), shall be flushed and sampled.

e. Individual components, such as drums, having an area greater than 0.5 m^2 must be flushed 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).

f. Small containers with less than 0.5 m^2 internal surface area, such as hoke cylinders, dewars, etc., must be sampled by using 500 mL of test fluid. Agitate the container to cover all significant surfaces with sample medium; then drain the test fluid from the container for analysis.

A.2.2 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.2.3 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 3.6.4.

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 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.2.4 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 which 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.3 MICROSCOPICAL PARTICLE POPULATION

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 4.2.3.4.2.

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 F312 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.4 GRAVIMETRIC NVR ANALYSIS METHOD

Perform the gravimetric NVR analysis in accordance with ASTM F331 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.3 into the clean, degreased flask.

b. Evaporate the 500-mL sample to 10- to 20-mL volume.

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 5 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 105 to 110 °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.5 AQUEOUS ULTRASONIC SAMPLING AND TOTAL CARBON 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.5.1 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. Rosemont/Dohrmann DC-190 total carbon analyzer (TCA) or equivalent high-temperature (880 °C) combustion analyzer with sensitivity of ±0.2 ppm carbon (c) (mgC/L) and direct sample injection into combustion furnace

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

A.5.2 Procedure.

A.5.2.1 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.5.2.2 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 (TC_S).

A.5.2.3 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 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.6 AQUEOUS IMPINGEMENT SAMPLING AND TOTAL CARBON NONVOLATILE RESIDUE (NVR) ANALYSIS

This procedure defines the method of performing aqueous impingement sampling performed at ambient temperature and total carbon NVR analysis of large parts.

NOTE

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

A.6.1 Equipment. - The equipment unique to performing this procedure is as follows:

a. Aqueous impingement hardware drawing 80K57369

   (1) Breathing air (BAIR)/water supply panel

   (2) Sampling nozzles

   (3) Hoses

b. Catchpan

c. Beaker (400 mL)

d. BAIR supply - 3100 kPa (450 psig) supply pressure minimum

e. Rosemount/Dohrmann DC-190 TCA or equivalent high-temperature (880 °C) combustion analyzer with sensitivity of ±0.2 ppm carbon (mgC/L) and direct sample injection into the combustion furnace.

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

g. Sampling water - reagent grade water (RGW)

A.6.2 Procedure.

A.6.2.1 Preliminary Steps.

a. Set the TCA to the syringe mode and set the optimum parameters with the furnace temperature at 880 °C. Calibrate the TC analyzer in accordance with the manufacturer's instructions.

b. Set up BAIR water supply panel with hoses and nozzle. Fill the water supply vessel with fresh RGW. Secure the water supply vessel in the operational mode.

c. Set the BAIR pressure to 2070 kPa (300 psig). To begin impingement flow, first open the BAIR supply valve and then open the reagent water supply valve.

d. Using the impingement system, impinge the catchpan for 1 minute per 0.1 m^2 surface area. Dry the catchpan with the BAIR. Allow water to run through the system at a reduced system pressure of 345 to 690 kPa (50 to 100 psig) and collect 50 to 100 mL of water from the nozzle on the catchpan for blank water sample (TOC_B).

e. Perform TCA on 200 mL of blank water sample.

f. Record the TCA reading of the blank water sample. If the TOC_B value is not less than 1.0 ppm (mgC/L), drain the water tank, refill the tank, and repeat the TCA (steps d through f).

A.6.2.2 Sampling.

a. Suspend the clean component above the catchpan with a 400-mL beaker to collect the sample from the catchpan drain.

NOTE

This is a noisy operation. The operator and anyone in the immediate area shall wear eye and double ear protection.

b. Begin the nozzle flow with the BAIR pressure 2070 kPa (300 psig). Allow excess water accumulated in the hose to be drained from the nozzle.

c. Beginning at the high point of the critical surface to be sampled, begin impingement sampling. Hold the nozzle within 50 mm (2 in) of the surface. Move the nozzle back and forth and downward across the sampling surface at a rate of approximately 0.05 m^2/min (0.5 ft^2/min) until the entire critical surface has been sampled. The sampling rate or time is a function of the critical surface area (refer to calculations).

d. When the impingement sampling is complete, turn off the water supply and lower the BAIR supply pressure to approximately 345 kPa (50 psig). Gently air sweep water droplets in the catchpan towards the sampling beaker collection point (drain) and collect in a beaker. If the water sample contains visible scum, the test sample fails NVR.

e. Draw a 200-microliter sample of water from the beaker with a syringe.

f. Inject a 200-microliter sample of water into the TCA following the instrument operating instructions.

g. Record the sample TCA results (TOC_S): the sampling time (T_{S_1}) and the critical surface area (A) sampled.

h. Repeat steps f through g for a minimum of three injections until a stable reading is obtained and average the three most stable readings.

A.6.2.3 Calculation.

a. Equivalent Nonvolatile Residue (Aqueous Impingement Sampling)

$$NVR = \frac{[(TOC_S - TOC_B)VOL_C]}{146.6 x SF_A \ x \ A^{2.5}}$$

Where:

NVR	=	Equivalent NVR (mg/m^2 or mg/0.1 m^2)
TOC_S	=	Total organic carbon value of sample (mgC/L or ppm)
TOC_B	=	Total organic carbon value of blank (mgC/L or ppm)
A	=	Surface area sampled (m^2)
SF_A	=	Sensitivity factor (mgC/mg contaminant), empirical constant derived from text of known contaminants, at a known area A.
VOL_C	=	Sample volume of water collected (mL)

b. Estimated Sampling Time (Aqueous Impingement Sampling)

$$T_S = \sqrt{21A}$$

Where:
T_S = Sampling time (minutes)
A = Critical surface area to be sampled (m^2)

c. Sensitivity Factor (Aqueous Impingement Sampling)

$$SF_A = \frac{(TOC_S - TOC_B)\ VOL_C}{A \times D}$$

Where:
SF_A = Sensitivity factor (mgC/mg contaminant) at a known area A
D = Contaminant distribution concentration (mg of contaminant/m^2)

The sensitivity factor will vary based on A and T_S. It is recommended that SF be determined for 0.05, 0.1, 0.2, and 0.5 so that a practical maximum A can be determined.

A.7 VACUUM DRYING

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

A.7.1 EQUIPMENT

a. Vacuum oven - temperature control range of 43 °C (110 °F) to 121 °C (250 °F)

b. Purge (test) gas - in accordance with 3.6.4

c. Thermocouple - independent temperature monitoring of parts

A.7.2 PARTS HEATING

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

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

b. The maximum drying temperature for parts containing nonmetallics shall be 65 °C (150 °F)

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

A.7.3 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 for the period specified in table A-1. Once the parts have been dehydrated, the heat should be discontinued and the oven slowly back-filled with the test gas.

Table A-1. Vacuum Drying Time (Hours)

Vacuum Oven Pressure		Temperature				
psia	torr	43 °C (110 °F)	54 °C (130 °F)	65 °C (150 °F)	76 °C (170 °F)	87 °C (190 °F)
2.9	150	-	-	-	0.9	0.75
2.4	125	-	-	1.3	0.8	0.75
1.9	100	-	4.8	1.2	0.75	0.75
1.4	75	-	2.0	0.8	0.75	0.75
0.93	50	3.4	1.1	0.75	0.75	0.75
0.44	25	0.9	0.75	0.75	0.75	0.75
0.29	15	0.75	0.75	0.75	0.75	0.75

APPENDIX B

ROUGH CLEANING PROCESSES

B.1 SCOPE

This appendix provides nonmandatory supplemental guidance information relating to establishing cleaning procedures.

B.2 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.3. ROUGH CLEANING TYPES

The following cleaners or their equivalents may be used for removing gross forms of contamination.

NOTE

> Chemical cleaning agents must be compatible with material composition to prevent excessive attack or latent degradation.

B.3.1 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.3.2 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.3.3 Degreasers (Organic and Aqueous Based Solvents). - Degreasers are used to remove some forms of organic contamination; e.g., oils, grease, and hydrocarbon fuels.

B.3.4 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.3.5 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.3.6 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.

B.3.7 Mechanical Cleaning. - Mechanical cleaning removes contamination by abrasive action. It is used only when physical damage to the item being cleaned will not occur. Mechanical cleaning includes wire brushing, shot blasting (wet and dry), grinding, abrasive blasting (wet or dry), the use of aluminum oxide, abrasive-coated papers and cloths, and related methods.

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.4 ROUGH CLEANING PROCESSES

Table B-1 shows recommended rough cleaning processes and sequences.

Table B-1. Selection Chart for Rough Cleaning Processes

NOTE:
Symbols in the block denote 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
Nonmetallic parts	As received					X					X	X	X
Electroplated parts and dissimilar metals	As received		X	X							X	X	X

* ASTM A380 describes in detail recommended methods for descaling and cleaning stainless steel.