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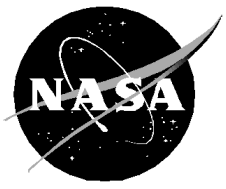
CONTAMINATION CONTROL REQUIREMENTS MANUAL

Occupational Safety and Quality Assurance Branch

Occupational Safety and Institutional Assurance Division

May 2000



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

CONTAMINATION CONTROL REQUIREMENTS MANUAL

NOTICE

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REVISIONS AND CHANGES			
REV LTR	CHANGE NO.	DESCRIPTION	DATE
----	----	Baseline	September 1970
A	----	Revision A	December 1974
A	1	Change 1	August 1980
B	----	Revision B	November 1982
C	----	Revision C	February 1994
C	1	Change 1 (revised Table V, page B-7)	September 1995
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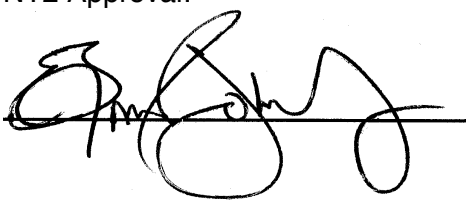
		NT2 Approval: 	

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1.0 INTRODUCTION

1.1 PURPOSE

The JSC Contamination Control Requirements Manual establishes the requirements and criteria for coordinated contamination control activities. This manual provides the minimum controls necessary to establish and maintain an effective contamination control system.

JSCM 8080, "JSC Design and Procedural Standards Manual," stipulates additional mandatory contamination control requirements. The latest issue of JSCM 8080 should be reviewed to ensure that standards relating to contamination control which are issued after publication of this document are also implemented.

1.2 APPLICABILITY

This manual is applicable to JSC organizations and on-site contractors who are responsible for designing, developing, manufacturing, inspecting, processing for shipment, and testing of flight or flight-related equipment. Portions of this document may be specified in JSC contracts as applicable.

1.3 ACRONYMS AND DEFINITIONS

Definitions of and acronyms for terminology used in this manual are contained in appendix A.

1.4 TRADE NAMES

The use of trade names of commercially available products does not constitute an endorsement of those products by NASA nor does it imply that there are no other suitable products available.

1.5 WAIVERS AND DEVIATIONS

If it is apparent that the requirements of this manual cannot be complied with, a waiver or deviation shall be initiated by the responsible technical organization and submitted in sufficient time to allow for proper evaluation and disposition. Requests shall be submitted by memorandum to the Director, Safety, Reliability, and Quality Assurance (SR&QA). The Director, SR&QA, has approval authority with concurrence, as required, by the Director, Space and Life Sciences.

At White Sands Test Facility (WSTF), the manager responsible for contamination control activities shall have full authority over waivers and deviations to the requirements contained in this document.

1.6 QUALITY ASSURANCE

At JSC, the Institutional Safety and Quality Division is responsible for ensuring compliance with this manual. Applicable inspection requirements are delineated within the text.

1.7 REVISIONS AND CHANGES

All revisions and changes to this manual must be approved by formal JSC concurrence procedures, as specified in applicable JSC management documentation. The Director, SR&QA, has approval authority for editorial changes (e.g., correction of typographical errors) to this manual.

Many American Society for Testing and Materials (ASTM) and Institute of Environmental Sciences (IES) publications are considered to be "full-consensus" publications and are used by representatives of all sectors of industry and government. Contamination control requirements should follow ASTM, IES, or similar guidelines when not specified in this manual.

2.0 REFERENCE DOCUMENTS

The latest revisions of the documents listed below are applicable to the extent specified herein. Any conflicts between the documents referred to herein and the contents of this manual should be referred to the Occupational Safety and Quality Assurance Branch for resolution.

NOTE: References on nonairborne breathing systems and on air, oxygen, and oxygen-rich systems are listed in sections 20.0 and 21.0, respectively.

2.1 FEDERAL STANDARDS AND SPECIFICATIONS

a. FED-STD-102, "Preservation, Packaging, and Packing Levels"

b. FED-STD-209E, "Federal Standard, Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones"

c. PPP-T-66, "Type I, Class B - Tape: Pressure Sensitive Adhesive Water-Proof - for Packaging and Sealing"

d. TT-I-735, "Specification, Isopropyl Alcohol"

2.2 ASTM STANDARDS AND PRACTICES

a. ASTM D2109-71, "Nonvolatile Matter in Halogenated Organic Solvents and Their Admixtures"

b. ASTM F51-65T, "Sizing and Counting Particulate Contamination in and on Clean Room Garments"

c. ASTM D1605, "Standard Recommended Practices for Sampling Atmospheres for Analysis of Gases and Vapors"

d. ASTM D2407, "Standard for Sampling Airborne Particulate Contamination in Clean Rooms for Handling Aerospace Fluids"

e. ASTM E21.05, "Standard Method for Measurement of Nonvolatile Residue (NVR) on Surfaces"

f. ASTM E 595-20, "Standard Test Method for Total Mass Loss and Collected Volatile Conder Materials From Outgassing in a Vacuum Environment"

g. ASTM F24, "Standard Method for Measuring and Counting Particulate Contamination on Surfaces"

2.3 INSTITUTE OF ENVIRONMENTAL SCIENCES PUBLICATIONS

a. "IES Handbook of Recommended Practices, Contamination Control Division"

b. IES-CC-009-84, "Compendium of Standards, Practices, Methods, and Similar Documents Relating to Contamination Control"

c. IES-RP-CC-002-83-T, "Laminar Flow Clean Air Devices"

2.4 MILITARY HANDBOOKS, SPECIFICATIONS, STANDARDS, AND TECHNICAL ORDERS (TOs)

a. MIL-A-18455, "Argon, Technical"

b. MIL-C-10578, "Corrosion Removing and Metal Conditioning Compound (Phosphoric Acid Base)"

c. MIL-P-116, "Preservation, Methods of"

d. MIL-P-27401, "Nitrogen, Grade A, B, or C"

e. MIL-HDBK-406, "Cleaning Materials for Precision-Cleaning and Use in Clean Rooms and Clean Work Stations"

f. MIL-HDBK-407, "Precision-Cleaning Methods and Procedures"

g. MIL-HDBK-410, "Contamination Control Technology, Logistic Protection of Precision-Cleaned Material"

h. MIL-M-9950, "Military Specification: Missile Components; Liquid Oxygen, Liquid Nitrogen, Gaseous Oxygen, Gaseous Nitrogen, Instrument Air, Helium and Fuel Handling Systems; Cleaning and Packaging for Delivery"

i. MIL-STD-1246, "Product Cleanliness Levels and Contamination Control Program"

j. MIL-STD-1695, "Military Standard: Environment, Working, Minimum Standards"

k. TO 00-25-203, "Contamination Control of Aerospace Facilities, US Air Force"

l. TO 42C-1-11, "Cleaning and Inspection Procedures for Ballistic Missile Systems"

2.5 NASA PROCEDURES, REQUIREMENTS, SPECIFICATIONS, AND STANDARDS

a. JSC-01218, "JSC Standard Procedures for Liquid and Gas Sampling"

b. JSCM 5341, "Requirements for Sampling Atmospheric Gases and Hydrogen"

c. JSCM 8080, "JSC Design and Procedural Standards Manual" (G-5, G-9, G-13, G-20, G-21, E-10, F-11, F-17, F-20, F-23, F-24, F-25, F-26, F-27, F-28, F-29, and M/P-9)

d. KSC-C-123, "Specification for Surface Cleanliness of Fluid Systems"

e. MSCF-PROC-166D, "Procedures for Cleaning, Testing, and Handling Hydraulic System Detailed Parts, Components, Assemblies, and Hydraulic Fluids for Space Vehicles"

f. MSFC-SPEC-164A, "Specification for Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems"

g. MSFC-STD-246, "Standard Design and Operation Criteria of Controlled Environmental Areas"

h. NHB 53401, "NASA Standard Procedures for the Microbiological Examination of Space Hardware"

i. NHB 5340.2, "NASA Standards for Clean Rooms and Work Stations for the Microbially Controlled Environment"

j. NHB 8060.1C, "Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion"

k. NSTS 07700, Volume XIV, "Space Shuttle System Payload Accommodations," section 3.6.12, "Contamination Control"

l. NSTS 08242, "Limitations for Nonflight Materials and Equipment Used in and Around the Shuttle Orbiter Vehicles"

m. SE-S-0073, "NSTS Specification, Fluid Procurement and Use"

n. SN-C-0005, "Contamination Control Requirements for the Space Shuttle Program"

o. SP-5015, "Advances in Sterilization and Decontamination, A Survey," 1978

p. SP-5076, "Contamination Control Handbook," 1969

2.6 OTHER REFERENCES

a. SAE-ARP-598, "SAE Aerospace Recommended Practice for the Determination of Particulate Contamination in Liquids by the Particle Count Method"

b. ANSI Z9.2, "Fundamentals Governing the Design and Operation of Local Exhaust Systems"

c. MDC H4070 (Space Station), "Contamination Control Plan"

d. NFPA B93.19, "Method for Extracting Fluid Samples from the Lines of an Operating Hydraulic Fluid Power System for Particulate Contamination Analysis"

e. NFPA 318, "Standard for Fire Protection in Cleanrooms"

f. Rockwell MA0110-301, "Product Cleanliness"

g. SAE ARP-743, "Procedures for the Determination of Particulate Contamination of Air in Dust Controlled Spaces by the Particle Count Method"

h. "Spacecraft Cleanliness Control for Particles," 10th International Symposium on Contamination Control (ICCCS 90), Zurich, Switzerland, September 10-14, 1990

3.0 PROCUREMENT

Procurement documents for flight and flight-related equipment, environmental test facilities, nonairborne breathing systems, facility fluid systems, precision-cleaned packaging materials, and garment maintenance services shall include appropriate contamination control requirements. These requirements shall be based upon the design and application of the procured item and shall be appropriately tailored for each procurement.

Requirements may be selected from JSC documents; e.g., SN-C-0005, "Contamination Control Requirements for the Space Shuttle Program," and this manual. The Occupational Safety and Quality Assurance Branch will, upon request, assist JSC organizations in the selection of cost-effective contamination control requirements.

3.1 CONTAMINATION CONTROL PLAN

The purpose of a contamination control plan is to ensure product cleanliness. Procurements for spacecraft and spacecraft systems and subsystems shall include the requirements for a contamination control plan. Procurements for items of lesser complexity may also require a contamination control plan when stringent cleanliness requirements are specified or when contamination control is important.

3.2 CLEANLINESS CERTIFICATION

Procurement documents for systems, subsystems, and major assemblies shall require that the contractor submit a certification of cleanliness which identifies the cleanliness level to which the contract item was cleaned and verified.

3.3 REVIEW OF PROCUREMENT DOCUMENTATION

Contamination control provisions of contracts shall be submitted to the Mechanical and Chemical Process Engineering and GFE Branch, or approved alternate, for review.

4.0 RECEIVING INSPECTION

Items cleaned to precision levels must be inspected upon receipt to ensure that storage, transit, and handling of the packaged item have not violated the cleanliness integrity. Requirements applicable to visibly clean plus ultraviolet (VC + UV), visibly clean (VC), and generally clean (GC) items are stated herein.

4.1 PACKAGING INSPECTION

Precision, VC + UV, or VC items shall be visually inspected for packaging integrity. If the seal integrity is found to have been violated, the items shall be returned to the supplier or routed for cleaning and certification.

4.2 PACKAGING REMOVAL

During inspection, precision and VC + UV packaging shall be removed (if removal is necessary) in only a controlled environment to prevent degradation of item cleanliness.

4.3 ITEM INSPECTION

Visible evidence of item damage from transit, handling, packaging, or other causes shall be reason for rejection. This requirement is applicable to all items. GC items shall be inspected for cleanliness and, if necessary, cleaned to the GC level using a hardware-compatible process. Visible contamination on items cleaned to precision, VC + UV, or VC levels shall be cause for rejection.

4.4 REPACKAGING

If a controlled environment is required, all items (except GC items) shall be repackaged before their removal from the controlled environment and after completion of receiving inspection. In those cases where item cleanliness cannot be ensured, the item must be recleaned before repacking.

4.5 DOCUMENTATION

Documentation accompanying precision, VC + UV, or VC items shall be reviewed for compliance with applicable purchase order or engineering requirements, including certification of cleanliness. Such documentation and/or item certification shall be maintained as a permanent record traceable to the item received.

5.0 ENVIRONMENTALLY CONTROLLED AREAS (ECAs)

Areas designated as ECAs shall include clean rooms, laminar flow clean work stations, and controlled work areas (CWAs). When a facility is so identified, it shall be controlled by a documented cleaning and process procedure which, as a minimum, meets the requirements delineated herein. Clean rooms used for final cleanliness verification, assembly, testing, and packaging of precision, VC + UV, and VC cleaned articles, and all laminar flow clean work stations used to process flight or flight-related equipment, shall be certified.

5.1 TYPES AND CLASSIFICATIONS

5.1.1 Clean Room Design

FED-STD-209E describes several clean room types which include conventional and laminar airflow designs. The final filters used in clean rooms shall be high-efficiency particulate air (HEPA) filter assemblies. The Occupational Safety and Quality Assurance Branch will, upon request, assist JSC organizations with the selection of an appropriate clean room design.

5.1.2 Selection of Clean Room Class

Cleanliness classes of clean rooms used at JSC shall comply with FED-STD-209E. Selection of the clean room classes to be used shall include consideration of the surface cleanliness level required, the articles to be processed, and the time required for processing. As the processing time increases, the airborne particulate control required becomes more stringent; therefore, two articles requiring the same surface cleanliness level, but greatly different processing times, will also require different clean room classes. The Occupational Safety and Quality Assurance Branch must concur in the selection of clean room classes for flight and flight-related equipment (see table I, appendix B).

NOTE: Regardless of clean room class, prolonged exposure of unprotected surfaces will result in contamination in excess of the allowable cleanliness level; therefore, operating procedures shall specify intermediate packaging of all items when the items are not actually being processed.

5.1.3 Laminar Flow Clean Work Stations

The final filters used in clean work stations shall be HEPA filter assemblies. Regardless of the surrounding environment, clean work stations reflect the efficiency and integrity of the HEPA filter; therefore, all JSC clean work stations shall be classified and maintained to a *Class 100 Level*, as a minimum, and shall meet the detailed requirements specified in sections 5.2 and 5.4.

5.1.4 CWA Classification

Laboratories, special workrooms, vacuum chambers, or other facilities that require environmental and contamination controls, which are not clean rooms but do meet the minimum requirements of sections 5.2 and 5.5, may be identified as CWAs.

5.2 ENVIRONMENTALLY CONTROLLED AREA OPERATIONAL REQUIREMENTS

These are common requirements applicable to all ECAs at JSC. Detailed requirements for each specific facility type are contained the in subsections below. Table II, appendix B, provides a ready reference matrix of requirements relating to ECAs.

5.2.1 Garments

a. All personnel using an ECA shall wear approved clean room garments. Minimum garment requirements for ECAs are listed in table III, appendix B. Clean room garment requirements for ECAs shall be approved by the Mechanical and Chemical Process Engineering and GFE Branch.

b. Garments shall be changed as required to maintain product cleanliness.

c. Personnel must remove clean room garments in the change area before leaving the ECA. In the event the garments are worn outside the ECA, personnel shall be barred from reentry until they have changed garments. Garments worn outside the ECA or worn during contaminant-generating operations shall be considered contaminated and must be exchanged for clean garments.

d. Special footwear may be optional, depending upon the type facility; however, mud-caked or dirty shoes shall not be allowed in the ECA. Shoes shall be cleaned with a mechanical shoe cleaner or by other appropriate cleaning methods before the wearer enters the clean room. Tacky mats or other approved mats (e.g., magna mats) shall be used at the entry to the ECA.

5.2.2 Personnel Training

ECA personnel shall be trained in accordance with section 14.0.

5.2.3 Tools and Fixtures

a. Tools and fixtures shall be kept in drawers or stainless steel wire baskets and shall be covered when not in use. Tools shall not be kept in toolkits with felt-lined drawers or leather cases. Tools may be kept on clean polyurethane foam wipers.

b. Tools used in all clean room activities for spacecraft operations, or in work associated with flight equipment, shall be corrosion resistant and shall be constructed of minimum particulate-generating materials.

c. All equipment shall be cleaned to a VC condition before its entry into the clean room, clean bench, or CWA. Each tool shall be examined before each use to verify that the VC condition has been maintained. Tools with cracks, chips, or evidence of corrosion shall be removed from the area and the discrepancy remedied. Metal-abrading tools (e.g., pipe wrenches, pliers, and knurled-jaw holding tools such as vise grips) and vises shall not be permitted in an ECA.

d. All cabinets, stools, benches, etc., shall be constructed of minimum particle-generating material.

5.2.4 Oil, Grease, and Lubricants

Oil, grease, and lubricants, other than those approved for specific applications, shall not be permitted in the ECA.

5.2.5 Grease or Oil Deposits

Operations, equipment, or other sources causing grease or oil deposits shall not be permitted. Equipment that generates hydrocarbons (oil, grease, smoke, etc.) shall not be allowed in the

ECA. Electrically operated equipment or other non-hydrocarbon-generating equipment may be used; however, it shall be verified clean by the appropriate quality organization before use.

5.2.6 Compressed Gas

Compressed gas used within the ECA shall be supplied from a source that is equipped with dehydrators and filters capable of removing all types of contamination. Regular maintenance of this equipment shall be scheduled and recorded.

5.2.7 Paper Products

All paper products not necessary for operation shall be excluded from the ECA. Paper products required for operation shall be of a type treated to prevent particulate generation or shall be enclosed in a plastic bag, except at times when exposure is required to read or sign off a particular operation.

5.2.8 Wiping Material

Only approved, clean, low-lint wiping cloths or clean polyurethane wipers shall be used for cleaning operations.

5.2.9 Smoking, Food, and Beverages

Smoking, food, and beverages shall not be allowed in the ECA.

5.3 CLEAN ROOM REQUIREMENTS

Clean rooms shall be certified in accordance with section 6.0. The requirements stated below shall be observed in addition to those specified in section 5.2.

5.3.1 Clean Room Operational Requirements

Clean room operational requirements shall be established to ensure effective contamination control of the article to be processed. Requirements may be selected from, but are not limited to, those contained in the appendix to FED-STD-209E. The items described below are mandatory for JSC clean rooms.

5.3.1.1 Clean Room Furnishings. Clean room furniture shall be constructed of materials which exhibit a minimum of chipping, flaking, oxidizing, or other deterioration. Paint shall be hard and nonflaking, such as epoxy. For furniture subjected to abrasion and bumping, stainless steel or laminated plastic surfaces shall be chosen.

5.3.1.2 Work Station Location. The most contamination-sensitive articles shall be processed at work stations closest to the filter bank or in laminar flow clean rooms, and processed at the worker level. Obstructions to the airflow shall be kept to a minimum, particularly upstream of critical work.

5.3.1.3 Airborne Particle Monitoring. Particulate contamination of the clean room shall be determined at various periods during the work cycle to ascertain peak contamination times. The clean room shall then be monitored at least once daily during those periods of greatest con-

taminant generation (normally during those periods of greatest occupancy). Air sampling shall be performed with an isokinetic nozzle.

5.3.1.4 Positive Pressure. The minimum positive pressure differential between the clean room and any adjacent area subject to lesser cleanliness requirements shall be 1.27 millimeters (0.05 inch) of water, with all entryways closed. When the entryways are open, the blower capacity shall be adequate to maintain an outward flow of air to minimize contaminants migrating into the room.

5.3.1.5 Temperature Range. Temperature in clean rooms shall be maintained at 19.4°C to 23.9°C (67°F to 75°F) with the exception of those laboratories or work areas for which other temperatures are actually required by the items being processed. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch must concur in the selection of temperature ranges other than the above-noted range.

5.3.1.6 Relative Humidity (RH) Range. The RH in clean rooms shall be maintained at 30% to 50% unless other ranges are actually required by the articles being processed. Rusting of parts may occur at RHs above 50%. Electrical static charges on dielectric materials or parts may cause problems because of particle attraction at low RHs.

The above-noted RH maximum of 50% may be increased to 60% for clean rooms that are used solely for the processing of corrosion-resistant articles. However, such a high humidity level can only be approved after a careful evaluation of the articles to be processed and of the equipment within the room. When approved, this level shall be stipulated in the operating procedure for that specific clean room. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch must concur in the selection of RH ranges other than 30%-50%.

5.3.1.7 Clean Room Lighting. Shadowless, uniform incident lighting of 800 to 1,000 lumens (75 to 100 foot-candles, 24 to 30 meter-candles) per square meter shall be provided at all work locations within the clean room.

5.3.1.8 Shutdown During Nonuse Periods. The shutdown of clean rooms to conserve energy during periods of nonuse will not invalidate the rooms' annual certification status; however, all the required environmental conditions shall be restored before commencing work operations. Subsequent to reestablishment of the required particulate levels, all work surfaces and equipment must be cleaned to a VC level using vacuum equipment and polyurethane wipes dampened with an approved cleaning solution.

Laminar flow rooms usually regain proper airborne particulate populations within a matter of minutes. Nonlaminar (conventional) rooms, however, have poor "clean-down" capability and sometimes require several days before acceptable levels are obtained. The reestablishment of proper temperature and humidity levels has been a problem in both laminar and nonlaminar flow clean rooms. Periods of up to 1 week are sometimes required. Therefore, only by actual testing of each individual clean room can the net benefit of shutdown be determined. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch will, upon request, assist with these evaluations.

5.3.2 Operating Procedures

Documented operational procedures are required for all classes of clean rooms. Procedures shall describe clean room monitoring, personnel discipline, and clothing requirements.

Procedures for use at JSC shall be submitted for review and approval to the Mechanical and Chemical Process Engineering and GFE Branch.

5.4 LAMINAR FLOW CLEAN WORK STATION REQUIREMENTS

Laminar flow clean work stations shall be certified as specified in section 6.0. In addition to ECA requirements specified in section 5.2, the requirements stated below shall also be observed for the maintenance, use, and operation of laminar flow clean work stations.

5.4.1 Maintenance and Use

A protective screen shall be provided in front of the filters. The screen should be cleaned to remove any particles before work begins. A vacuum device with a plastic intake nozzle is recommended for this cleaning. All sensitive material must be removed from the station or must be properly covered during this operation. To avoid the premature loading of prefilters, the floor area surrounding the air intake shall be maintained GC.

5.4.1.1 Work Surfaces. After the screen has been cleaned and the air supply is operating, the work surface should be wiped thoroughly with a clean polyurethane wiper dampened with filtered isopropyl alcohol. The work surface should be wiped at least once each shift to maintain a VC level; and as often as necessary to remove contamination generated by the task performed.

5.4.1.2 Personnel Discipline. Proper personnel operating techniques are required to control contamination which may be carried into the work station on hands, tools, fixtures, and other materials. When work stations are operated in an uncontrolled ambient environment, there is a greater possibility of contaminants being introduced.

Care should be taken to ensure that hands and clothing are clean and free from loose dirt and lint before they are placed inside the clean work station. Smocks with snug fitting wristbands, caps, and gloves should be used, as necessary, to maintain the required cleanliness. Clean gloves used to handle parts must not be used to handle material outside the clean work station and then returned to the station. If close inspection of the workpiece requires the worker to lean over the part, a headcovering shall be worn which adequately covers facial and head hair.

5.4.1.3 Equipment and Materials. All materials (workpieces, tools, containers, and jigs) should be cleaned before being placed in the station. Only the items actually required for the task should be placed in the work station. The area between the filter and the precision, VC + UV, or VC item being processed should be maintained free of all equipment. High particulate-generating materials, such as paper and wood, should never be allowed in the station.

5.4.1.4 Shutdown During Nonuse Periods. The shutdown of laminar flow clean work stations during periods of nonuse will not invalidate the work stations' annual certification status. The following procedures shall be used for the powerdown and restart of laminar flow clean work stations:

a. Powerdown. All tools, processing hardware, and flight-related hardware shall be removed from the laminar flow clean work station before cutting off power.

b. Restart. The laminar flow clean work station shall be operated for a minimum of 15 minutes before cleaning work surfaces. Cleaning shall then be performed as specified

in section 5.4.1.1. Processing operations shall not be performed until at least 5 minutes after the completion of work surface cleaning.

5.4.1.5 Monitoring Laminar Flow Clean Work Stations. Subsequent to recertification, clean work station filters shall be inspected quarterly. More frequent inspection may be conducted for special applications or when it is determined to be necessary by the operating organization or the Mechanical and Chemical Process Engineering and GFE Branch. The due dates for yearly certification shall be posted on the exterior of the flow bench. The following procedures shall be used to monitor laminar flow clean work stations:

a. Prefilters. Prefilters shall be vacuum cleaned or replaced. Prefilters which are damaged or structurally unsound must be replaced.

b. Sampling. Each clean work station shall be considered to have four equal-sized work areas: left, left center, right center, and right. Sampling shall be conducted at each of the four work areas. Samples shall be taken midway between the final filter face and the forward exhaust area. An automatic particle counter having current calibration status and a sampling rate of at least 0.003 cubic meter (0.1 cubic foot) per minute shall be used.

   Air sampling shall be performed with an isokinetic nozzle. The particle counter shall be allowed to operate in the bench area until stable readings are obtained. A 0.028-cubic-meter (1.0-cubic-foot) sample shall then be taken at each of the four work areas, as defined above. The use of diocytal phtalate (DOP) smoke to challenge the filter when monitoring clean work stations is not allowed. The particulate count of the sample shall not exceed the limits of a Class 100 station.

c. Records. Monitoring and maintenance records shall be maintained for each laminar flow clean work station.

5.5 CONTROLLED WORK AREA REQUIREMENTS

The requirements stated below are in addition to ECA requirements specified in section 5.2 and may be used where a high degree of shop cleanliness is required. Applicability of these requirements includes, but is not limited to, such facilities as any suitably enclosed room, environmental test chamber, or immediate vicinity of a spacecraft. Housekeeping procedures, personnel controls, and contaminant-generation constraints shall be specified to obtain and maintain an acceptable level of work area cleanliness and to protect, as applicable, workpiece cleanliness. Although annual certification is not required, the minimum requirements stated below shall be observed.

5.5.1 Facility Requirements

a. The CWA or the environment surrounding the CWA shall be air conditioned, and the air supply shall be filtered. Cleanable or throw-away filters shall have an efficiency rating of 90% and shall be cleaned or changed as required.

b. Temperature may be controlled for personnel comfort; however, humidity shall be controlled to the extent necessary to prevent condensation or corrosion on all surfaces (50% RH or less) or to preclude buildup of electrical static changes (minimum of 30% RH). At JSC, the Mechanical and Chemical Process Engineering and GFE Branch must concur in the selection of RH ranges other than 30%-50%.

c. A space shall be provided at the entrance to the CWA for storage of clean room garments and for dressing. This area shall be separated from the enclosed rooms by an enclosed

anteroom or by a partition. This partitioning may consist of flame-retardant plastic curtains.

d. CWAs shall be protected from overhead operations; e.g., crane, high-lift, or facility maintenance. A flame-retardant plastic covering may be used for this purpose.

5.5.2 Maintenance of the CWA

a. Sweeping and sweeping compounds will not be permitted in CWAs.

b. Floors will be vacuumed at least once each 8-hour shift, or more frequently if required, to maintain a GC condition. (This is not required during test preparations which require more than 8 hours for operation; however, vacuuming shall be accomplished once each 24-hour period.) The vacuum source shall be either located outside the CWA or equipped with absolute type filters on the exhaust. As an alternative, the vacuum exhaust may be vented outside the CWA.

c. Floors, walkways, and other walking surfaces shall be damp mopped with water at least weekly. Walls and other surfaces shall be cleaned at least monthly, or more frequently if required, to maintain a GC condition. Cleaning shall be performed by vacuuming; clean room adhesive roller; wiping with clean, low-lint cloths; or wiping with polyurethane wipers dampened with water, as required. A water solution with a suitable detergent; e.g., trisodium phosphate, may be used for stubborn soils, but shall be followed by water-rinse mopping or wiping. Alternative cleaning solutions must be approved by the appropriate operating or surveillance organization.

5.5.3 CWA Operations

a. Records of particulate population or fallout are not required for CWAs; however, visual or wipe evidence of dust, dirt, or oils shall be reason for ceasing operations in the immediate area and cleaning the affected area to a VC condition. Upon completion of cleaning and acceptance by the appropriate quality group, the operations may proceed. Articles subjected to out-of-control conditions should be inspected to verify a VC condition.

b. All parts, equipment, tools, test fixtures, and apparatuses shall be cleaned before placing them in the CWA. The responsible quality group shall verify that these are VC before they're placed in the CWA.

c. Assembly, disassembly, modification, or repair to systems or subsystems which require that a system cleanliness level be maintained shall be performed under localized clean conditions, as specified in sections 17.0 and 18.0.

d. ALL SURFACES, LINES, OR PARTS OPENED BECAUSE OF PART OR ASSEMBLY REMOVAL OR SYSTEM BREAK-IN SHALL BE PROTECTED WITH STANDARD CLOSURE (METAL PLUGS, CAPS, BLIND FLANGES) OR COVERED WITH CERTIFIED CLEAN INNER PACKAGING FILM AS SPECIFIED IN TABLE V, APPENDIX B. FILM COVERS SHALL BE SECURELY SEALED OR TAPED TO THE UNIT.

e. Contaminant-generating operations; e.g., sanding, grinding, chipping, drilling, welding, and painting, shall not be permitted in the CWA unless specifically approved by the responsible quality organization. Controls will then be exercised and monitored as follows:

   1) Areas and portions of the assembly adjacent to the contaminant-generating operation shall be securely covered to prevent accumulation or entrapment of particles.

2) Plastic or other approved material of sufficient size to catch particles generated shall be placed below the contaminant-generating operation.

3) Upon completion of the contaminant-generating operation, the cover below the operation shall be thoroughly vacuumed and then removed. The surfaces and areas exposed by removal of the covers shall be vacuumed. All adjacent areas, including walls and floors, shall then be vacuumed to the extent required to provide a GC work area. Cleanliness shall be verified prior to further operations.

4) Personnel who performed the contaminant-generating operation must leave the CWA and must change garments prior to performing other operations within the CWA.

6.0 CERTIFICATION OF CLEAN ROOMS AND LAMINAR FLOW CLEAN WORK STATIONS

Certification and recertification of clean rooms and laminar flow clean work stations shall be performed in accordance with the minimum requirements stated below.

6.1 INSTRUMENT CALIBRATION

All instruments and applicable equipment, including permanent clean room monitoring equipment, used during the certification process shall have current calibration status.

6.2 PREPARATION

Before certification begins, all clean room equipment and furniture shall be cleaned and properly located in the room. Locations shall be selected to effect the least interference with the airflow within the room, to provide protection for "downstream" operations, and to locate the heaviest contaminant-generating operations closest to the room exhaust area.

Laminar flow clean work stations shall be operating a minimum of 15 minutes before beginning certification procedures. The immediate surroundings should be evaluated. Although the clean work station is designed to operate in an uncontrolled ambient environment, particles generated around the station may penetrate the laminar airstream or may follow the worker’s arms into the station. The area should also be checked for any other operations producing high-velocity air, particles, or vapors which could be introduced into, interfere with, or penetrate the airstream.

6.3 INTEGRITY INSPECTION

Prefilters shall be vacuum cleaned or replaced, and the internal blower motor areas shall be vacuum cleaned. Motors shall be inspected for excess lint, evidence of overheating, and worn or damaged drive belts. All internal wiring shall be inspected for damaged insulation, evidence of heating, and general condition.

6.4 DOCUMENTATION

A documented procedure or test preparation sheet (TPS) shall be prepared for the certification process. The Occupational Safety and Quality Assurance Branch will, upon request, assist in the preparation of the certification procedure. Before implementation, the procedure shall be approved by the Occupational Safety and Quality Assurance Branch.

6.5 TESTING REQUIREMENTS

The certification procedure shall, as a minimum, consist of the tests described below.

6.5.1 Clean Room Testing Requirements

6.5.1.1 Filter Particulate Leak Test. The final HEPA filter bank shall be scanned with a calibrated automatic particle counter to verify the absence of leaks. The particle counter shall have a sampling rate of at least 0.003 cubic meter (0.1 cubic foot) per minute. Particle counters should sample at a rate of about 0.03 cubic meter/minute for a reasonably accurate sampling and fast sampling time.

Air sampling shall be performed with an isokinetic nozzle. Scanning shall be conducted slowly; i.e., approximately 2 meters (6 feet) per minute with the probe held 8 to 15 centimeters (3 to 6 inches) from the filter protection screen. DOP smoke shall not be used to test the HEPA filter. Undamaged HEPA filters will normally pass less than 15 particles per 0.028 cubic meter (1.0 cubic foot). Any reading in excess of 30 particles indicates a leak.

In vertical laminar flow rooms having high ceilings, the sampling of numerous locations at the workbench level may be conducted in lieu of the filter leak check.

If a leak is detected, it must be determined if the leak is in the filter or around the filter (indicating a poor seal). Small pinhole leaks in the filter may be repaired with room temperature vulcanized silicone on the upstream side of the filter. Tightening filter clamps may correct poor seals or seat sealing gaskets properly. If these corrections do not correct the leak, the filter should be replaced.

6.5.1.2 Room Particulate Sampling. Subsequent to a successful filter leak check, particulate concentrations shall be determined at selected locations within the room. The sample locations must be selected carefully to ensure evaluation of major work locations and representative areas of the room. In vertical laminar flow clean rooms, sampling shall be done at approximately 1 meter (30 to 40 inches) above the floor surface. A minimum sample is 0.084 cubic meter (3 cubic feet) per sample location. The concentration of particles per 0.028 cubic meter (1 cubic foot) of 0.5 micron and greater and 5.0 microns and greater shall be determined (see table I, appendix B). The evaluation procedure or TPS must include a sketch of the room which shows the selected sampling locations.

6.5.1.3 Temperature and Humidity. Temperature and humidity values within the clean room shall be determined. Normally, temperature and humidity are uniform in laminar flow facilities, but may vary significantly in nonlaminar facilities. More locations, therefore, should be checked in nonlaminar flow facilities. For convenience, some of the same locations selected for airborne particulate sampling may be used.

6.5.1.4 Static Pressure. The static pressure within the clean room and adjacent rooms or areas shall be determined and recorded.

6.5.1.5 Light Intensity. Using a calibrated light intensity meter, incident illumination shall be recorded for major work locations.

6.5.1.6 Consistent Performance. The airborne particulate sampling, temperature checks, and humidity checks shall be performed and recorded for 3 consecutive days, unless rooms are monitored daily. Note recertification requirements, section 6.7.

6.5.2 Laminar Flow Clean Work Station Testing Requirements

Requirements specified in section 6.5.1.1 are applicable to laminar flow clean work stations with the exception that scanning is to be performed at a distance of 5 to 10 centimeters (2 to 4 inches) from the filter by overlapping horizontal passes. Stations must be operated a minimum of 15 minutes before testing.

6.6 FLAMMABLE AND TOXIC FLUID FACILITIES

Clean rooms and laminar flow clean work stations which contain cleaning facilities using flammable and/or toxic fluids will be evaluated and approved by the JSC Medical Operations Branch and the Test, Operations, and Institutional Safety Branch before certification.

6.7 RECERTIFICATION

Clean rooms shall be recertified annually. Evaluation for recertification shall include all items required for initial certification. The airborne particle sampling, temperature checks, and humidity checks may be done only once, provided daily monitoring records for these items are available for the 2 workdays preceding the recertification evaluations of the clean room.

Laminar flow clean work stations shall be recertified annually. Laminar flow clean work station prefilters shall be inspected quarterly. If the prefilters are maintained properly, a laminar flow clean work station will function properly unless a mechanical breakdown (e.g., a fan belt breakage) occurs. More frequent recertification may be performed for special applications or when requested by the using organization.

6.8 CERTIFICATION DECAL

A certification decal shall be affixed to all clean rooms and work stations. This decal shall specify the environment classification and the date of certification and recertification. Decals for JSC clean work stations shall include JSC Institutional Safety and Quality approvals.

7.0 SURFACE CLEANLINESS LEVELS

7.1 GENERAL

Cleanliness levels shall be selected by the responsible design or using organization from table IV, appendix B. The following two categories of cleanliness levels are available for use in providing uniform and cost-effective contamination control applicable for a wide range of cleanliness needs:

a. Precision cleanliness. Precision cleanliness levels may be described as "quantitative," since particulate counts, with or without nonvolatile residue (NVR) or other suitable film/nonparticulate method limits, are required. These levels are usually specified for internal surfaces of fluid systems.

b. Visible cleanliness. Visible cleanliness levels (see section 7.2) may be described as "qualitative," in that verification and/or inspection of these levels is visual. However, these levels are not considered to be inadequate, since the application of these levels must be viewed with respect to hardware design and operation. These levels represent a cost-effective alternative to precision cleanliness levels and offer greater flexibility for the appropriate design or using organizations. Visible cleanliness levels may be used as either interim or final cleanliness levels.

All aspects of cleaning, certification, packaging, storage, and field operations for precision cleanliness levels are addressed in sections 8.0, 9.0, 10.0, 11.0, 17.0, and 18.0. Visible cleanliness requirements are detailed in section 12.0, and in some instances refer to applicable precision cleanliness requirements for brevity. Section 7.2 is provided to aid in the selection of visible cleanliness levels.

7.2 GUIDELINES FOR SELECTION AND USE OF VISIBLE CLEANLINESS LEVELS

As a point of reference, the human unaided eye (corrective lenses are acceptable) can detect particles as small as 40 to 50 microns under ideal conditions.

7.2.1 VC + UV

This level provides a surface condition free of all visible contamination (particulate and nonparticulate) augmented by UV (UV light of 3,200 to 3,800 angstroms wavelength) inspection. UV inspection will detect some, but not all, hydrocarbon film matter. This level is usually specified for hardware that cannot tolerate buildup of hydrocarbons between uses or operations.

NOTE: Quantitative (gravimetric) hydrocarbon detection is provided by NVR or other suitable film/nonparticulate measurement.

The VC + UV level requires (1) mandatory cleaning and (2) heat-sealed double bagging for preservation.

7.2.2 VC

This level provides a surface condition similar to VC + UV except that UV inspection is not a requirement. This level is usually designated for (1) hardware that requires removal of surface particulate and nonparticulate contamination for operation or use; or (2) hardware for which recleaning would be difficult and/or time-consuming, therefore making continuous packaging protection desirable. This level requires mandatory cleaning and protection by heat-sealed bagging.

7.2.3 GC

This level is similar to VC but differs in the following significant areas:

a. Cleaning is only required if the item does not pass inspection. If the item has ever been inspected ; i.e., is acceptable "as is," it does not need to be cleaned.

b. Inspection is not as rigorous as VC in that clumps or agglomerations of contamination are removed instead of individual particles.

c. Heat-sealed bagging protection is not required; but normal protection is required for handling, shipping, and storage.

The GC level should therefore be specified for hardware that is not sensitive to contamination and is easily and quickly cleaned or recleaned.

8.0 PRECISION-CLEANING REQUIREMENTS

The intent of this section is to specify those general requirements applicable to precision-cleaning processes. Precleaning precedes final or precision-cleaning. Since the characteristics of the assemblies or components being cleaned vary, this section does not describe the many methods of precleaning. These methods can be found in detailed procedures written for that purpose. Because of the nature of the materials, nonmetallic precleaning methods vary markedly from those used for metallic parts and are each covered separately in section 8.6.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

8.1 GENERAL CLEANING PROCESS CONTROLS

All fluids, equipment, and facilities used for precision-cleaning shall be subject to the following minimum requirements for contamination control. These requirements are designed to avoid the inadvertent introduction of contaminants into parts, components, and subsystems during the cleaning, assembly, functional testing, and packaging processes.

8.1.1 Cleaning Fluids

Requirements shall be established, documented, and implemented for all cleaning fluids. They shall control fluid composition, purity, cleanliness, and use. The cleaning fluids selected for use as precleaning solutions shall be controlled during use by analysis, solution replacement, or adjustment to maintain cleaning effectiveness and compatibility with the type of material being cleaned. Final flush and verification fluids for precision cleanliness shall be analyzed prior to use to determine compliance with the stipulated specification requirements.

8.1.2 Solution Control Records

Records shall be maintained indicating the scheduled analysis, analysis results, and any solution replacement or adjustment activities.

8.1.3 Special Cleaning Processes

Special cleaning processes, such as ultrasonic cleaning and surge cleaning, shall be controlled by documented procedures.

8.1.3.1 Ultrasonic Cleaning. Ultrasonic cleaning equipment shall be tested to verify that adequate cavitation turbulence for good cleaning action is maintained. Such tests shall be conducted using the manufacturer's recommended test method.

8.1.3.2 Ultrasonic Fluid. The fluid used in ultrasonic cleaning equipment should be as recommended by the manufacturer. However, if an alternative fluid is used, tests shall be performed to verify that the alternative fluid does, indeed, perform the proper cleaning action and is compatible with articles to be cleaned.

8.1.3.3 Surge Cleaning. Surge or pressure and vacuum cycle cleaning of components and systems shall be subjected to specific pressure or flow controls to prevent damage to the item from pressure or vacuum. Items such as pressure vessels, which are sensitive to pressure cycle fatigue, shall not be cleaned using a surge cleaning procedure.

8.2 PRECLEANING METALLICS

Each item requiring precision-cleaning shall be precleaned (rough cleaned) to the VC level before placing it in a clean room or clean work station. The precleaning shall be controlled by detailed procedures that have been approved by the responsible agency. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch has approval authority.

8.2.1 Precleaning Process Controls

Precleaning of parts shall accomplish the removal of all visible contaminants without removing or changing the characteristics of the base materials. All traces of precleaning materials shall be removed from parts at the completion of the precleaning process to prevent the future formation of mineral salts and corrosion products. Tests, such as pH testing, shall be used to verify removal of all residuals.

8.2.2 Work Flow

All steps in precleaning procedures must progress in an uninterrupted work flow through the final rinse and drying operation. If the work flow is unavoidably interrupted, the precleaning procedure shall specify a recycling operation. Precleaning procedures shall include, as a minimum, protection of the item by interim packaging or other approved means to prevent recontamination through all subsequent operations.

8.3 INSPECTION

Prior to precision-cleaning, items shall be inspected to the VC level as described below.

8.3.1 Visual Inspection

A visual observation shall be made with the unaided eye (corrective lenses are acceptable) under a white light of sufficient intensity to well illuminate the surface being inspected. Borescopes, mirrors, or other devices may be used to increase accessibility during inspection, but magnifying lenses may be used only to further identify visible contaminants. Where configuration, color, or other item characteristics interfere with visual observation, the tests described below are to be used to augment visual inspections.

8.3.1.1 Wipe Test. The surface to be inspected will be wiped with a lint-free, item-safe, and fluid-safe medium, and the medium is to be observed for the presence of contaminants. Care must be taken not to wipe too hard, since soft metals; e.g., aluminum, will abrade and soil the medium, giving an erroneous indication of contamination. The wiping medium shall be subjected to the blacklight test specified in section 8.3.2.

NOTE: When the wiping medium is subjected to further tests, such as blacklight or hydrocarbon evaluation, a baseline reading of the blank medium must be determined and accounted for in subsequent evaluations.

8.3.1.2 Water Break Test. The surface to be inspected shall be placed in the horizontal, face-upward position, if possible. The surface is then to be sprayed with distilled purified water, such as distilled water from an atomizer, so as to completely cover the area of interest. The presence of droplets or breaks in the water film will be an indication of possible oily hydrocarbons.

8.3.2 Blacklight (UV) Inspection

A visual observation shall be made of the item with the unaided eye (corrective lenses are acceptable) under UV light (3,200 to 3,800 angstroms wavelength) for the presence of hydrocarbons. Where the surface to be inspected is inaccessible, a wipe test shall be performed, and the wiping medium shall be inspected under UV light.

NOTE: Any contamination detected by the visual inspection or blacklight inspection shall be cause for recleaning. If recleaning fails to remove fluorescent indications, an investigation should be made to determine if the item material is naturally fluorescent.

8.4 PRECISION CLEANLINESS LEVELS

Precision cleanliness levels shall be selected from table IV, appendix B. The level of cleanliness shall be specified by the responsible design or using organization. Sampling and certification tasks to attain specified cleanliness levels shall be performed by personnel trained in accordance with section 14.0 of this manual.

8.5 PRECISION-CLEANING

All precision-cleaning shall be performed in a clean room environment, following precleaning operations described herein. The items to be precision-cleaned shall be flushed or wiped with a suitable cleaning solution or solvent and/or vacuum cleaned or blown off with clean dry air to prevent the entry of gross contaminants into the clean room environment.

Precision-cleaning shall be accomplished using a precision-cleaning agent. All precision-cleaning processes shall be documented and must be approved by authorized personnel. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch has this authority.

8.6 CLEANING FLUID PERFORMANCE REQUIREMENTS, OTHER DESIGN CONSIDERATIONS, AND CLEANLINESS VERIFICATION

8.6.1 Cleaning Fluid Performance Requirements

The cleaning fluid used in a cleaning method or procedure should be capable of assisting to clean the component, product, etc., to the required cleanliness level. The cleaning methods and procedures should be well understood. Additionally, the cleaning fluid should be:

a. Nontoxic (not harmful if inhaled or spilled on the skin) and nonpoisonous.

b. Nonexplosive.

c. Noncorrosive under normal use.

d. Nonflammable. This does not limit potential cleaning fluids only to nonflammable fluids. Flammable cleaning agents, such as isopropanol, should be used with care in cleaning oxygen systems or equipment that may combust flammable materials. Fuel systems may allow limited and careful usage of isopropanol or other flammable cleaning agents. In general, combustible cleaning agents should be used with care to clean systems or products that may combust the cleaning agent during cleaning; or even at a later time such as when the system or product is packaged, stored, used, etc.

e. Environmentally sound. Waste streams should be minimized. The cleaning agent should be recoverable and/or disposable. A good disposal system is one whose discharge

passes no contaminants to the environment; a better system is one that has no discharge at all.

f. Compatible with the system or product materials. The cleaning fluid purity and composition should be to a level that is demonstrated to allow the desired level of cleanliness to be achieved without adversely affecting the product. The cleaning fluid should not react with, combine with, etch, or otherwise cause immediate or later degradation of the system or product being cleaned.

8.6.2 Other Design Considerations

a. If cleaning must be performed, consider using tap water or detergents/soaps with tap water first. If tap water is not acceptable, consider distilled or deionized water. Dry without heat if possible. Consider mechanical cleaning and drying methods as well.

b. Breathing air and breathing oxygen systems that use metal hydroxides for rebreathing should not be cleaned with halogenated substances to avoid the reaction under heat and subsequent production of toxic compounds.

c. CFC-113 should not be used to clean the Orbiter reaction control system subsystem fuel components because of the potential reactivity of the CFC-113 with monomethyl-hydrazine.

d. Systems with filters that require changing or systems with components that require servicing or cleaning should be designed so that changeout, cleaning, and reassembly are easily performed.

e. Aluminum, magnesium, and other porous materials may not be suitable for ultrasonic cleaning.

8.6.3 Cleanliness Verification

Following precision-cleaning, unless otherwise specified, each item shall be rinsed using 100 milliliters of unused precision-cleaning solvent for each square foot of critical surface. Rinsing shall be accomplished by agitation, sloshing, or by spraying the test solvent over the critical surface in such a manner as necessary to obtain a reliable test solution. The test solvent shall be drained immediately to prevent particle redeposition on the test surface. Clean components should be placed in the inner packaging wrap (not sealed) during the particle/NVR determination to preclude contaminating the component. Particulate determination shall be made in accordance with the requirements of SAE-ARP-598. NVR shall be determined in accordance with ASTM D2109-71.

8.7 NONMETALLIC MATERIALS CLEANING METHOD AND RINSE TEST

For the purpose of this document, nonmetallic materials include natural rubber, polytetrafluoroethylene, Teflon, nylon, Kel-F, polyethylene, polycarbonates, and other plastic or synthetic rubber materials. Caution shall be taken to ensure that the cleaning solution used in the method will not adversely affect the materials; i.e., cause external damage or absorption of the cleaning solution and consequent outgassing. Care should also be taken to ensure that nonmetallic materials are compatible with the use fluid.

8.7.1 Cleaning Method

The following method or its equivalent is acceptable for cleaning nonmetallic materials:

a. Materials shall be decontaminated using a cold tap water flush until the pH of the effluent is within one-half a pH unit of the influent.

b. They shall be detergent cleaned with a biodegradable non-ionic detergent using nylon brushes as necessary.

c. The materials shall be spray rinsed with 65.5° to 82°C (150° to 180°F) tap water, followed by a rinse with deionized water that has a minimum specific resistance of 50,000 ohm-centimeter.

d. Nitrogen gas, as specified in MIL-P-27401, grade B (at approximately 48°C [102°F]), shall be used for drying.

8.7.2 Rinse Test

When a final flush is required for cleaning verification, it shall be performed in accordance with section 8.6.3, except that the solvent medium shall be high-purity water.

8.8 FINAL PACKAGING

All precision-cleaned items shall be packaged in accordance with section 10.0 of this document immediately subsequent to cleaning and drying.

9.0 PROCUREMENT REQUIREMENTS FOR PRECISION-CLEANED PACKAGING MATERIAL

The material cleanliness and packaging requirements for the procurement of packaging materials used for the packaging of precision-cleaned components are specified in this section. Materials shall be of the type specified in table V, appendix B.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

9.1 PROCUREMENT REQUIREMENTS

All packaging procurement documentation shall reflect the requirements stated below.

9.1.2 Cleanliness Level

Outer packaging material shall be cleaned to the VC level. *Inner* packaging material shall be precision-cleaned to the appropriate precision cleanliness level in accordance with hardware requirements.

NOTE: Procurement of inner packaging materials precision-cleaned to levels stricter than Level 100 (e.g., Level 50 or Level 25) requires the concurrence of the Occupational Safety and Quality Assurance Branch.

Bags, sheeting, tubing, roll stock, and other cleaned film shall be double bagged as specified in section 10.0 and table V, appendix B. The inner bag shall be constructed of the same material as the one being packaged (e.g., nylon film packaged in nylon). Roll stock shall be wound on clean cores made from nondusting plastic or metal.

9.1.3 Environmental Control

All processing and inspections shall be accomplished within an environment compatible with the required cleanliness level for the packaging material being processed. Clean, white, nylon (or equivalent) gloves shall be worn for handling packaging materials.

NOTE: Plastic films generate large electrostatic charges when handled. These charges may cause attraction of large quantities of airborne particles to the surfaces of such film unless precautions are taken to minimize exposure of clean film surfaces to the clean room atmosphere before testing for verification of the cleanliness level.

9.1.4 Visual Inspection Requirements

No evidence of oil, grease, water, solvents, paints, ink, dirt, metal chips, labels, preservatives, or other foreign matter shall be permitted on the external surfaces or the internal surfaces of intimate packaging materials nor on the internal surfaces of the overwrap packaging when inspection is made with the unaided eye.

9.1.5 Rinse Test

A minimum sample of 1% of the procured bags and a minimum of one sample per roll of sheet or tubing stock shall be tested. The procedure set forth below, or an equivalent procedure approved by the responsible personnel, shall be used to verify compliance with the required cleanliness level.

9.1.5.1 Preparation. The bag shall be heat-sealed across the open end. Using surgical scissors or another extremely sharp blade (to minimize particle generation when cutting), one corner of the bag shall be cut off so that an opening not over 2 centimeters (0.75 inch) in length is created. Plastic tubing for precision packaging applications shall be sealed at both ends of a length to give an inside test area of approximately 0.1 square meter (1 square foot) and sampled by rinse testing. Plastic film (flat roll stock) shall be cut carefully with surgical scissors or another sharp blade to a length of 30 centimeters (12 inches). The section shall be folded in half, sealed into a bag form in such a manner as to minimize exposure of the interior to airborne particles, and sampled by rinse testing.

9.1.5.2 Rinsing. Through the opening, 100 milliliters of solvent for each 0.1 square meter (1 square foot) of interior surface shall be introduced from a wash bottle or similar apparatus. A bag having less than 0.1 square meter (1 square foot) of interior surface shall be considered as 0.1 square meter (1 square foot). The opening shall be held shut by a practical means. The exterior of the bag shall then be rinsed down with the same agent to prevent exterior particles from being picked up when the bag is decanted. The rinsing agent within the bag shall be agitated by a gentle but rapid sloshing.

9.1.5.3 Collection of Sample. The rinsing agent within the bag shall be poured out through the same opening that was held shut during rinsing and will be poured through a microporous membrane filter.

9.1.5.4 Testing. The effluent of the rinse test shall be examined for particulate matter by the particle count method in accordance with the requirements of SAE-ARP-598. The purity of the solvent rinse shall be determined in accordance with ASTM D2109-71, or an appropriate substi-

tute procedure which will effectively measure nonparticulate contamination. The material used in this test shall not be subsequently used to package precision-cleaned items.

9.2 CERTIFICATION

Certification showing evidence of compliance with these requirements, as specified in the procurement documents, shall be furnished by the supplier with each package.

10.0 PACKAGING OF PRECISION-CLEANED PARTS

Packaging methods and the packaging sealing requirements for parts and components that have been precision-cleaned are specified in this section.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

10.1 PROCEDURES

Packaging of precision-cleaned parts and components shall be in accordance with documented procedures. At JSC, the Mechanical and Chemical Process Engineering and GFE Branch shall approve these procedures before their implementation.

10.2 PRECISION PACKAGING

NOTE: Items cleaned to levels stricter than Level 100 (e.g., Levels 50 and 25) should be assembled as soon as possible after cleanliness verification. Packaging of such items may degrade item cleanliness.

10.2.1 Environment

All packaging operations shall be accomplished within a clean room or laminar flow clean work station.

10.2.2 Equipment

Heat sealing devices shall be maintained in a clean condition at all times. Daily inspections shall be conducted to determine condition of the sealing bars. Damaged, burned, or worn sealing bars shall be replaced. Temperature and timing cycle adjustments shall be determined by sample sealing exercises to prevent "under" or "over" heat conditions during sealing operations. Seal strength testing shall be in accordance with section 10.2.5.c.

10.2.3 Handling of Components

Clean, low-lint, white, non-contaminant-generating gloves whose materials are compatible with cleaning fluids shall be worn by persons handling precision-cleaned components during the packaging operations. Items cleaned to visual cleanliness levels shall be handled in accordance with section 12.3.

NOTE: Liquid oxygen (LOX) and gaseous oxygen (GOX) components with exposed critical surfaces shall be handled with gloves constructed of an approved, compatible material only.

10.2.4 Garments

Clean room attire as specified in table III, appendix B, shall be worn during packaging operations.

10.2.5 Packaging Techniques and Materials

Items to be cleaned to a precision cleanliness level shall be packaged using the double-bagging technique. Materials used for double bagging must conform to the requirements of section 9.0 and table V, appendix B. Double bagging of precision-cleaned parts is required to provide redundancy if one bag is damaged. Double bagging also enables removal of the outer bag before placement of the parts in the clean room, spacecraft, or test chamber to maintain area cleanliness requirements. Materials used for the outer bag may differ from those used for the inner bag in order to obtain overall slough resistance and moisture barrier qualities. Table V, appendix B, provides a ready reference to applicable bagging techniques and materials for component cleanliness requirements. Characteristics of the bags shall be as follows:

a. LOX compatibility. LOX parts, components, subsystems, and systems shall be protected by an inner bag of LOX-compatible film, as specified in table V, appendix B, unless surfaces which will be in contact with oxygen are effectively sealed (capped or plugged) from particles which may slough from the inner bag.

   NOTE: LOX-compatible bags must be sealed on all sides, never center-folded.

b. Size. The size of the bag to be used must be determined in relation to the part. Adequate room within the inner bag shall be allowed in order that the part is easily encapsulated.

c. Strength. The strength of the bag to be used must be determined in relation to the part contained. Many bags used have three sides sealed, as contrasted to the end sealing of tubing. When a seal test is to be performed, the method described by MIL-P-116 shall be used.

10.2.6 Sealing Orifices

Where parts have many orifices, it may be necessary to seal each one. During assembly, parts shall not be exposed to the environment more than one at a time. This is to retard the entry of particulate contamination. Squares of appropriate inner packaging material shall be cut and taped in place to cover critical surfaces. (Use fluid-approved tape or at least noncontaminating tape.) Care shall be exercised to ensure the tape adhesive does not contact critical surfaces. A polyester tape (e.g., Mylar) with low-adhesive and low-residue properties shall be used.

For male fittings and tube ends, the protrusion shall be wrapped with film and the film drawn over the critical portions of the part or over the film itself by stretching the tape. The tape used shall be a polyvinylchloride type conforming to PPP-T-66, type I, class B. Connector nuts with tubing shall be restrained by taping over the clean film to secure the nut tightly.

10.2.7 Plastic Closures

When plastic closures (e.g., caps, plugs, and heat-shrinkable sleeves) are specified to seal openings of precision-cleaned internal surfaces, the closures shall be of suitable size and type so as not to generate particulate matter or otherwise be detrimental to the item.

10.2.8 Metallic Closures

When closure plates are specified to close flanged items, the materials used shall be precut and/or drilled like metal of the flanges being cleaned. The external and internal surfaces of metallic closures shall be examined for evidence of fluorescence under UV light. Fluorescent areas shall be recleaned.

10.2.9 Film Cushioning

Heavy items or items having threads, sharp points, or sharp edges, which may puncture or otherwise damage the barrier bags, shall be overwrapped with a sufficient amount of the appropriate inner packaging material to form a cushion. Small, light items which, if dropped, would not cut or otherwise damage the barrier bags need not be film cushioned. The cushioning film shall be secured with an approved tape (PPP-T, type I, class B, unless otherwise specified) whose adhesive shall not come in contact with the body of the precision-cleaned item.

10.2.10 Inner Bag Purging Gases

When purging is specified, the purging material shall be a precleaned, dry, inert gas (e.g., argon), conforming to MIL-A-18455; or nitrogen, conforming to MIL-P-27401, grade A, or equivalent. Gases shall be prefiltered to meet the cleanliness level of the item being precision packaged. Purging shall be accomplished by directing a stream of inert gas into the inner bag and over the contents for a sufficient length of time to replace the entrapped air with inert gas. A partial vacuum shall then be pulled on the bag before sealing.

10.2.11 Dissimilar Metals

To prevent galvanic corrosion, metals dissimilar to the item shall not come in contact with the item.

10.2.12 Preservatives

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

10.2.13 Sealing Techniques

Bag sealing techniques shall ensure that the volume of gas sealed in the bag is the minimum possible, thus permitting room for expansion of entrapped gas during air shipment.

10.3 PACKAGING OF SMALL ITEMS

A sandwich package is an acceptable alternative for packaging light, regular, or symmetrical items; e.g., O-rings, seals, and gaskets. A sandwich package consists of a number of identical items that are heat sealed between two film sheets of appropriate inner packaging material. Each item must be in a separate, purged, heat-sealed compartment so that each compartment may be separated from the others by cutting with scissors without degrading the integrity of the remaining compartments. The sandwich package shall then be identified with evidence of cleaning and placed into a bag of appropriate outer packaging material. The bag shall then be purged and heat-sealed.

10.4 PACKAGING OF LARGE, HEAVY, OR ODD-SHAPED ITEMS

Items which cannot normally be heat-sealed in a transparent film bag because of size, weight, or configuration and have precision-cleaned interior surfaces may be prepackaged as specified below.

10.4.1 Capped or Plugged Closures

All fittings or other openings leading to precision-cleaned inner surfaces shall be capped, plugged, or otherwise sealed. Closures shall mate with and be tightened to sealing surfaces to preclude breathing of the sealed item. Cap or plug material shall be compatible with system fluids and cleanliness levels.

10.4.2 Film Sheet Closures

Items containing openings leading to precision-cleaned inner surfaces, which cannot be sealed with caps or plugs, shall have each opening overlaid with two sheets or bags of the appropriate inner and outer packaging material. Each sheet or bag shall be secured in place by at least two tight wraps of tape. The tape shall not contact the item.

10.4.3 Film Overwrap

Each item with sealed openings shall be completely overwrapped with an appropriate outer packaging material. The overwrap shall be secured with tape or heat sealed where practicable. In any case, sealing of items that may be exposed to temperature variations during transport and storage shall be adequate to prevent the internal volumes of the item from breathing.

10.5 PACKAGING OF HOSE AND TUBE ASSEMBLIES

Precision-cleaned hose and tube assemblies whose external surfaces do not require critical or visual cleanliness shall be purged internally and sealed to preserve their cleanliness. Each end fitting shall be sealed with appropriate inner packaging material and then covered with an outer packaging material.

10.5.1 Film Sleeve

Each purged, sealed, and identified hose or tube assembly shall be placed into a sleeve of appropriate outer packaging material, purged, and heat-sealed.

10.5.2 Flanged Items

Flanged items with only cleaned internal surfaces shall be closed by placing a minimum of two precut gaskets of the appropriate inner packaging material over the flange face. A metallic closure plate shall be applied over film gaskets, and attachment hardware shall be inserted through all flanged holes and tightened to recommended torque value for the type and size attachment bolt used.

10.6 PROVISIONS FOR TESTING ELECTRICAL AND ELECTRONIC ITEMS

Electrical and electronic items which will require testing upon arrival at destination and during storage shall be prepackaged in a manner that will permit access to the leads, pigtails, etc., without degrading the integrity of the unit package.

NOTE: Caution shall be exercised when processing electrical or electronic hardware that is sensitive to electrostatic discharge (ESD) damage. Special materials and techniques may be necessary to control ESD. Materials used for both contamination and ESD control shall be used only if approved by the Occupational Safety and Quality Assurance Branch. Contamination control packaging shall not be placed inside ESD-control packaging.

10.7 CERTIFICATION DECALS

The bagged item shall be identified with a decal containing identification, inspection, and certification of cleanliness information. Decals procured to meet the requirements of this section are not intended for direct application to parts or equipment; therefore, the decals need not be compatible with fuels or oxidizers. Decals shall be applied to the outside of the inner bag and over the ends of tape-sealed closures.

11.0 STORAGE OF PRECISION-CLEANED ITEMS

Completely precision-cleaned and -packaged items shall be removed from the clean room and shall be placed in an appropriate container or storage area to protect the plastic bags and contents.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

11.1 ENVIRONMENTAL CONTROL

All precision-cleaned items shall be stored in an enclosed, controlled area where temperature and humidity are maintained within limits compatible with the item and its packaging material. The air supply shall be filtered through an industrial-grade filter. The enclosed area shall be maintained in a manner consistent with good housekeeping practices. Periodic cleaning schedules shall be established and documented.

11.2 INSPECTION

Stored precision-cleaned items shall be inspected periodically, at least once every 2 years, for the integrity of the outer bag and, on a sample basis, for corrosion or other degradation of the packaged item. The inspection shall consist of removal of the outer bag and visual inspection of the item through the inner wrap. Any discoloration, visible contamination, etc., shall be cause for rejection and recleaning of the lot sampled. If no cause for rejection is found, a new outer bag shall be applied and resealed in the normal manner.

11.3 ACCESS CONTROLS

Adequate controls shall be established to limit access to storage areas for precision-cleaned items to personnel specifically trained in the handling of precision-cleaned items.

11.4 POSTSTORAGE DECONTAMINATION

Items removed from the storage area shall have the outer packaging vacuum cleaned before opening to remove any possible accumulation of dust or other contamination.

12.0 VISUAL CLEANLINESS LEVEL REQUIREMENTS

This section describes the various visual surface cleanliness levels. Methods of attaining these levels vary and those methods used to preclean surfaces before precision-cleaning procedures are acceptable and recommended. Cleaning with an approved, compatible solvent (e.g., solvent wipe), however, is mandatory for VC and VC + UV items, unless other methods are required by the hardware in question. Specific packaging requirements are also included. Refer to section 7.2 for further information.

12.1 VISUAL CLEANLINESS LEVELS

Definitions of the visual cleanliness levels are stated below.

12.1.1 VC + UV

VC (as defined in paragraph 12.1.2) and inspected with the aid of a UV light of 3,200 to 3,800 angstroms wavelength.

NOTE: Any evidence of fluorescence shall be cause for recleaning. If recleaning does not reduce the fluorescence, an investigation shall be made to determine whether the fluorescing material is a contaminant or the basic material.

12.1.2 VC

VC is free of all particulate and nonparticulate visible to the normal unaided eye (corrective lenses are acceptable). Particulate is identified as matter of miniature size with observable length, width, and thickness. Nonparticulate is film matter without definite dimension. Borescopes, mirrors, or other devices may be used to increase accessibility during inspection, but magnifying lenses may be used only to further identify visible contaminants.

12.1.3 GC

Free of manufacturing residue, dirt, oil, grease, processing debris, or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. The GC level shall not be designated for hardware that is sensitive to contamination. This level may be attained in any area where the cleanliness integrity of the article being processed would not be jeopardized.

12.2 VISUAL CLEANING PROCESS CONTROLS

All fluids, equipment, and facilities used for cleaning to the VC or VC + UV cleanliness levels shall be subject to the same minimum requirements specified for precleaning procedures (sections 8.1, 8.2, and 8.6). Cleaning with an approved, compatible solvent (e.g., solvent wipe) is mandatory for VC and VC + UV items, unless other methods are required by the hardware in question. GC items do not require cleaning before inspection; cleaning is required only if the item does not pass GC inspection. The GC cleaning process used shall be compatible with the hardware materials.

12.3 HANDLING

Items cleaned to the VC + UV, VC, and GC levels shall be handled as follows:

a. VC + UV level. Items cleaned to the VC + UV level shall be handled the same as precision-cleaned items (i.e., with gloves, forceps, or tweezers).

b. VC level. Items cleaned to the VC level shall be handled with gloves if so specified by the responsible design or using organization.

c. GC level. Gloves are not required for the handling of GC items.

12.4 VISUAL INSPECTION

Non-UV visual inspection shall be accomplished under a white light of sufficient intensity to adequately illuminate the surface being inspected. The inspections shall be performed as follows:

a. VC and VC + UV levels. Inspection shall be performed as specified in sections 8.3, 12.1.1, and 12.1.2.

b. GC level. Inspection shall be as specified in section 12.1.3; particular attention shall be paid to those locations with cracks, crevices, holes, etc., which may trap or retain contamination.

12.5 PACKAGING REQUIREMENTS

Unique packaging requirements exist for items cleaned to visual cleanliness levels. The requirements stated below supplement packaging requirements delineated in sections 9.0 and 10.0. Procurement documents shall reflect specific packaging requirements selected from this section when visual cleanliness levels are specified.

12.5.1 VC + UV Level

The VC + UV cleanliness level requires the use of the double-bagging technique as specified in section 10.0 and table V, appendix B. Section 9.0 is applicable with the following exceptions: (1) *Inner* packaging materials shall be cleaned and verified to the VC + UV level as a minimum; and (2) visual inspection verification of the VC + UV levels shall be performed instead of rinse testing. Packaging operations shall be accomplished within a *Class 100,000* ECA or better.

12.5.2 VC Level

The VC cleanliness level requires packaging only in a single bag as specified in table V, appendix B. Section 9.0 is applicable with the following exceptions: (1) Packaging material shall be cleaned and verified to the VC level as a minimum; and (2) visual inspection verification of the VC level shall be performed instead of rinse testing. Section 10.0 is applicable, except for the double-bagging requirements. Packaging operations shall be accomplished, as a minimum, within a CWA.

12.5.3 GC Level

The GC cleanliness level has no specific contamination packaging requirements. This does not preclude protective packaging of the article for handling, shipping, and storage activities. Items scheduled for shipment for subsequent spaceflight shall be processed and packaged in an area where the cleanliness integrity of the article being processed would not be jeopardized.

At JSC, GC hardware in transit between facilities shall be environmentally protected. Acceptable means of protection shall include plastic boxes with snug-fitting covers or reusable plastic, non-heat-sealable bags. Hardware compatible foam or other acceptable means of cushioning may be used if necessary. Deteriorated or contaminated boxes or bags shall not be used.

12.6 IDENTIFICATION, CERTIFICATION, AND STORAGE

12.6.1 VC and VC + UV Levels

Items processed to the VC or VC + UV cleanliness levels shall be identified with a decal containing identification, inspection, and certification of cleanliness information, in accordance with instructions contained in paragraph 10.7 of this manual. Since VC items are single-bagged, identification/certification decals shall be placed on the outside of the single bag. Storage, environmental control, inspection, access controls, and poststorage decontamination requirements shall be as specified in section 11.4.

12.6.2 GC Level

This level does not require a cleanliness certification decal, since protective packaging for contamination control is not required. Nominal storage requirements shall be established as necessary, and consideration shall be given to such parameters as length of storage, fungus growth, etc.

12.7 FABRICATION, TESTING, ASSEMBLY, AND FIELD OPERATIONS

Field operations include, but are not limited to, repair, replacement, and maintenance.

12.7.1 VC + UV Levels

Requirements specified in sections 17.0 and 18.0 are applicable to items cleaned to the VC + UV level.

12.7.2 VC and GC Levels

Requirements detailed in sections 17.0 and 18.0 may be applied to VC or GC items if so specified by the responsible design or using organization.

13.0 CLEAN ROOM GARMENTS

The minimum requirements for the materials, construction features, laundering processes, and controls for clean room garments and accessories, including biologically clean garments, are stated below.

13.1 GENERAL

13.1.1 Garment Construction

The garment shall cover the body adequately and shall incorporate adjustable collars and cuffs to give a snug fit. It may be fastened by either snaps, ties, or zippers and shall not have pockets. Garments selected must have been tested and proven to exhibit limited linting characteristics. Flame-retardant materials may be used for personnel protection; however,

such materials shall comply with the requirements contained in this section and must be approved by the Mechanical and Chemical Process Engineering and GFE Branch.

Where antistatic garments are required, garments having surface resistivity approaching 11.0 log R units (log of resistivity per square unit of surface) shall be selected. This may be achieved by addition of an antistatic agent to the material.

13.1.1.1 Fabric. Garments shall be of a 100% synthetic textile fiber, such as Dacron or nylon, of a white or pastel color, and have a taffeta or herringbone twill weave.

13.1.1.2 Thread. The thread shall be a continuous filament, stranded, 200 denier, 100% polyester, and of the same color as the garment.

13.1.1.3 Seams. Seams shall be closed, double stitched, and free of loose threads.

13.1.1.4 Style. All smocks and coats shall be at least knee length, and all coveralls shall have full-length legs.

13.1.2 Accessory Construction

13.1.2.1 Head Coverings. Head coverings may be any of the types described below provided hair is fully covered:

a. Surgeon caps for short hair styles.

b. Snood caps with drawstring or bouffant style caps for long hair styles.

c. Hoods and face covers. Hoods shall completely cover head and neck, except for face. Hoods should also cover the nose when necessary. Hoods shall fit inside the neck of the coverall. A face mask shall completely cover beards or mustaches.

13.1.2.2 Shoe Coverings. The tops of the shoe covers shall be made of the same material as the basic garment, be high enough to cover the coverall pants legs, and be secured to the pants legs by either a tie or snaps. All seams shall be turned inside and double stitched. The soles shall be made of skid-resistant plastic or other acceptable material.

13.1.2.3 Shoe Socks. Shoe socks shall be made of stretch nylon, or equivalent material, one-size design, with coverage of leg to midcalf. The use of other types of shoe coverings shall be subject to approval by the Mechanical and Chemical Process Engineering and GFE Branch.

13.1.2.4 Gloves. Gloves shall be a form-fitting, one-size design, and shall provide complete coverage. Each using organization should determine the least contaminant-generating material for its particular application.

13.1.2.5 Wiping Cloths. Reusable cloths shall be lint free and constructed of a synthetic, low particulate-generating fiber. Single-use or throw-away cloths may be used for specific applications if they are compatible for precision-cleaning use.

13.2 LAUNDERING REQUIREMENTS

13.2.1 Processing

All laundering shall be conducted in facilities which provide airborne particulate control compatible with the cleanliness required for the garments.

13.2.2 Cleaning Techniques

Cleaning may be performed by water washing or dry cleaning using approved clean room techniques. Either method or a combination of the two is acceptable as long as particulate content is held within acceptable limits.

13.3 INSPECTION

Inspection of clean room garments shall be accomplished as described below.

13.3.1 Sampling

Two percent of each shipment shall be checked to ensure that garments meet particulate requirements listed in 13.4. Particulate determination shall be conducted in an environment equal to or better than the environment wherein the garment was cleaned, if possible. Points of garments to be checked shall be in accordance with a method, or a method similar to that, established by ASTM F51-65T or TO 00-25-203.

13.3.2 Visual Inspection

Each garment and accessory shall be inspected for needed repairs, missing snaps, and broken zippers. This inspection shall be the responsibility of the user. Any garment or accessory showing breakdown of fabric, as evidenced by loose fiber ends protruding from the surface, shall be rejected.

13.4 ACCEPTANCE CRITERIA AND LIMITS

13.4.1 Particulate

The maximum permissible concentration of particles and fibers per square foot of fabric surface shall not exceed 5,000 particles of 5 microns and larger, with a maximum of 25 fibers. The method of sampling shall be in accordance with or equivalent to ASTM F51-65T or T.O. 00-25-203. Alternative methods with higher flow rates and particle and fiber concentrations may be used if approved by the procuring agency.

13.4.2 Particle Counting Method

Suitable counting techniques of particles shall be in accordance with a method, or a method similar to that, established by ASTM F51-65T or TO 00-25-203.

13.4.3 Hydrocarbons

Sample garments shall have no visible hydrocarbons, such as oil stains or grease, as determined by UV light.

13.4.4 Packaging

All garments shall be packaged individually in a polyethylene bag which shall be hermetically sealed in the clean room before exposure to an uncontrolled environment.

13.4.5 Certifications

Certification showing evidence of compliance with these requirements shall be submitted by the supplier with each shipment.

14.0 PERSONNEL TRAINING

This section defines the minimum training requirements for operational, technical, and management personnel.

14.1 APPLICABILITY

The requirements of this section are applicable to all operational, quality, technical, and management personnel.

14.2 TRAINING FOR ENVIRONMENTALLY CONTROLLED AREA DISCIPLINES

Personnel training for individual ECA operations is required and shall be accomplished by the successful completion of a formal training program in each unit operation (as applicable).

ECA disciplines are individual operations required in a listed ECA to permit flexibility in personnel training. In addition to ECA disciplines, personnel need only be trained and qualified in the operations that encompass their particular job responsibilities. Individual clean room operations and personnel required to be trained are as shown below.

OPERATION	PERSONNEL REQUIRING TRAINING
ECA discipline	All personnel (see note)
Precision-cleaning and packaging	Personnel cleaning parts and handling cleaned parts
Part/item sampling	Sampling personnel

NOTE: Personnel requiring entry to the ECA on a visit or on a temporary basis must be knowledgeable in the basic ECA disciplines or shall be instructed before entering. Such personnel shall be accompanied by and be the direct responsibility of an escort who is qualified for ECA entry. Entry of visitors or temporary personnel shall be controlled by the appropriate ECA supervisor to prevent overpopulation and compromise of ECA integrity.

14.3 QUALIFICATION STATUS

Qualification status may be acquired as specified below.

14.3.1 Previous Qualifications

In the event that personnel have been previously trained for individual ECA operations, those persons shall furnish the responsible training officer with copies of training results, certificates, or any other data requested for proof of qualification.

14.3.2 New Employees

Newly employed personnel may be issued temporary permits for entry into the ECA room for periods not to exceed 90 days. New employees granted temporary permits for ECA entry shall only be granted such permits after they have been verbally indoctrinated in ECA entry procedures, garment donning procedures, and ECA rules and regulations.

Personnel having temporary permits shall be assigned to and be the direct responsibility of a qualified operations, quality, technical, or supervisory person. Formal training in specific ECA unit operations shall be provided to these personnel. New employees shall be given (1) a minimum of 2 hours' formal training which shall encompass an introduction to contamination control disciplines, the applicable governing requirements, and the unit operations applicable to the individual assignment; or (2) on-the-job training.

14.3.3 Janitorial Services

Personnel performing janitorial services may be granted temporary permits after thorough verbal indoctrination in ECA entry procedures, garment donning procedures, and ECA rules and regulations. Janitorial personnel shall be the direct responsibility of a qualified operational or supervisory person.

14.3.4 Training Records

Records listing all employees and the specific operations for which they are qualified shall be maintained by the ECA operating organization.

14.4 CERTIFICATE

Upon successful completion of the appropriate qualification requirements, a certificate of training may be issued. This certificate shall bear the signature and title of the authorized training officer.

14.5 RETRAINING AND QUALIFICATION

The authorized training officer or the responsible division, branch, or section chief may require a person to be retrained any time there is reason to question the proficiency of the individual.

15.0 SPECIAL CLEANING REQUIREMENTS

15.1 PORTABLE GAS CYLINDER CLEANING

Portable cylinders (metal only) used for breathing oxygen and breathing air shall, as a minimum, be cleaned in accordance with the following or equivalent procedure. The cleanliness and gas purity tests shall be performed regardless of the procedures used. Portable cylinders shall be defined as a cylinder that contains a 5- to 30-minute supply of oxygen or air for emergency use.

15.1.1 Recommended Procedure

15.1.1.1 Inspection. Using a light source with an intensity level of 1,000 to 1,600 lumens (30 to 45 meter-candles, 100 to 150 foot-candles) per square meter, inspect the internal surfaces of the gas bottles for the presence of scale, slag, oxide, or grease.

15.1.1.2 Degreasing. When the visual inspection dictates the need, degrease the gas bottles by flushing them with solvent. Make another visual inspection and repeat the process as required. When cleanliness is achieved, dry the gas bottle with nitrogen gas.

15.1.1.3 Sand or Grit Blasting. Remove scale, slag, and oxides by sandblasting, using a 20- to 30-grit silicone sand at a minimum nozzle pressure of 95 psi. Ensure that the sandblast air is free of oil and moisture. Exercise care to avoid blasting threaded areas of the bottle. Ground blast hoses and nozzles to dissipate static charges.

15.1.1.4 Flush Cleaning. When sand or grit blasting is performed, follow by a flush cleaning with solvent. If scale, slag, oxides, or grease are still visible, resandblast and reflush as necessary. When cleanliness is achieved, dry the bottle with nitrogen gas.

15.1.1.5 Hydrostatic Testing. Following degreasing, sandblasting, and flush cleaning, hydrostatically test the bottles as applicable according to Department of Transportation regulations.

15.1.1.6 Final Cleaning. Subsequent to hydrostatic testing, subject the bottle to a final cleaning. Using phosphoric acid as specified in MIL-C-10578 (or other cleaning agents that are compatible with the gas bottle), flush or immerse the bottle for a period of 25 to 30 minutes and then flush with water until the pH is within 0.5 pH of the influent water and dry with nitrogen gas.

NOTE: For water-flushing operations, invert the bottle and flush as quickly as practical to prevent excessive flash corrosion on the interior surface.

15.1.2 Mandatory Verifications

15.1.2.1 Cleaning Verification. Final cleanliness shall be verified by a solvent flush. Immediately subsequent to flushing, the bottle shall be positioned upside down and purged thoroughly with filtered nitrogen as specified in MIL-P-27401, grade B. The flush fluid shall be analyzed for NVR content. The maximum allowable film/nonparticulate contamination shall be 1.0 milligram per 0.1 square meter (1 square foot) of bottle internal surface area if NVR, equivalent total organic carbon (TOC), or other film-verification method is used.

15.1.2.2 Gas Purity Verification. After it has been verified that the NVR level is acceptable, the bottle shall be pressurized with the required amount of oxygen or air from a certified clean source and capped. A sample of the gas shall be drawn from the bottle and analyzed. If the gas sample meets the applicable gas specification requirements, the bottle shall be refilled from a certified source. If the sample fails because of excessive solvent fumes, a vacuum purge may be required. The bottle may have to be simultaneously heated and vacuum purged for adequate cleaning. After the vacuum purge, the gas sampling and analysis shall be repeated until an acceptable sample is obtained.

15.2 CLEANING SMOOTH-BORE HOSES AND TUBING

Smooth-bore hoses and tubing shall be cleaned as specified below.

15.2.1 Precleaning

Hoses or tubes shall be examined for evidence of kinks, bends, or thread damage and decontaminated by immersion or flush rinsing with cold tap water until pH of effluent is within one-half pH unit of influent.

15.2.2 Detergent Cleaning

Detergent cleaning shall proceed as follows:

a. Clean exterior surfaces of hoses or tubing with non-ionic biodegradable detergent cleaner using nylon brushes as required. Exposure time, temperature (not to exceed 62.7°C [145 °F]), and concentration shall conform to the manufacturer's recommended procedures.

b. Rinse the cleaned surfaces with tap water and dry with hot (49° to 60°C [120° to 140°F]) nitrogen gas (MIL-P-27401, grade A, or equivalent).

c. Carefully clean end fittings of hoses and tubes with solvent using nylon brushes as required. Care must be taken to ensure that the solvent does not contact the hose.

d. Install the adapter fitting and connect the hose or tube to be cleaned to the pump discharge line.

e. Install a restricter fitting in the downstream end of the hose or tube being cleaned. This provides backpressure so that cleaning and rinsing solutions will contact all interior surfaces.

15.2.3 Cleaning of Hose Assemblies

Cleaning of hose assemblies shall proceed as follows:

a. Flush the hose with a non-ionic biodegradable detergent cleaner (or suitable cleaner/rinsing fluid) for 5 to 15 minutes (or for however long it takes).

b. Change the flush pump suction to deionized water that has a minimum specific resistance of 50,000 ohms and flush the hose for 1 to 2 minutes.

c. Detach the hose from the flush pump discharge hose, and remove all adapter fittings. Thoroughly rinse end fittings of the hose with the deionized water.

d. Dry the hose with hot (49 to 60°C [120 to 140°F]) nitrogen gas (MIL-P-27401, grade B, or equivalent). Dry in heated (49 to 60°C [120 to 140°F]) vacuum chamber for 25 to 30 minutes at maximum vacuum.

15.2.4 Final Rinse and Cleaning

The final rinse and cleaning shall be performed as follows:

a. Flush rinse small hoses or tubes with 0.8-micron-filtered rinse fluid.

b. Fill and drain large hoses or tubes with 0.8-micron-filtered rinse fluid.

c. Use deionized water to rinse nonmetallic items.

d. Restrict the flow of fluid at the downstream end of the hose or tube as necessary to provide fluid contact with all interior surfaces of the hose or tube.

e. After completion of the final rinse, continue the rinse and collect 100 milliliters of water per square foot of interior surface of the hose or tube.

f. Dry interior surfaces and end fittings with 10-micron absolute filtered hot (49° to 60°C [120 ° to 140°F]) nitrogen gas (MIL-P-27401, grade B, or equivalent).

16.0 FLUID SAMPLING

This section defines general requirements for sampling liquids and gases. All phases of sampling (e.g., equipment cleaning and handling) instructions are the responsibility of the operating organization and are not within the scope of this document. JSC-01218 details the preferred methods of sampling and may be used as a guide in establishing detailed procedures. Sampling procedures used at JSC shall be approved by the Occupational Safety and Quality Assurance Branch.

NOTE: The use of liquid-borne particle counters requires Mechanical and Chemical Process Engineering and GFE Branch concurrence.

16.1 GENERAL REQUIREMENTS

16.1.1 Sample Points

System test points (identified as the "most severe" locations; i.e., the bottom of propellant tanks, just upstream of engines, etc.) shall only be sampled when specifically required by controlling documentation.

16.1.2 Samplers

Sampler configurations and materials differ because of the pressures of the gases supplied. Materials for construction of samplers must be compatible with the sampled fluids and shall contribute a minimum of contaminants to the sample. Samplers shall be serialized and identifiable as to the material sampled and the sample source. Other requirements are cited below.

16.1.2.1 Sample Bottles for Breathing Systems. Subsequent to its initial cleaning and certification for use in sampling breathing systems, the sample bottle shall not be used for sampling any other fluid. Recleaning is not required for each sampling, provided the bottle remains sealed (except when in use) and a preceding sample has not failed. The bottle shall be heated, purged, and/or evacuated to remove residual contaminants prior to reuse. The bottle will be sealed with AN-type caps or plugs.

16.1.2.2 Cryogenic Samplers. Liquid cryogenic samplers must be maintained in a clean condition during storage because of the rigid purity requirements for the fluids they contain. In cleaning before storage, the samplers may be heated and/or vacuum purged to remove absorbed impurities. Purge gases shall be those of the material normally sampled and shall be of sufficient purity to preclude contaminating the sampler. Storage configuration (e.g., positive pressure or vacuum) of liquid cryogenic samplers shall be in accordance with JSC-01218.

16.2 SAMPLING APPARATUS PREPARATION

16.2.1 Cleaning of Sampling Apparatus

All sampling apparatuses shall be cleaned to a level consistent with the operations being performed. If particulate contamination of the sampler is suspected, "blank" rinses, using a specified cleaning solvent filtered through a membrane filter (0.2 to 0.8 micron), shall be run to determine the contaminant level of the sampler. Cleaning of samplers to a particulate level should be limited to those instances in which the particle count is required. Sampling apparatuses shall, as a minimum, be cleaned as follows:

a. Wash each part of the disassembled sampling apparatus (filter holder, sample bottle, fittings, hoses, etc.) with a hot detergent and water solution.

b. Rinse or flush thoroughly with distilled water, tap water, or deionized water, as needed.

c. Rinse or flush thoroughly with isopropyl alcohol as specified in TT-I-735, or appropriate water.

d. Rinse or flush thoroughly.

e. Certify by liquid sample that the required cleanliness of the sampling apparatus has been met.

f. Purge dry with filtered nitrogen, as specified in MIL-P-27401, grade B.

16.2.2 Sampling Hoses, Tubing, and Fittings

Subsequent to cleaning and drying, hoses and tubing shall be sealed with clean AN-type plugs and then packaged with an appropriate outer packaging material as specified in table V, appendix B. Fittings shall be individually double bagged as specified in section 10.0.

16.2.3 Preparation and Assembly of Filter and High-Pressure Filter Holder

The preparation and assembly of high-pressure filter holders shall, as a minimum, proceed as follows:

NOTE: The preparation of the high-pressure filter holder and the particulate sample analysis shall be performed in at least a Class 10,000 clean room or work station.

a. Using clean forceps, remove the filter from its container.

b. Pressure rinse the grid side of the filter with a stream of filtered solvent compatible with and approved for the system being sampled.

c. Microscopically examine the filter for holes, gouges, or other damage. Also size and count all particles over 10 microns in size. This particle count shall be known as the sample "blank" and shall be recorded.

d. Place the filter with grid side up on the lower half of the filter holder.

e. Immediately place, do not slide, the upper half of the filter holder containing the O-ring into position.

f. Install and torque the bolts and closures.

g. Double bag the assembled high-pressure filter holder as specified in section 10.0 and table V, appendix B.

16.3 CONTAMINATION CONTROL DURING SAMPLING

Reasonable precautions should be taken to prevent contaminating the sampling apparatus, fluid, or system before, during, and after extraction of the sample. The sample port on the line (container) to be tested shall be flushed immediately before connection of the sampler. The flushing shall be done with a specified precision-cleaning solvent that is compatible with the system being sampled. When cleaning the sample ports, care should be exercised, even when

using a compatible solvent, that the cleaning solvent does not contaminate the sampler. Sample ports shall be properly capped and/or packaged.

16.4 SAMPLING PROCEDURES

General procedural requirements applicable to fluid sampling are as stated below.

16.4.1 Agitation

When containers of liquids to be sampled have been at rest for a time during which particles in the liquids may have settled, the liquids shall be agitated before sampling to ensure a representative sample. Liquids in stationary (e.g., permanently installed) containers and/or pressurized containers shall not be agitated. Gas samples for particulate should be taken with the sampling system operating at the design mass flow rate or, in the event this is not practicable, at a flow rate producing turbulence.

16.4.2 Gas Particulate Sampling

Gases shall be sampled for particulate by connecting to a system or storage test point and directing the flow of the gas through a membrane filter. Filters must show a complete O-ring indentation on the membrane, or else resampling is required. A high-pressure gas membrane filter assembly with an appropriately sized membrane filter should be used. When attaching the sampler assembly to the sample port, extreme care shall be taken to prevent the generation of particles. The filter assembly shall be held vertically so that the particles impinge on the horizontal filter membrane in a downward, vertical flow.

16.4.3 Dynamic Samples

Whenever possible, a closed system (i.e., one not exposed to the atmosphere) should be used for sampling. For samples taken during a fill operation, a flowthrough sampler should be used at the same flow rate as the system being serviced.

16.4.4 Static Samples

Where flowthrough cannot be realized, the sampler shall be filled and drained twice before retaining a sample. Whenever safety or other constraints demand, the sampler must be evacuated before use. The fill-and-drain methods, however, provide the least representative samples and should be used only when no other choices are available.

16.4.5 Filter Handling

Subsequent to sampling, the loaded filter shall be placed in a precision-cleaned petri dish. The petri dish shall not be opened until the particles have been counted.

16.5 SAFETY

Safety requirements are not delineated in this section. These shall be included in detailed operating procedures which respond to the requirements of the responsible safety organization.

17.0 CONTAMINATION CONTROL DURING FABRICATION, ASSEMBLY, AND TESTING

This section establishes the minimum contamination controls necessary to prevent the recontamination of precision-cleaned items.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

17.1 GENERAL REQUIREMENTS

Precision-cleaned items shall be protected from airborne contaminants during processing performed subsequent to cleaning. This protection shall include the use of temporary packaging or covering. Upon completion of all required processing, the cleaned item shall be double=bagged as specified in table V, appendix B.

17.2 FABRICATION

The fabrication operations for each component must be completely evaluated and appropriate cleanliness requirements established and documented for each phase of the operation. Environmental and personnel controls shall be determined considering such factors as the complexity of the fabrication or item and whether required cleanliness can be satisfactorily accomplished at a later level of assembly. Environmental and contamination controls shall be implemented for, but not limited to, such processes as soldering, welding, plating, bonding, and application of lubricants. These controls shall be sufficient to ensure the cleanliness and purity required for process and product reliability.

17.3 ASSEMBLY

Precision-cleaned items shall be assembled in an appropriate class clean room or laminar flow clean work station.

NOTE: Final assembly operations in which only small areas of critical surface are exposed (e.g., connections and fittings) may be performed in a CWA upon approval from the Mechanical and Chemical Process Engineering and GFE Branch. It may be necessary, however, to monitor airborne particulate in the CWA during such operations.

Certified clean parts shall be protected from recontamination by interim packaging or other protection before and during assembly operations. Process controls, including use of clean rooms, laminar flow clean work stations, purge gases, dry box enclosures, and strict personnel controls, shall be established as required to ensure that no contaminants are introduced into the component being assembled.

Visual inspections shall be performed frequently during the assembly process to ensure that cleanliness has not been degraded. Parts and components shall be rejected if visible contaminants are detected during the assembly process.

Assembly techniques and subsystem assembly controls are as stated below.

17.3.1 Assembly Techniques

Typical techniques to prevent the contamination or recontamination of the items being assembled are listed below. Additional techniques or improvement of the listed techniques should be developed as required for the particular assembly operation being performed.

a. Precision-cleaned items shall only be handled with clean forceps, tweezers, or gloved hands during assembly. Items cleaned to visual cleanliness levels shall be handled in accordance with section 12.3.

   NOTE: When gloves are used for the handling of LOX or GOX components with exposed critical surfaces, they shall be constructed of an approved, compatible material.

b. Lines, hoses, and components with B-nut type fittings shall be aligned with the mating part and only the threaded fitting shall be rotated to prevent the generation of particulate and the subsequent contamination of the item. Movement of the mating surfaces must be held to an absolute minimum.

c. To prevent the generation of packaging material contaminants, packaging materials shall be opened using a sharp instrument.

d. Purges shall be used in all possible instances to prevent the entry of contaminants into precision-cleaned items.

e. Strict personnel controls shall be maintained to minimize contamination in assembly areas.

f. Assembly work areas, benches, tools, and aids shall be maintained in a clean condition to prevent the contact transfer of contaminants.

17.3.2 Subsystem Assembly Controls

Components and subassemblies shall be rejected if contaminants are detected during the assembly process. If a subsystem is contaminated, appropriate authorities shall determine whether to disassemble and clean the subsystem or perform in-place cleaning to meet the appropriate cleanliness levels.

17.4 TESTING

The functional testing of precision-cleaned items is governed by test procedures delineating the test methods and acceptance criteria. When specific contamination control requirements are not stipulated by the governing document, the requirements stated below shall be implemented.

17.4.1 Component Functional Testing

Components, such as valves, which require functional testing shall be protected from particulates and other contaminants during testing. When feasible, all functional testing shall be performed inside a laminar flow work station. All functional testing equipment, such as pressurization consoles and connecting hardware, shall be sampled and certified to meet the required cleanliness level. Components contaminated beyond the acceptable level during the process shall be rejected, disassembled, and recleaned.

17.4.2 Test Facility/Equipment

The test facility and test equipment shall be verified by inspection and/or sampling as required to ensure that the precision-cleaned item will not be contaminated by the facility or the test fluid to be used.

17.4.3 Fluid Line Connections

Fluid line connections shall be sealed when not in use to ensure equipment cleanliness integrity.

17.4.4 Mechanical Connections

Lines, parts, and fittings of cleaned items and test equipment shall be mechanically connected with a minimum of slide fitting to reduce the generation of particles.

17.4.5 Item Protection

Components which have been tested using liquid shall be drained and sealed leak tight with clean caps or plugs at all ports. The exterior surfaces shall then be wiped with non-lint-producing material moistened with approved, compatible solvent and dried.

18.0 CONTAMINATION CONTROL DURING REPAIR, REPLACEMENT, AND MAINTENANCE

This section establishes the minimum contamination control requirements for repair and replacement of or maintenance operations performed on systems which have previously been precision-cleaned. The cleanliness of precision-cleaned, contaminant-critical systems may be compromised by improper contamination control techniques during any operation. Localized clean operations may be conducted in a number of ways, any of which are acceptable provided the general requirements stated below are met.

NOTE: The requirements in this section are also applicable to visual cleanliness levels to the extent specified in section 12.0.

18.1 OPERATIONS PRECEDING SYSTEM BREAKING

18.1.1 Area Cleanup

The area in which the repair, replacement, or maintenance is to be performed shall undergo a stringent housecleaning process, before which all loose or extraneous equipment shall be removed from the area.

18.1.2 Controlled Environment Enclosures

A temporary enclosure shall be constructed around the portion of the system to be opened to prevent contaminating the open system (or replacement part) by exposure to the normal working environment. The air source used shall furnish filtered air to provide an environment equivalent to or better than the environment required for the initial assembly of that particular system. Depending on the size of the components or the complexity of the repair operation, the enclosure may be a small "dry box" design or a large, walk-in, tent-type configuration as described below.

18.1.2.1 Small "Dry Box" Enclosure. This enclosure, normally made of a polyethylene sheet, shall be large enough to admit the hands. The inside of the enclosure shall be wiped VC and then the system opened to admit a flow of dry filtered inert gas from the system. The gas flow pressure shall be such that no dust or other environmental contaminants can enter the enclosure. When purging the system is not feasible (e.g., small tubing in liquid system) a purge of filtered air shall be established through the "dry box."

18.1.2.2 Walk-in Enclosures. The nature of the operation may necessitate the construction of a large walk-in enclosure. This enclosure shall be made of a polyethylene sheet, suitably reinforced (if necessary) and shall be wiped VC before use. Air shall be pumped into the enclosure so as to provide a controlled environment required for the system components. This shall be accomplished by properly operating a HEPA filter assembly and temperature and humidity controls as required. The rate of airflow into the enclosure shall be sufficient to preclude dust or other environmental contaminants from entering the enclosure; however, the influent airflow shall not be so great as to force contaminants into the opened system. A good method is to install the filtered air blowers onto the enclosure and pressurize the entire enclosure to 1 or 2 inches (water psig).

NOTE: The design, configuration, and operation of all walk-in enclosures must be approved by the JSC Test, Operations, and Institutional Safety Branch, and the Mechanical and Chemical Process Engineering and GFE Branch.

18.1.3 System Purge

In operations on nonliquid systems or systems which have been drained, a purge with inert gas shall be established in the system before opening. The gas shall meet or exceed system cleanliness level requirements. The gas flow rate shall be such that a positive pressure from the system to the environment shall prevail upon opening the system. The purge shall continue until the repair, replacement, or maintenance operation is completed and the system is closed. When a gas purge is not used, the open system lines shall be protected by a bag (constructed of an appropriate inner packaging material as specified in table V, appendix B) secured around the open port, or sealed by an approved method to prevent the entry of contaminants.

18.2 REPAIR, REPLACEMENT, OR MAINTENANCE OPERATIONS

18.2.1 Garments

Personnel in the enclosure during repair, replacement, or maintenance operations shall wear clean room attire as required to maintain the cleanliness requirements of the system components. Table III, appendix B, may be used as a guide in establishing garment requirements. Items cleaned to visual cleanliness levels shall be handled in accordance with section 12.3.

NOTE: Precision-cleaned items shall be handled with clean forceps, tweezers, or gloved hands only. When gloves are used for the handling of LOX or GOX components with exposed critical surfaces, they shall be constructed of an approved, compatible material.

18.2.2 Enclosure Operations

No operations shall be conducted in the enclosure unless the system purge and filtered air inputs are "on." "Operations" shall include the unwrapping of precision packaged components

or tools, opening or closing of the system, installation or removal of components, etc., by properly clothed personnel.

18.2.3 Removed Parts

All contamination-sensitive parts removed from assemblies shall be handled as specified below.

18.2.3.1 Local Clean Area. All surfaces, lines, ports, etc., opened or exposed because of part removal or system breaking shall be protected with caps, covers, or plugs to prevent contamination of the exposed system. Removed components, parts, or system shall have critical surfaces or tube openings closed with clean protective plugs or caps, or shall be covered with a clean plastic bag constructed of an appropriate inner packaging material as specified in table V, appendix B.

In addition, a clean plastic bag (constructed of an appropriate outer packaging material as specified in table V, appendix B) shall be placed over the plugged, bagged, or capped area. Immediately after removal, the item shall be completely covered with a plastic bag (constructed of an appropriate outer packaging material as specified in table V, appendix B) for transporting to the clean room.

18.2.3.2 ECA. All subsequent operations involving parts, systems, etc., which are to be reinstalled on the spacecraft shall be conducted in an ECA of a level meeting the cleanliness requirements established for the specific item. Upon completion of final cleaning, and before being removed from the ECA, the item shall be protectively packaged as specified in section 10 before being returned for reinstallation. All protective coverings shall be removed inside the localized clean areas. When the item is to be returned to a contractor for repair, it shall be double-bagged (as specified in table V, appendix B) in the ECA before shipment.

18.2.3.3 Cleaning and Sampling. Repair, replacement, or maintenance operations which may result in the contamination of interfacing items shall be cause for cleaning and sampling of the contaminated items to ensure the cleanliness integrity of the assembly being serviced.

18.2.4 Fluid Spills

Cleanup of all fluids spilled in or upon the system shall be in accordance with approved documented procedures. The cleanup operations shall be witnessed by JSC Institutional Safety and Quality personnel and shall be adequately documented for corrective action traceability.

19.0 ENVIRONMENTAL TEST CHAMBER CLEANLINESS

This section establishes the minimum cleanliness requirements for environmental test chambers. It also includes requirements for maintaining cleanliness standards while components are being removed or replaced. Cleanliness levels of subsystems shall be as established in the applicable subsystem specification.

19.1 GENERAL REQUIREMENTS

Environmental test chambers shall be designated as CWAs as a minimum. Other requirements are stated below.

19.1.1 Personnel Access

Access to the immediate vicinity of the test article or work area shall be restricted to those personnel essential to the operation. Details of control shall be jointly established by the responsible test organization and the operating organization, the contractor, or the responsible JSC representative.

19.1.2 Garments

Clean room garments shall be worn by personnel working in or visiting the CWA. Personnel entering the test article shall wear clean coveralls or smocks, foot covers or approved shoe socks, and hoods or caps. All garments shall be donned at the test article entrance or appropriate location before entry.

NOTE: Items cleaned to visual cleanliness levels shall be handled in accordance with section 12.3.

19.1.3 Access to Test Article

Entry to the test article shall be restricted to personnel who must enter to perform necessary tests, checkouts, maintenance, inspections, and/or repair functions.

19.1.4 Systems/Subsystems Assembly or Rework

Maintenance or parts replacement shall be performed under localized clean operational conditions ("dry box" or walk-in enclosure as specified in section 18.0) when the specifications for the systems indicate that more rigid contamination controls are required than provided by the surrounding CWA.

19.1.5 Checklist

An accountability checklist shall be provided for all items (parts and tools) taken into environmental chambers. There shall be no exceptions. Installed hardware shall be verified by the responsible quality group and removed parts accounted for. Any item not accounted for shall be located or its disposition mutually determined before continuing testing and/or maintenance.

19.1.6 Training Requirements

All personnel having access to the test article work area shall be properly trained before entering. This training shall be sufficiently extensive to enable these persons to fully implement the intent and requirements of this specification.

19.1.7 Test Article Cleanliness

19.1.7.1 Interior Cleanliness. The interior of the test article shall be cleaned; i.e., vacuumed and/or wiped down, at the end of each working period. The vacuum source shall be located outside the work area with a well-cleaned hose and pickup attachment inside. If this is impractical, an approved industrial-type vacuum cleaner with filtered exhaust shall be used.

19.1.7.2 Exterior Cleanliness. The vacuuming and wipe-down of the outside of the test article shall be performed, as required, in accordance with applicable specifications. Wipe-down shall not be performed where damage to protective coatings may result.

19.1.8 Fluid Spills

Cleanup of spills shall be in accordance with paragraph 18.2.4.

19.1.9 Access Openings to Test Article or Chamber

During nonoperational periods, all entrances to the test article or chamber shall be kept closed.

19.1.10 Contaminant-Generating Operations

Contaminant-generating operations; e.g., sanding, grinding, chipping, soldering, and drilling, shall not be permitted in the chamber unless specifically approved by the operating organization. When such operations are approved, the work area shall be cleaned to its original cleanliness condition before work continues.

19.2 TEST ARTICLE INSTALLATION

19.2.1 Preparations

Before installation of the test article, the interior of the chamber shall be cleaned in accordance with an effective, approved cleaning procedure. Cleaning shall be performed, as required, to maintain the required cleanliness.

19.2.2 Installation of Test Article

Before installation of the test article, its exterior shall be completely vacuumed and wiped down, if necessary, to remove all visible soil. Wipe-down shall not be accomplished if damage to protective coatings may result.

19.2.3 Postinstallation of Test Article

After the test article is positioned and all electrical and mechanical connections are completed, the chamber will be thoroughly vacuumed. All visible film matter shall be removed before operations are continued.

20.0 NONAIRBORNE BREATHING AIR SYSTEMS

This section establishes the minimum cleanliness requirements for both portable and permanently installed nonairborne breathing systems. Also included are the sampling requirements to be met during operational and nonoperational periods.

20.1 PROCEDURES

Procedures for system operation, maintenance, preventive maintenance, servicing, sampling, certification, and safety shall be developed, documented, and approved. Procedures prepared for JSC on-site breathing systems shall be approved by the JSC Medical Operations Branch;

Test, Operations, and Institutional Safety Branch; and Mechanical and Chemical Process Engineering and GFE Branch, before implementation.

20.2 SYSTEM CLEANLINESS

Parts, components, subassemblies, and assemblies shall, as a minimum, be cleaned to *Level 300A* of table IV, appendix B. A more stringent cleanliness level shall be used when required to ensure system safety and functional integrity. Other requirements are stated below.

20.2.1 Cleanliness Maintenance

All openings into the breathing system; e.g., ports, open ended lines, and interconnecting fittings, shall be closed and protected with fittings or covers of a material which is compatible with the system fluids.

20.2.2 Periodic Cleanliness Evaluation

The organization responsible for the integrity of a breathing system shall document procedures for periodic evaluation of system cleanliness. The procedures shall establish the frequency of these evaluations. Frequencies shall be compatible with the system gas, functional requirements, and applications involved. Evaluation frequencies shall be approved by the JSC Medical Operations Branch and the Operations Safety Branch.

The evaluation, including particulate matter determination and NVR or other suitable film/non-particulate matter (e.g., TOC) determination, shall be performed as necessary. A minimum of 1 cubic meter (35 standard cubic feet) of gas from the system shall be purged through a sample filter to determine the particulate level per 0.1 square meter (1 square foot) of surface area.

20.3 SYSTEM CERTIFICATION

Systems used for breathing purposes shall be certified as stipulated below. The dispositions of systems failing the required purity levels, when analyzed in accordance with applicable requirements and this section, shall be determined by the responsible safety and medical officers before testing. This requirement is applicable to all vacuum chambers, facilities, and hazardous testing operations.

20.3.1 System Certification Sampling Requirements

New systems and systems modified or contaminated subsequent to certification shall be sampled initially and once each 24 hours for the following 48 hours. If the samples, when analyzed, meet the applicable specification, system, and test requirements, the system may be considered certified. *A system shall be considered contaminated as specified in sections 17.0 and 18.0 or if routine sampling procedures reveal particulate or nonparticulate matter exceeding specified requirements*.

NOTE: New breathing air systems shall be initially checked for mercury contamination as specified in applicable medical and safety requirements.

20.3.2 Breathing Source Supply Certification

20.3.2.1 General. Fluids (liquid and gas) shall be analyzed and certified to applicable requirements before being supplied to a breathing system.

20.3.2.2 Mixed-Gas Systems. For mixed-gas systems, each constituent gas must be analyzed and certified before the blending process. After the blending process, the synthesized gas must be sampled (at the farthest use point) and analyzed to ensure compliance with the applicable specification or test requirements.

NOTE: Because of the difference in boil-off temperatures between liquid oxygen and liquid nitrogen, liquid air systems shall require strict analysis sampling schedules to preclude a breathing system from becoming nitrogen rich.

20.4 MAINTENANCE AND SAMPLING

Systems and fluids certified in accordance with paragraph 20.3 shall be maintained and sampled in a accordance with table VI, appendix B. Whenever more stringent controls and sampling frequencies are required to ensure system integrity and safety, these controls and frequencies shall be reflected in the applicable operating procedures.

NOTE: Maintenance shall be scheduled and performed on system and fluid supply filtration equipment (i.e., particulate, oil, moisture, activated carbon, etc.) to ensure system safety and reliability.

20.5 IDENTIFICATION AND MARKING

Use-point outlets shall be identified by displaying a sign, tag, or label that reads "Compressed Gas for Breathing Purposes"; states the system pressure (psig) and date of last acceptable test; and has approval signatures affixed. Pressurization cylinders shall be stenciled, tagged, or labeled with the following information: Identification of product, applicable specification number, contract or purchase order number, supplier's identification, lot identification, and fill date.

20.6 REFERENCES

a. FED-SPEC BB-A-1034, "Compressed Air, Breathing"

b. MIL-A-27420, "Air, Liquid, for Breathing Purposes"

c. MIL-O-27210, "Oxygen, Aviator's Breathing, Liquid, Gas"

d. MIL-STD-1622, "Cleaning of Shipboard Compressed Air Systems"

e. NASA SD-B-0023-A, "Helium/Oxygen Breathing Mixtures"

f. NASA JSC TSD QI 1760.1, "Procedure for Cleaning Breathing Air and Oxygen Systems"

g. NASA JSCM 1700, "JSC Safety Manual"

h. NASA JSCM 8080 Standard F17, "Cleanliness of Flowing Fluids and Associated Systems;" F27, Liquid or Gas Containers - Verification of Contents; M/P-9, "Breathing Systems - Requirement to Test for Mercury Contamination"

i. NASA SP-3006, "Bio-Astronautic Databook"

21.0 AIR, OXYGEN, AND OXYGEN-RICH SYSTEMS REFERENCES

Contamination control is important regarding oxygen systems. Contaminants in oxygen systems can be fire hazards. Particulate matter in oxygen systems can become ignition sources if the particles move through the system and impact various components. Films,

nonparticulate matter, NVR, oils, greases, etc., may be flammable to some degree and act as a fuel source for a fire.

Engineers, technicians, and other people who work with oxygen systems should be aware of the hazards (fire hazards, specifically) related to oxygen systems. These hazards are addressed in the references listed below. The ASTM Technology Training Course regarding oxygen systems is also useful for anyone dealing with oxygen systems and the minimization of fire hazards.

a. ASTM Standard Technology Training Coursebook, G4.05, "Fire Hazards in Oxygen Systems," 1990

b. NSS 1740.15, "Safety Standard for Oxygen and Oxygen Systems"

APPENDIX A
ACRONYMS AND DEFINITIONS

ACRONYMS

ANSI	American National Standards Institute
ASTM	American Society for Testing Materials
CWA	controlled work area
DOP	dioctyl phtalate
ECA	environmentally controlled area
ESD	electrostatic discharge
FEP	fluorimated ethylene propylene
GC	generally clean
GFE	government-furnished equipment
GOX	gaseous oxygen
HEPA	high efficiency particulate air
IES	Institute of Environmental Sciences
JSC	Lyndon B. Johnson Space Center
LOX	liquid oxygen
MSFC	George C. Marshall Spaceflight Center
NASA	National Aeronautics and Space Administration
NVR	nonvolatile residue
psi	pounds per square inch
psig	pounds per square inch gauge
RH	relative humidity
SAE	Society of Automotive Engineers
SR&QA	Safety, Reliability, and Quality Assurance
TOC	total organic carbon
TPS	test preparation sheet
UV	ultraviolet
VC	visibly clean
VC + UV	visibly clean plus ultraviolet
WSTF	White Sands Test Facility

DEFINITIONS

Airborne Particulate Matter	Particulate matter suspended in the ambient atmosphere
Clean Room	An enclosed area employing control over the particulate matter in air with temperature, humidity, and pressure control, as required
Clean Work Station	A work bench or similar working enclosure having its own filtered air or gas supply
Cleanliness Level	(1) An established maximum of allowable contaminants based on size, distribution, or quantity on a given area or in a specific volume or (2) absence of particulate and nonparticulate matter visible under white light and/or UV illumination
Contaminant	Any unwanted matter which could be detrimental to the required operation, reliability, or performance of a part, component, subsystem, or system
Controlled Work Area (CWA)	An area maintained to a high degree of shop cleanliness
Critical Surface	A surface which requires precision cleanliness or requires contamination control
Dioctyl Phtalate (DOP)	A chemical used for filter efficiency testing
Environmentally Controlled Area	A classification which includes clean rooms, laminar flow clean work stations, and CWAs
Electrostatic Discharge	A transfer of electrostatic charge between bodies at different electrostatic potentials caused by direct contact or induced by an electrostatic field
Fiber	A particle whose length-to-width ratio is in excess of 10:1 (If not visible it may be referred to as a microfiber)
Fluid	A liquid or gaseous material
Flush	A rinsing of a part, component, subsystem, or system, using a liquid as the rinsing medium
Generally Clean (GC)	Free of manufacturing residue, dirt, oil, grease, processing debris or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing

High Efficiency Particulate Air Filter	A filter with minimum efficiency of 99.97% determined by the homogeneous DOP or other equally sensitive method at airflows of 20% and 100% of the rated flow capacity of the filter
Micrometer/Micron	A unit of measurement equal to one-millionth of a meter or approximately 0.00003937 inch (e.g., 25 microns are approximately 0.001 inch)
Nonparticulate Matter	Matter (usually film) with no definite dimension
Nonvolatile Residue	Soluble (or suspended) material and insoluble particulate matter remaining after controlled evaporation of a filtered volatile solvent, usually measured in milligrams. Filtration is normally through a 0.45-micrometer or 0.8-micrometer membrane filter before evaporation
Particle	Matter with observable length, width, and thickness usually measured in microns; this definition includes fibers
Particle Counters	Automatic electronic devices designed to separate, size, and count individual particles
Particulate Matter	The general term applied to matter with observable length, width, and thickness (as contrasted to nonparticulate film matter without definite dimensions)
Precision-cleaning	Final or fine cleaning accomplished in a controlled environment to achieve precision cleanliness. Surface cleaning with an approved, compatible solvent (e.g., solvent wipe) is satisfactory for VC + UV and VC items
Precision Cleanliness	A degree of cleanliness which requires special equipment and techniques for determination; precision cleanliness levels normally include limits for particulate sizes and quantities
Precision-Cleaning Agent	Any solvent used in precision-cleaning that has been filtered or otherwise cleaned to a specified cleanliness level. Precision-cleaning agents must be specified for a process or system application to ensure compatibility of fluids and materials
Precision-Clean Packaging	Packaging or protection used to preserve precision cleanliness for a specific period and condition

Purge	To flow a gas through a system (or pipeline, tube, tank, etc.) for the purpose of removing residual fluid or for providing a positive flow of gas from some opening in the system
Total Solids	The residue from a known volume of liquid which has been evaporated to dryness in an oven
Visibly Clean (VC)	Free of all particulate and nonparticulate matter visible to the unaided eye (corrective lenses are acceptable)
Visibly Clean Plus Ultraviolet (VC + UV)	Visibly clean (as defined above) and without fluorescent matter detectable with a UV light (blacklight) of 3,200 to 3,800 angstroms wavelength
Visual Cleanliness Levels	A category which includes VC, VC + UV, and GC cleanliness levels

APPENDIX B

TABLE I

CLEAN ROOM CLASSES BY PARTICULATE DISTRIBUTION

(NOTE 1)

CLASS (NOTE 2)	MAXIMUM PARTICLE COUNT PER 0.028 CUBIC METER (1.0 CUBIC FOOT)	
	SIZE ≥ 0.5 MICRON	SIZE ≥ 5.0 MICRONS
100	100	< 10 (NOTE 3)
1,000	1,000	< 10 (NOTE 3)
10,000	10,000	65
100,000	100,000	700

NOTES

NOTE 1 Particle size distribution curves may be found in FED-STD-209. Other counting methods for particle distributions are acceptable if appropriate.

NOTE 2 Other classifications (i.e., 400, 8,000, 30,000, etc.) may be used for particle count levels where unique situations dictate their use. The Occupational Safety and Quality Assurance Branch must concur in the selection and use of classifications that are not baselined in this table.

NOTE 3 Counts below 10 particles per cubic foot (0.028 cubic meter) are unreliable except when a large number of samplings are taken.

TABLE II

ECA REQUIREMENTS MATRIX

AREA REQUIREMENTS (NOTE 1)	CLEAN ROOMS		LAMINAR FLOW CLEAN WORK STATIONS	CWAs	REFERENCE PARAGRAPHS
	LAMINAR FLOW	NON-LAMINAR FLOW			
ANNUAL CERTIFICATION	X	X	X	---	6.7
CONTROLLED BY APPROVED DOCUMENTED PROCEDURES	X	X	X	X	5.0, 5.3.2
HEPA FILTER SYSTEM	X	X	X	---	5.1.1, 5.1.3
POSITIVE PRESSURE	X	X	---	---	5.3.1.4
AIRBORNE PARTICLE MONITORING	X	X	X (NOTE 2)		5.3.1.3, 5.4.1.5
TEMPERATURE CONTROL	X	X	---	---	5.3.1.5
RH CONTROL	X	X	---	X	5.3.1.6, 5.5.1.b
LAMINAR FLOW CRITICAL	X	---	X	---	5.1.1, 5.1.3
ROOM AIR CHANGE CRITICAL	---	X	---	---	5.1.1
SPECIAL TOOL CONTROLS	X	X	X	X	5.2.3
SPECIAL GARMENTS	X	X	X	X	5.2.1, 5..4.1.2
CONTAMINANT-GENERATING OPERATIONS MAY BE AUTHORIZED	---	---	---	X	5.5.3.e
STRICT PERSONNEL DISCIPLINE	X	X	X	X	5.4.1.2
FORMAL PERSONEL TRAINING	X	X	X	X	5.2.2, 14.0

NOTES

NOTE 1 The intent of this matrix is to provide a quick-look comparison of significant requirements for clean rooms, laminar flow clean work stations, and CWAs. It should *not* be inferred that this matrix represents *all* requirements necessary for the design, operation, maintenance, and use of ECAs.

NOTE 2 Airborne particulate monitoring may be necessary as specified in section 17.3.

TABLE III

ECA GARMENT REQUIREMENTS

	ECA			
GARMENT	CLASS 100 (NOTE 1) M3.5	CLASS 10,000 M5.5	CLASS 100,000 M6.5	CWA
COVERALLS	REQUIRED	REQUIRED	OPTIONAL	OPTIONAL
HOODS	REQUIRED	REQUIRED	(NOTE 2)	(NOTE 2)
SMOCKS	----------	(NOTE 3)	REQUIRED	REQUIRED
CAPS	----------	----------	REQUIRED (NOTE 2)	REQUIRED
BOOTIES	REQUIRED	OPTIONAL	OPTIONAL	OPTIONAL
SLIP-ON SHOE COVERS	----------	REQUIRED (NOTE 4)	REQUIRED (NOTE 4)	OPTIONAL
HAND COVERINGS	(NOTE 5)	(NOTE 5)	(NOTE 5)	(NOTE 5)

NOTES

NOTE 1 Laminar flow clean work stations: Garments are required only for those parts of the body that are extended into the clean work area (i.e., hands, arms, upper torso, facial and head hair, etc.).

NOTE 2 Hoods shall be worn when caps do not fully cover facial and head hair.

NOTE 3 Smocks may be used in lieu of coveralls in Class 10,000 vertical laminar flow clean rooms provided applicable airborne particulate requirements are met.

NOTE 4 Shoe coverings may be deleted from use in these classes of vertical laminar flow clean rooms provided applicable airborne particulate requirements are met.

NOTE 5 The use of hand coverings (e.g., gloves) is dependent upon the type of operation being performed. Hand coverings are mandatory for handling exposed critical surfaces of precision or VC + UV cleaned items.

When hand coverings are used in the handling of LOX/GOX components with exposed critical surfaces, they shall be constructed of an approved, compatible material.

TABLE IV

SURFACE CLEANLINESS LEVELS

VISUAL CLEANLINESS LEVELS

Generally Clean (GC) (NOTE 1). Free of manufacturing residue, dirt, oil, grease, processing debris or other extraneous contamination. This level can be achieved by washing, wiping, blowing, vacuuming, brushing, or rinsing. The GC level shall not be designated for hardware that is sensitive to contamination.

Visibly Clean (VC) (NOTE 2). Free of all particulate and nonparticulate visible to the normal unaided eye (corrected vision acceptable). Particulate is identified as matter of miniature size with observable length, width, and thickness. Nonparticulate is film matter without definite dimension. This level requires precision-cleaning methods, but no particle count.

Visibly Clean Plus Ultraviolet (VC + UV) (NOTE 2). VC (as defined above) and inspected with the aid of an ultraviolet light (blacklight) of 3,200 to 3,800 angstroms wavelength. This level requires precision-cleaning methods, but no particle count.

NOTE - Any evidence of fluorescence shall be cause for recleaning. If recleaning does not reduce the fluorescence, an investigation shall be made to determine whether the fluorescing material is contamination or the basic material.

PRECISION PARTICULATE LEVELS

LEVEL		PARTICLE SIZE RANGE MICROMETERS	(NOTES 3, 4, AND 6)
1,000	<	500	UNLIMITED (NOTE 5)
		500 thru 750	34
	>	750 thru 1,000	5
	>	1,000	0
750	<	250	UNLIMITED (NOTE 5)
		250 thru 500	205
	>	500 thru 750	9
	>	750	0
500	<	100	UNLIMITED (NOTE 5)
		100 thru 50	1,075
	>	250 thru 500	27
	>	500	0
300	<	100	UNLIMITED (NOTE 5)
		100 thru 250	93
	>	250 thru 300	3
	>	300	0
250	<	100	UNLIMITED (NOTE 5)
		100 thru 200	39
	>	200 thru 250	3
	>	250	0

(CONCLUDED NEXT PAGE)

NONVOLATILE RESIDUE (NVR) LEVELS

LEVEL	MAXIMUM QUANTITY NVR PER 0.1 SQUARE METER (1 SQ FT) (NOTES 3 AND 6)
A	1 milligram
B	2 milligrams
C	3 milligrams
D	4 milligrams

TABLE IV (CONCLUDED)

SURFACE CLEANLINESS LEVELS

PRECISION PARTICULATE LEVELS (CONCLUDED)

LEVEL		PARTICLE SIZE RANGE MICROMETERS	(NOTES 3, 4, AND 6)
250	<	100	UNLIMITED (NOTE 5)
		100 thru 200	39
	>	200 thru 250	3
	>	250	0
200	<	50	UNLIMITED (NOTE 5)
		50 thru 100	154
	>	100 thru 200	16
	>	200	0
150	<	50	UNLIMITED (NOTE 5)
		50 thru 100	47
	>	100 thru 150	5
	>	150	0
100	<	25	UNLIMITED (NOTE 5)
		25 thru 50	68
	>	50 thru 100	11
	>	100	0
50	<	10	UNLIMITED (NOTE 5)
		15 thru 25	17
	>	25 thru 50	8
	>	50	0
25	<	5	UNLIMITED (NOTE 5)
		5 thru 15	19
	>	15 thru 25	4
	>	25	0

EXAMPLE: Level 300 would be particulate Level 300. Level 300C would be particulate Level 300 plus NVR Level C.

NOTES

NOTE 1 GC items *do not* require cleaning before inspection; cleaning is required *only* if the item does not pass GC inspection.

NOTE 2 Surface cleaning with an approved, compatible solvent (e.g., solvent wipe) is mandatory for VC and VC + UV items, unless other methods are required for the hardware in question.

NOTE 3 Particulate and NVR allowables are based on 0.1 square meter (1 square foot) of surface area. Flush fluid quantity for sampling shall be 100 milliliters per 0.1 square meter (1 square foot) of surface area. Small parts should be grouped together to obtain 0.1 square meter (1 square foot) of surface area.

NOTE 4 Maximum quantity per 1.0 standard cubic meter (35 standard cubic feet) of effluent gas when systems are being evaluated by purging. If feasible, the sampling must be accomplished at the maximum system operation flow rate.

NOTE 5 "Unlimited" means particulate in this size range is not counted; however, if the accumulation of this silt is sufficient to interfere with the analysis, the sample shall be rejected.

NOTE 6 Other precision particulate levels or residual analyses (i.e., Levels 80, 400, 800, etc., or total hydrocarbon content analysis) may be specified when design requirements dictate their use. The Occupational Safety and Quality Assurance Branch must concur in the selection and use of classifications that are not baselined in this table.

TABLE V

PACKAGING FOR CLEANLINESS PROTECTION

CLEANLINESS REQUIREMENT	PACKAGING TECHNIQUE AND MATERIAL REQUIREMENTS
All precision-cleaning except (1) LOX service or (2) GOX service > 800 psi.	Double-bagging technique required. *Inner* bag of nylon 6, 2 mils thick. *Outer* bag of antistatic polyethylene film, 6 mils thick. Aclar 22A, FEP Neoflon, and FEP Teflon films may be used instead of nylon 6 for the *inner* bag.
Precision-cleaned for (1) LOX service or (2) GOX service > 800 psi.	Double-bagging technique required. *Inner* bag of Aclar 22A, approximately 1.5 mils thick. *Outer* bag of antistatic polyethylene film, 6 mils thick. FEP Neoflon and FEP Teflon may be used instead of Aclar 22A for the *inner* bag film.
Cleaned to VC + UV.	Double-bagging technique required. *Inner* bag of nylon 6, 2 mils thick. *Outer* bag of antistatic polyethylene film, 6 mils thick (NOTE 4).
Cleaned to VC.	Shall be *single-bagged*. Bag shall be antistatic polyethylene film, 6 mils thick (NOTE 1).
GC.	No precision packaging is required. Protective packaging as required for storage, shipping, and preservation (NOTES 2, 3).

NOTES

NOTE 1 The cleanliness certification decal is applied to the outside of the single bag.

NOTE 2 At JSC, GC hardware in transit between facilities shall be environmentally protected. Acceptable means of protection include plastic boxes with snug-fitting covers or reusable, non-heat-sealable plastic bags. Hardware-compatible foam or other acceptable means of cushioning may be used if necessary. Deteriorated or contaminated boxes or bags shall not be used.

NOTE 3 The GC level does not require a cleanliness certification sticker, since protective contamination control packaging is not required.

NOTE 4 Antistatic polyethylene film (pink polyethylene, purple polyethylene, etc.) shall not contain tertiary amine compounds which may cause metal corrosion. Antistatic agents may affect sensitive optical surfaces.

TABLE VI

PARTICULATE SAMPLING FREQUENCY REQUIREMENTS
FOR NONAIRBORNE BREATHING SYSTEMS

- FLUID SOURCE SUPPLIES

  (Include K-bottles, tube trailers, compressors, etc. Can be either offsite-procured or on-site-generated fluids) (NOTE 1).

  - Maintain positive pressure of container during periods of nonuse.
  - Particulate/NVR (nonparticulate) analysis required prior to initial services.

- NONEMERGENCY BREATHING SYSTEMS (NOTES 2, 3, 4, 5, 6)

  - Maintain positive pressure during periods of nonuse.
  - Particulate analysis required prior to first human operation.

NOTES

NOTE 1	Requirements for approved compressed air breathing sources are handled on a case-by-case basis.
NOTE 2	Sampling must be accomplished at each use point or at the downstream use point in a series of adjacent use points.
NOTE 3	A continuous test series, using the same gas supply, is considered as one human operation.
NOTE 4	Used for emergency and therefore cannot be sampled prior to each human operation.
NOTE 5	The first human operation is the first human use after fabrication, modification, or recleaning. If sampling or use depletes the supply, recharge from a certified source.
NOTE 6	The systems downstream of primary and secondary source supplies shall be sampled and analyzed within 1 working day before beginning human operation.