JSC-08080-2B

JSC Design and Procedural Standards

Engineering Directorate

Availability:

JSC & JSC contractor employees and other NASA & NASA contractor employees as required

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National Aeronautics and
Space Administration
Lyndon B. Johnson Space Center
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1. PREFACE

This document contains design and procedural requirements for human spaceflight equipment based on lessons learned and best practices.

The design and procedural requirements are located in Section 5 of this manual and are identified according to the applicable discipline or category, with letter codes as follows:

G	General
E	Electrical
F	Fluids
M/P	Materials and Processes
M/S	Mechanical and Structural
P	Pyrotechnics

This document is controlled by the JSC Engineering Directorate (EA) Configuration Control Board (CCB).

Requests for information, corrections, or additions to this Standard should be submitted to Russell Yates.

2. CHANGE LOG

Revision	Date	Originator	Description of Changes
Basic	January 2015	EA5 / Russell Yates / 281-483-0996	Renumbered document from JSC-STD-8080 to JSC-08080-2. Reformatted requirements. Deleted key word index, signature block, and historical changes. Added applicable documents, requirement guidelines, and reference documents. Rewrote Preface and Introduction. Improved consistency of numbering and capitalization. Corrected superscripts / subscripts. Corrected document titles. Added “None.” to Remarks if none.

			Deleted superseding comments. G-5: Replaced JSC 49774 reference with NASA-STD-6016. G-11: Replaced NASA FAR Supplement text with reference. G-14: Updated FED-STD-595A reference to current revision. G-22: Reverted to 2005 revision of requirement, changed “until installed in an assembly” to “throughout their lifecycle,” added JSC references to Remarks section. G-29: Updated NPR 8705.2 reference to current revision. G-37: Deleted reference to NASA-STD-3000. G-39: Updated lightning protection standard references to current revisions. E-1: Updated NASA-STD-3000 reference to NASA-STD-3001. E-7: Updated MIL-PRF-39003/10B reference to MIL-PRF-39003/10D w/Amendment 1. E-13: Updated symbols from uA to μA. E-14: Deleted JSC 49774 reference. E-20: Removed IEEE C62.38 from list of acceptable test methods. E-24: Replaced MIL-C-17 reference with MIL-DTL-17, and MIL-W-22759 with SAE AS22759. F-5: Deleted redundant paragraph F-27: Updated requirement for de-ionized water lesson learned. MP-9: Updated JPG 1700.1 reference to JPR 1700.1. MP-11: Updated pressure vessel standard references to current revisions. MP-13: Updated pressure vessel standard references to current revisions, and updated JSC-STD-1710 reference to JPR 1710.13. MS-4: Deleted reference to NASA-STD-3000.

			MS-5: Replaced JSC 49774 references with NASA-STD-5020, NASA-STD-6016, and MSFC-STD-557; added requirement that sole locking feature not rely on preload; changed NASA-STD-3000 reference to NASA-STD-3001. MS-7: Added reference to NASA-STD-5018. Approval Reference ECD 0209
A	Mar 2015	EA5 / Russell Yates / 281-483-0996	Preface: Added point of contact. G-10: Correction: removed extra numbering G-14: Added JSC hardware classifications to Remarks section. G-24: Added reference to G-14. G-25: Removed reference to SSP 30213. E-9: Replaced MA2-99-170 reference with SSP 51700. E-12: Correction: moved requirement from Remarks section to Statement of Standard section. E-22: Correction: removed extra header F-1: Added “and terminations” to Remarks section. F-12: Added reference to G-14. F-18: Added “with tolerances” to requirement. MS-5: Deleted requirement in favor of NASA-STD-5020, G-5, and EVA requirements. MS-11: Updated Remarks; replaced NASA SP-8042 and NASA SP-8013 references with NASA TM-2009-214785, NASA TP-2014-217370, and MEM R2. P-5: Reduced labeling requirements, replaced NSTS 08060 reference with JSC 62809. P-6: Updated Remarks; replaced NSTS 08060 reference with JSC 62809, deleted NSTS 07636 reference. Approval Reference ECD 0212

B	Sep 2015	EA5 / Russell Yates / 281-483-0996	General: Labeled retired requirements as "Reserved". 4.6: Deleted "Cancellation" section. G-9: Replaced requirement with reference to NASA-STD-5018. G-16: Removed *unlikely* from remarks. E-7: Deleted redundant paragraphs. E-13: Removed IEC 60601-1 revision from remarks. F-30: Updated definition of maximum design pressure. MS-5: Revived requirement with references to NASA-STD-5020 and JSC 28918. MS-7: Deleted requirement in favor of G-9. P-1: Replaced requirement with reference to JSC 62809. P-2, P-5, P-6: Deleted requirements in favor of P-1. Appendix A: Updated requirement guidelines. Approval Reference ECD 0217

3. TABLE OF CONTENTS

4. INTRODUCTION

4.1 PURPOSE

This document contains design and procedural requirements for human spaceflight equipment based on lessons learned and best practices.

4.2 BACKGROUND

JSC originally published its design and procedural requirements as bulletins circa 1964. In 1971, these bulletins were combined into a single document, JSCM 8080. Since then, JSC has, as needed, issued minor updates to the document, with major revisions occurring in 1991 and 2005. Through the years, the document has undergone several formatting and document number changes (e.g., JSCM 8080, JPR 8080.5, JSC-STD-8080).

4.3 APPLICABILITY

These requirements are appropriate for the acquisition, design, development, test, evaluation, operations, and sustaining engineering of any human spaceflight program, project, spacecraft, system, or end item.

The requirements may be imposed via directive, specification, or agreement.

The requirements may be imposed individually (by referring to individual requirement numbers) or wholly (by referring to the document number). If the requirements are imposed wholly, it is appropriate to assess the applicability of individual requirements (e.g., via an applicability matrix).

4.4 AUTHORITY

JPD 8080.2, JSC Design and Procedural Standards for Human Space Flight Equipment.

4.5 APPLICABLE DOCUMENTS

The latest version of these documents apply unless otherwise specified. The documents only apply when the referencing requirement applies (see Section 4.3), and only to the extent specified in the referencing requirement. The referencing requirements for each applicable document are listed in parenthesis following the document name. Documents are grouped as follows and listed alphabetically by document number within each group: law, NASA directives, NASA standards, non-NASA government standards, and other standards.

JPR 1710.13, Design, Inspection, and Certification of Ground-Based Pressure Vessels and Pressurized Systems (MP-13)

JSC 28918, EVA Design Requirements and Considerations (MS-5)

JSC 62809, Human Rated Spacecraft Pyrotechnic Specification (P-1)

NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware (MS-14)

NASA-STD-5018, Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications (G-9)

NASA-STD-5020, Requirements for Threaded Fastening Systems in Spaceflight Hardware (MS-5)

NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft (MP-1)

NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring (E-14)

SSP 30423, Space Station Approved Electrical, Electronic, and Electromechanical (EEE) Parts List (E-24)

DD Form 250, Material Inspection and Receiving Report (G-14)

DD Form 1149, Requisition and Invoice/Shipping Document (G-14)

FAA AC 20-136, Aircraft Electrical and Electronic System Lightning Protection (G-39)

FED-STD-595, Colors Used in Government Procurement (G-14)

MIL-DTL-17, Cables, Radio Frequency, Flexible and Semirigid (E-24)

MIL-PRF-39003/10D w/Amendment 1, Capacitors, Fixed, Electrolytic (Solid Electrolyte), Tantalum, (Polarized, Sintered Slug), Established Reliability, Styles CSS13 and CSS33 (High Reliability Applications) (E-7)

ANSI/NEMA WC 27500, Standard for Aerospace and Industrial Electrical Cable (E-24)

AIAA S-080-1998, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components (MP-13)

AIAA S-081A-2006, Space Systems – Composite Overwrapped Pressure Vessels (COPVs) (MP-13)

ASME Boiler & Pressure Vessel Code (MP-13)

ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance (F-1, F-16, F-19)

NAS412, Foreign Object Damage / Foreign Object Debris (FOD) Prevention (G-5)

SAE ARP5412, Aircraft Lightning Environment and Related Test Waveforms (G-39)

SAE ARP5414, Aircraft Lightning Zoning (G-39)

SAE ARP5415, User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lighting (G-39)

SAE ARP5577, Aircraft Lightning Direct Effects Certification (G-39)

SAE AS22759, Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy (E-24)

5. DESIGN AND PROCEDURAL STANDARDS

5.1 GENERAL

G-1 Equipment Accessibility for Maintenance

STATEMENT OF STANDARD

Systems, subsystems, equipment, and components shall be designed with features that contribute to the ease and rapidity of maintenance.

Equipment expected to require servicing, replacement, or maintenance shall be designed to be accessible without removal of other equipment, wire bundles, and fluid lines. This should include accessibility during ground operations (horizontal and vertical) as well as on orbit.

Electrical connections and cable installations shall be designed with sufficient flexibility, length, and protection to permit disconnection and reconnection without damage to wiring or connectors.

Panel-mounted displays and controls that are inside the habitable areas shall be capable of being totally maintained from the habitable area. Each display and control installation shall be designed to permit removal and replacement without disturbing the validity and integrity of other components or subsystems.

REMARKS

The version updated in October 2004 modifies the text to align better with longer-term maintenance activities encountered on longer duration space missions such as the International Space Station (ISS) or exploration missions.

G-2 Separation of Redundant Systems

STATEMENT OF STANDARD

Redundant systems, redundant subsystems, and redundant major elements of subsystems (such as assemblies, panels, power supplies, tanks, controls, and associated interconnecting wiring and fluid lines) shall be separated or protected to ensure that an unexpected event which damages one is not likely to prevent the other from performing the functions.

Electrical wiring of redundant systems, redundant subsystems, or redundant major elements of subsystems shall not be routed in the same wire bundle or through the same connector with wiring of the other redundant system, subsystem, or subsystem element.

This standard is not applicable to redundant components or piece parts mounted in common housings within redundant systems, subsystems, or subsystem elements.

This standard does not apply to redundant explosive charges that are located adjacent to each other in order to sever structural members at a given point or along a given line. However, the electrical wiring of redundant systems and routing shall apply.

REMARKS

For purposes of this standard, "redundancy" is defined as the ability to perform a function by more than one means.

This recommended separation for electrical wiring also applies to fluid lines.

G-3 Electrical and Fluid Systems Checkout Provisions

STATEMENT OF STANDARD

Electrical and fluid systems and subsystems shall be designed to permit checkout tests and shall include provisions (e.g., test points) that permit these checkout tests to be conducted without disconnecting any tubing, mated flight couplings, or any other mated flight connectors.

Test points shall allow checkout of the system without loss of integrity (e.g., loss of pressure, leakage, loss of continuity, etc.).

REMARKS

None.

G-4 Protection from Debris – Electrical & Mechanical Systems

STATEMENT OF STANDARD

Electrical and mechanical systems shall be shielded in such a way that encounters with debris or foreign material do not cause a malfunction. Acceptable methods include, but are not limited to, the following:

1. Design and fabricate electrical circuitry to prevent the establishment of unwanted current paths from such debris.

2. Provide critical electrical items with debris-proof covers, suitable containers, housings, potting, or conformal coatings.

3. Provide critical mechanical systems with debris-proof covers, shrouds, or containers that protect the entire system prior to use, or that prevent debris from entering into critical areas of the mechanism where the debris could cause binding, jamming, or seizing.

4. Incorporate filters, strainers, traps, screens, or other devices in moving-fluid components of electrical or mechanical systems to trap debris in a manner that will eliminate it as a threat to critical mechanical or electrical components. In systems where flow reversal may occur, install such devices on both sides of critical components. Make sure all such devices are able to be cleaned in-flight and/or are able to be replaced as part of the maintenance program.

REMARKS

Refer to G-5 for prevention of debris.

Crew cabin module ventilation fans are low pressure-drop devices with small clearances between blades and duct to maximize efficiency and minimize power consumption. Under microgravity conditions ventilation systems are particularly prone to blockage due to particulates. International Space Station ventilation systems suffered up to 80% reduction in flow due to the entrainment of clusters of particulate or fibrous debris in the ventilation systems. This debris penetrated through a protective screen with .02-inch diameter hole size, but then combined to block internal flow paths with .125-inch diameter. Because simple screens have been shown to be ineffective in long duration protection of ventilation systems in microgravity, depth filters should be used to protect ventilation systems from particulate fouling for long-duration missions. A similar phenomenon can occur in liquid media systems where particulates chemically combine downstream of the filter to produce larger than screen-size debris clumps. These systems should be assessed for the use of depth filters or more effective chemical filters.

G-5 Prevention of Debris – Electrical & Mechanical Systems

STATEMENT OF STANDARD

A Foreign Object Debris (FOD) prevention program shall be established for all ground operations of mechanical and electrical systems of flight hardware including the design, development, manufacturing, assembly, repair, processing, testing, maintenance, operation, and check out of the equipment to ensure the highest practical level of cleanliness.

The FOD prevention program shall conform to NAS412, Foreign Object Damage / Foreign Object Debris (FOD) Prevention.

REMARKS

Refer to G-4 for protection from FOD.

NAS412 is available through NASA Technical Standards Program at Marshall Space Flight Center.

Refer to NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft, for selection of materials to prevent growth of biological contaminants.

G-6 [Reserved]

G-7 [Reserved]

G-8 Design for Redundancy Verification

STATEMENT OF STANDARD

Spacecraft systems, subsystems, and equipment shall be designed to permit verification of redundant functions or operational modes any time the system, subsystem, or equipment requires testing prior to launch or during the mission.

REMARKS

This standard is not to be interpreted to require verification of redundancy every time the system, subsystem, or equipment is tested but merely to require that the systems/subsystems/equipment be designed in a manner to allow redundancy verification if it is deemed necessary. Verification of redundancy may occur at any time from acceptance testing through launch processing, mission operations, and post flight.

G-9 Shatterable Material

STATEMENT OF STANDARD

Uncontained shatterable materials shall meet the requirements of NASA-STD-5018, Strength Design and Verification Criteria for Glass, Ceramics, and Windows in Human Space Flight Applications.

REMARKS

Uncontained shatterable materials include any piece of glass and other glass-like materials, such as germanium and sapphire, which, if broken, will endanger the crew or the mission success.

Examples of items that are considered contained are camera lenses that are covered by lens caps while not in use and shatterable materials that are permanently and completely covered by clear plastic, tape, or screen protectors.

G-10 Time/Cycle Critical Part Control

STATEMENT OF STANDARD

Spacecraft components which are time-critical and/or cycle-critical or which have limited storage life shall be subject to the following controls:

1. Each time-critical or limited-life assembly, subassembly, component, and spare shall be clearly and indelibly marked with a serial number.

2. Appropriate documentation shall accompany all time-critical and limited-life items and shall include the date of manufacture of the item and of its most time-critical component. Realistic life limits shall be assigned and documented for each item and shall be suitably altered as new data and new evidence are obtained.

3. Status records shall be maintained on all such items after installation in the spacecraft. Operating-time logs shall be maintained for all items having limited operating lives. Components shall have sufficient life remaining to adequately support mission requirements.

4. Special storage requirements shall be carefully defined and strictly observed.

A time-age-life cycle database shall be maintained for verification (and notification) of time-age-life component status.

REMARKS

This requirement may be satisfied by the inventory management subsystem of the onboard data management system.

G-11 Procurement Document Identification for Human Spaceflight Items

STATEMENT OF STANDARD

Purchase requests (PRs), requests for proposal (RFPs), purchase orders (POs), credit card purchases, contracts, and subcontracts for items procured for use in human spaceflight shall be submitted with the statement shown below.

The information shall be printed, stamped, or added in boldface type.

> FOR USE IN HUMAN SPACEFLIGHT, MATERIALS, MANUFACTURING, AND WORKMANSHIP OF HIGHEST QUALITY STANDARDS ARE ESSENTIAL TO ASTRONAUT SAFETY.
>
> IF YOU ARE ABLE TO SUPPLY THE DESIRED ITEMS WITH A QUALITY WHICH IS HIGHER THAN THAT OF THE ITEMS SPECIFIED OR PROPOSED, YOU ARE REQUESTED TO BRING THIS FACT TO THE IMMEDIATE ATTENTION OF THE PURCHASER.

Procedures shall assure that new PRs, RFPs, POs, contracts, and subcontracts issued by prime contractors and their subcontractors down to the lowest tier include this information. Present contracts and subcontracts involving such hardware shall be amended at the earliest possible date to require the prime contractor or subcontractor to establish such procedures in all actions covering new procurement.

REMARKS

See 48 C.F.R. § 1852.246-73, NASA Federal Acquisition Regulations Supplement, Human Space Flight Item (1997).

G-12 Application of Previous Qualification Test Data

STATEMENT OF STANDARD

When certifying an item for a new application, use of qualification test data obtained during a previous certification shall meet the following conditions prior to use:

1. There is no change in design and specifications from the original item certified including operating limits, weight, dimensions, materials, performance and tolerance, reliability, and quality.

2. The configuration (part number and dash number) previously tested is identical to the configuration proposed for the new application.

3. Manufacturing/Fabrication methods and process have not changed and are certified

4. Previous environmental test conditions are greater than or equal to the environmental extremities and exposure durations required for the new application.

5. Previous functional/performance test results are greater than or equal to the accuracy, input-output, sensitivity, and other performance/operational characteristics required for the new application.

6. The previous test configuration is documented and is considered an adequate methodology/technology to provide test results for the new application.

7. Previous test equipment tolerances and data resolution are documented.

8. Inspection methods, inspection points, and acceptance test procedures are greater than or equal to the rigor of previous methodologies.

9. Previous operating environments, exposure duration, cycling, and usage are greater than or equal to the operations concept required for the new application.

10. Previous failures have been evaluated for impact to the validity of test and analysis data

REMARKS

Flight Certification of any item involves evaluation of verification data to determine if customer requirements have been met. When some of that data is already available from a prior flight certification program, and the appropriate technical evaluation determines that the data can be used to support a new certification program, it is cost effective to use existing data instead of performing additional testing. Previous failures and waivers must be reconsidered or resubmitted for approval by the authorizing organization. Environmental testing typically refers to vibration, thermal, thermal vacuum, radiation, loads, and electromagnetics.

G-13 [Reserved]

G-14 Classification of Flight and Non-Flight Equipment

STATEMENT OF STANDARD

The status of flight equipment and nonflight equipment (equipment which is not suitable for use in flight but which could be accidentally substituted for flight articles) shall be identified and classified as follows:

CLASS I	Equipment acceptable for flight use. Identification shall be in accordance with drawings and specifications.
CLASS II	Equipment acceptable for use in ground tests or training in a hazardous environment. The nameplate or a label adjacent to the nameplate shall be conspicuously marked "CLASS II, CONTROLLED EQUIPMENT" with flight compatible material.

CLASS III Equipment acceptable for nonhazardous training or display purposes. This equipment shall be conspicuously identified by red (or orange) stripes alternating with a contrasting base color or painted solid red. Red paint no. 28913 as specified by FED-STD-595, Colors Used in Government Procurement, is the preferred color. An alternative to the paint method of identification is a red (or orange) striped nameplate or label marked "CLASS III, NOT FOR FLIGHT" applied to the equipment. The identification shall be visible when the equipment is installed.

In addition, equipment not readily identifiable as nonflight equipment, as well as nonflight equipment hidden from view in a major module, shall have a red (or orange) serialized streamer attached to, or in the immediate vicinity of the installation. The streamer shall be of a size and material compatible with the environment under which it will be used. Streamers are to be traceable to the major module which identifies and controls the item. A record of nonflight equipment and, if appropriate, associated streamer serial numbers shall accompany each major module upon formal transfer (i.e., DD250/1149) from one organization to another.

Appropriate instructions shall be printed on each streamer. Streamers shall be numbered and accounted for prior to launch.

The color coding requirements of this standard do not apply to explosive devices.

REMARKS

Nonflight equipment or hardware must be identified to preclude possible use during a flight mission.

Hazardous environment is defined as a chamber environment (such as vacuum, high temperature, low temperature, and oxygen-rich atmosphere) or any other environmental condition that could subject the user of the equipment to a hazard of any kind.

In practice, JSC uses additional hardware classifications. Class IE is for experimental hardware and some commercial off-the-shelf hardware. Class IIIW equipment is acceptable for use in water immersion training in a hazardous environment. Ground Support Equipment (GSE) is non-flight equipment designed to interface with flight hardware. And Special Test Equipment (STE) are similar to GSE, but not controlled until time of use. See JPR 1281.10, Inspection and Testing, for more complete definitions of JSC hardware classifications.

Additionally, some JSC programs classify hardware as Flight Support Equipment, which includes government-furnished equipment.

Though not an official JSC classification, the term Airborne Support Equipment (ASE) refers to flight equipment installed to support operations. See MIL-HDBK-340A, Test

Requirements for Launch, Upper-Stage, and Space Vehicles, Vol I, Baselines, for a more complete definition of ASE.

G-15 Resolution of Flight Equipment Failures/Anomalies Prior to Launch

STATEMENT OF STANDARD

Where flight or flight-like equipment has failed or otherwise exhibited anomalous performance or intermittent operation, launch-to-orbit of identical or like equipment, either as part of the flight vehicle or as a replacement, shall not be permitted unless one of the following occurs:

1. It is verified that the basic deficiency which caused the failure or anomalous performance is not present in the flight equipment or its replacement.

2. The basic deficiency has been counteracted by changes in operational procedures to a degree that eliminates it as an unacceptable risk to the success of the mission or the safety of the crew.

3. The basic deficiency does not present an unacceptable risk to the success of the mission and safety of the crew.

Do not use equipment that exhibits or has exhibited intermittent malfunctions, failures, or anomalies for flight until the malfunction, failure, or anomaly has been corrected or resolved to the satisfaction of the Flight Readiness Review Board.

REMARKS

This standard supports the current philosophy that all failures or anomalous performance must be resolved before launch.

Where the cause of an inconsistency remains unresolved, equipment is unreliable.

G-16 Operational Limits on Temperature-Controlled Equipment

STATEMENT OF STANDARD

For spacecraft equipment where the operating temperature is normally controlled by heating or cooling equipment and the temperature is monitored in ground test and flight, the test program and/or appropriate analyses shall define the following:

1. The maximum and minimum temperatures expected in normal operations

2. The maximum and minimum temperatures (including duration and temperature rate of change, as appropriate) at which equipment may be expected to:

    a. Fail to meet specified performance until temperature is restored to normal range.

    b. Be permanently rendered inoperative.

For critical components, automatic safing with manual override only shall be used.

Information used to satisfy requirements 1 and 2 above shall be provided in operational constraints documentation.

REMARKS

Knowing the maximum and minimum operating limits of spacecraft equipment is essential for flight and mission management. This information needs to be readily available for real time decision-making.

Item #1:

This information is needed for equipment characterization and could be used for recognizing a thermal malfunction within the spacecraft equipment.

Item #2

This information provides guidance to NASA in an off-nominal mission scenario where normal operating temperatures may need to be exceeded due to malfunction(s) either external or internal to the equipment. In such a scenario it may become necessary to operate equipment beyond the qualification limits and mission manager's need to know how far the equipment can be pushed and reasonably expect that the equipment can be turned off and subsequently reactivated to support the safe return of the crew. The ultimate purpose of this information is to enable flight and mission management to make the best decisions possible in an off-nominal situation to maximize the probability of safely returning the crew.

Relevant information used to form the guidelines may include data or analysis from other program or manufacturer development (from Department of Defense (DoD) to Commerical of the Shelf (COTS)), data from operational programs due to unplanned thermal conditions, similar hardware data (document similarities and contrasts, e.g. non-screened parts data), sub-part data, bench testing that was not previously documented in reports, inadvertent test conditions, etc.

The desired outcome is a set of useful temperature and duration guidelines for the deliverable units at the lowest cost. Therefore, deriving the guidelines from the best available information is preferred and supplemental high-cost testing must be approved by the Program. Engineering judgment should also be applied and documented as appropriate in meeting this requirement.

G-17 Separate Stock for Spaceflight Parts and Materials

STATEMENT OF STANDARD

Assemblies, parts, and materials procured or designated specifically for use in space shall be:

- positively identified
- stored in controlled access areas
- physically separated from nonflight parts and materials to avoid mixing.

REMARKS

This standard is to prevent nonstandard, nonspaceflight, nonsegregated stock from being unintentionally used in space or in the fabrication of spaceflight equipment.

For purposes of this standard, the term "controlled access area" is defined as: stock areas or areas of rooms which are separated from nonflight stock areas or rooms by fences, walls, or other physical separations and which have access control to ensure the following:

1. Access by authorized personnel only
2. Proper parts and materials storage, maintenance, and withdrawal
3. Compliance with applicable quality assurance directives

G-18 Safety Precautions – Test and Operating Procedures

STATEMENT OF STANDARD

Procedures developed for testing and operating spaceflight equipment or ground support equipment shall clearly indicate any step which, if not correctly followed, would result in injury to personnel, damage to a system or equipment, or an environmental impact.

The cover sheet of the procedure shall indicate if the test or operation is hazardous.

REMARKS

A warning statement, preceded by the word WARNING in upper case letters, is commonly used to emphasize any instructions which, if not correctly followed, would result in injury to personnel, damage to a system or equipment, or an environmental impact. The statement usually indicates the reason for the warning.

G-19 Special Processes – Identification of Drawings

STATEMENT OF STANDARD

Manufacturing, assembly, or installation drawings for spacecraft, space flight equipment, experiments, and ground support equipment shall identify all special processes required to manufacture, assemble, and install the equipment.

Process specifications shall be referenced, or the processes shall be specified in detail on the respective drawings.

All referenced specifications not normally available shall be submitted upon request.

REMARKS

The requirements of this standard are in addition to other requirements of the drawing system used. The preferred method of documenting the special processes is to release separate process specifications and to make reference to the specifications on the drawings.

Examples of special processes are cleaning, potting, etching, wire splicing, soldering, welding, brazing, and bonding.

G-20 Spacecraft Equipment – Protection from Liquids During Ground Operations

STATEMENT OF STANDARD

Equipment sensitive to moisture and located where it is subject to liquid leaks during ground operations shall be identified in the design documentation. This documentation shall also include:

- The rationale for positioning the equipment in that location.
- A plan for implementing protection of this equipment.

REMARKS

Major damage to spacecraft and serious delay of programs can result from small, easily correctable leaks that would be of minor significance except for the effect of the leakage on exposed equipment. Experience has shown that fluid system leaks are particularly prevalent during initial ground testing of new spacecraft.

Sources of moisture and liquid leaks may include systems fluids, water condensation, fluid from GSE or facilities, and natural phenomena.

Protection from damage by leakage may include one or more of these methods:

1. Designing the equipment to be insensitive to the liquid leakage
2. Designing the plumbing or equipment containing the liquid to locate couplings, vents, service points, and other items where leakage from them could not reach the sensitive equipment
3. Providing ground support equipment or devices to protect the sensitive equipment from leakage during ground operation

4. Providing proper insulation to prevent condensate from forming and subsequently falling on the equipment

G-21 Spacecraft Equipment – Moisture Protection

STATEMENT OF STANDARD

Spacecraft equipment within a pressurized compartment shall be designed so that performance of the equipment will not be degraded by humidity or moisture droplets in the spacecraft atmosphere or by condensation of moisture from the spacecraft atmosphere.

REMARKS

None.

G-22 Product Identification

STATEMENT OF STANDARD

Parts used in flight hardware shall be identified by physical part marking or container marking per requirements defined on the applicable drawing.

Hardware drawings shall include identification processes necessary to control parts throughout their lifecycle.

REMARKS

Identification requirements, such as user control number, nomenclature, serialization, lot number, date code, values, tolerances, sizes, and polarization may also be necessary for specific parts. Marking systems may include human readable and/ or machine readable codes. Physical marking with alphanumeric characters, direct part marking, bar coding, and combinations of the three methods are example solutions.

For purposes of this standard, a part is defined as one piece or two or more pieces of material joined together that are not normally subject to disassembly without destruction of design use.

The detailed methods for numbering and marking parts should be provided in documentation, such as specifications and drawing system manuals.

This standard applies to all parts including electronic, electrical, electromechanical, mechanical, and machined parts.

JSC parts management and traceability requirements and processes are defined in the following documents:

- JPD 8500.3, Serial and Lot Numbers for Certain Items of Government-Furnished Equipment
- JPR 1281.8, Product Identification and Traceability
- JPR 8500.4, Engineering Drawing System Manual.

G-23 Pressure Garment Wiring – Ignition of Materials by Electrical Current

STATEMENT OF STANDARD

Electrical current entering a crew member's pressure garment shall be limited to a level that will not ignite or damage materials that would contact damaged wiring within the garment under the worst combination of short-circuit current and environment.

Energy storage or conversion devices capable of producing short-circuit current of a magnitude and discharge rate sufficient to ignite materials shall not be located inside pressure garments, unless:

1. adequate current limiting is provided, or
2. there is no contact between potentially damaged wires and the material in question

REMARKS

In this standard, "no contact" is defined as no electrically conductive path.

The fire hazard associated with inclusion of communications and bioinstrumentation wiring in the oxygen-rich environment of pressure garments necessitates the analysis and selection of suitable materials to minimize the potential flammability hazard. It is necessary to confirm the compatibility of the materials and electrical currents under failure conditions in the planned oxygen environment.

Current limiting may be required to assure values below the threshold level for ignition of materials caused by arcing or heating from high-resistance heat sources. An alternative to current limiting is strategic materials placement to ensure that flammable materials, that are demonstrated to ignite at the use conditions, are prevented from contacting potentially damaged electrical wiring or componentry.

Selection of materials with suitable flammability characteristics is constrained by other requirements, such as flexibility, bulk, weight, and comfort of the crew.

G-24 Protecting Flight Equipment from Support Equipment

STATEMENT OF STANDARD

Ground support equipment (GSE), airborne support equipment (ASE), facility equipment, or test equipment used in ground or flight operations shall be equipped with protective devices to preserve safe operation margins of the flight equipment.

REMARKS

GSE or ASE, as a result of misuse or malfunction, has the potential for causing irreparable damage to spacecraft flight systems if the GSE or ASE does not incorporate design features for protecting against such eventualities.

All GSE and ASE designs should be evaluated from the standpoints of inadvertent operator error and hardware (component) malfunction to ensure that protective features are adequate to safeguard spacecraft subsystems. Consideration should be given to the need for not only static overload protection (such as pressure relief, electrical fuses, etc.) but also protection from such elements as dynamic or transient conditions (e.g., electronic filters, accumulators) or contaminants (e.g., contaminant filters).

See the G-14 Remarks section for definitions of GSE and ASE.

G-25 Thermal Design and Analysis

STATEMENT OF STANDARD

Hardware shall be designed to function in the full range of the thermal environment to which it will be exposed.

Thermal analyses shall be performed for nominal and worst-case conditions for all temperature-sensitive components and structures.

Worst hot and cold cases shall be analyzed using realistic combinations of thermal parameters which produce the worst-case conditions.

REMARKS

Example: A solar constant with 3 percent seasonal variation will be used. Other heat flux impacts, solar absorptances, emittances, conductances, etc. will be varied to include measurement uncertainties, variations in application of coatings, and degradation. Boundary temperatures and heater voltages will be varied over the ranges expected.

Thermal analysis includes both transient and steady state.

G-26 Internally-Generated Radiation

STATEMENT OF STANDARD

Laser sources sufficiently powerful to be a hazard shall be positioned to preclude the possibility of looking directly at the source.

Sources emitting electromagnetic wavelengths between x-ray and visible light, sufficiently strong to pose a hazard, shall be positioned to preclude crew exposure or touch.

Hazard distance shall be marked.

REMARKS

None.

G-27 Fire Control

STATEMENT OF STANDARD

The primary means of fire control shall be the selection of materials that are nonflammable or nonpropagating in their use configuration. Materials flammability control is addressed in MP-1, Materials and Processes Control.

The capability for fire detection and suppression shall be provided.

The material used to extinguish fires shall be nontoxic to humans and shall be capable of being easily cleaned up after it is used.

REMARKS

Fire, particularly in a space vehicle, can be catastrophic. Special precautions are necessary, more so than on earth, because countermeasures must be self-contained within the space vehicle.

In microgravity conditions, fires that are not actively fed with oxygen will self-extinguish. One fire control strategy is to eliminate ventilation, remove electrical power, evacuate personnel, and allow the fire to self-extinguish.

Fire-resistant storage should be provided for hardware that is controlled for flammability by stowage when not in use.

G-28 Sealing – Solid Propellant Rocket Motors

STATEMENT OF STANDARD

On completion of final inspection following manufacture, each solid propellant rocket motor shall be sealed and pressurized to prevent damage due to entry of moisture or foreign material.

The pressurant shall be dry N_2 gas.

The pressure applied shall be sufficient to ensure against entry of contaminants under any anticipated storage conditions.

The seal shall be designed to withstand internal pressure corresponding to the maximum anticipated storage temperature with an adequate safety factor or shall include a relief device.

The seal shall be installed such that it can be expelled during normal rocket ignition without damage to the nozzle. If no other provisions can be made to inspect the grain, access shall be provided through the seal.

REMARKS

The seal may contain provisions for relief of pressure, pressurizing, and pressure gauge installation as necessary.

G-29 Reentry Propulsion Subsystem In-Flight Test

STATEMENT OF STANDARD

Crewed spacecraft which use a separate propulsion subsystem for reentry attitude control shall include means for testing this subsystem before jettisoning the last of any other attitude control systems which could be used to position the spacecraft in a reentry attitude.

REMARKS

Control circuitry and attitude cues should be developed to enable the crew to test the reentry propulsion subsystem of the reentry module before abandoning an operating attitude control subsystem.

This standard is not applicable for spacecraft without a separate propulsion subsystem for reentry attitude control. For such cases, refer to NPR 8705.2, Human-Rating Requirements and Guidelines for Space Flight Systems, Section 3.2, System Safety Requirements.

This standard does not preclude the need for redundant reentry attitude control systems.

G-30 [Reserved]

G-31 Detachable Crew – Operated Actuating Tools

STATEMENT OF STANDARD

Where possible, actuating devices shall be made an integral part of the equipment to be operated.

Detachable actuating tools, such as handles, pins, and ratchets, shall not be permitted in applications where tool nonavailability could compromise crew safety or primary mission objectives.

Where tools are allowed for system controls, provisions shall be made whereby the position of the control is readily apparent to the responsible crew member without the tool in place.

REMARKS

Detachable tools are generally undesirable for all applications in the crew compartment under zero-gravity conditions, but such devices may be used if a significant advantage in operation, weight reduction, or volume reduction is assured and if their application does not conflict with the constraints outlined above.

G-32 [Reserved]

G-33 [Reserved]

G-34 [Reserved]

G-35 [Reserved]

G-36 [Reserved]

G-37 Verification of External Visibility

STATEMENT OF STANDARD

Visibility verification for crewed spacecraft shall include tests, simulations, or analyses to verify visibility during all anticipated phases and environmental conditions of the planned mission and contingencies.

Simulations shall include mockups or high-fidelity computer simulation to ensure the view (picture) seen by the crew during each phase of the simulated mission will be comparable to that which will be seen in flight.

REMARKS

Whenever possible, visibility verification tests should incorporate actual flight hardware.

The external visibility may be provided using windows, external cameras, or alternative capability.

During previous crewed spaceflight missions, visibility problems have occurred. Deposits have covered windows. Visibility has been restricted by parts of the spacecraft during certain mission phases. Light gathering properties of some optical instruments have not been satisfactory. Reflections and parallax have caused difficulty. Moisture has condensed between inner and outer panes of windows. Fingerprints and smear marks have compromised optical surfaces.

Factors affecting satisfactory visibility include but are not limited to:

1. Visibility and field-of-view requirements during each phase of the intended mission and for all anticipated contingencies.

2. Protection or preventive measures to avoid unsatisfactory degradation of visibility due to buildup of solid or liquid deposits on all window surfaces, viewing ports, or other optical devices.

3. Scene displays that will be required for simulators and training to ensure satisfactory crew training.

4. Internal and external lighting conditions during the mission.

5. Parallax.

6. Possible angular reflections, particularly from rays of the sun.

7. Optical surface coatings and treatments used to control optical properties and the sensitivity of the treated surfaces to human contact and environmental exposure.

8. Thermal and vacuum conditions to which the viewing device will be subjected.

9. Obstruction of critical view by parts of the spacecraft itself.

High fidelity computer simulation capabilities may enable alternative methods for verifying visibility rather than using mockups. The computer simulations are flexible for trying out multiple window/camera configurations, whereas mockups are less flexible.

G-38 Pressurization or Repressurization – Preventing Ingress of Undesirable Elements

STATEMENT OF STANDARD

In the design of pressurization, repressurization, and ventilation systems for habitable areas, provisions shall be made to prevent ingress of undesirable elements.

This standard applies to spacecraft which have habitable areas pressurized at less than atmospheric pressure during normal mission and which must enter the earth's atmosphere or other atmospheres with pressures different from the spacecraft's normal operational pressure for habitable areas.

REMARKS

During atmospheric entry and landing, undesirable elements such as vented propellants, heat shield fumes, and water may be ingested into habitable areas unless design or procedural precautions are taken.

This standard in not intended to apply to airlock ingress and egress pressurization and depressurization procedures.

G-39 Lightning Protection Design

STATEMENT OF STANDARD

Lightning protection shall be designed into spacecraft which will operate in Earth's atmosphere such that, in the event of a lightning strike, flight hardware will not be damaged or affected to the extent that mission success, crew, or ground personnel safety is compromised.

Verification of adequate protection shall be accomplished using both test and analysis based on technical detail contained in:

- SAE ARP5412, Aircraft Lightning Environment and Related Test Waveforms
- FAA AC 20-136, Aircraft Electrical and Electronic System Lightning Protection
- SAE ARP5414, Aircraft Lightning Zoning
- SAE ARP5415, User’s Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lighting
- SAE ARP5577, Aircraft Lightning Direct Effects Certification

REMARKS

This standard has not been evaluated for its applicability to other atmospheres.

G-40 Radioactive Luminescent Devices

STATEMENT OF STANDARD

When radioactive material is to be used, such as radioactive luminescent devices, the following requirements shall be met:

1. Each proposed use of radioactive material shall be approved by the JSC Radiation Safety Committee.

2. A minimum amount of radioactive material shall be used consistent with the requirements.

3. Radioactive materials shall be completely sealed or encapsulated in substances having low damage potential from the inherent radiation.

4. Installation within or on the vehicle shall be such that it is unlikely that the seal of the radioactive material will be damaged because of ground or space environment, accidents, or mishandling. Installation in the habitable volume of a manned vehicle and/or in a location for potential contact with any crew member during extravehicular activity (EVA), intravehicular activity (IVA), ingress, or egress shall be protected against damage to eliminate the possibility of particle ingestion, inhalation, and/or skin contact by the crew.

5. The component bearing the radioactive substance shall be designed for replacement with no damage to the seal of the radioactive substance.

6. Each item containing radioactive material shall be permanently marked in a manner approved by the JSC Radiation Safety Committee.

REMARKS

A byproduct material license issued by the U.S. Nuclear Regulatory Commission authorizes JSC to use radioactive components on spacecraft. This license, issued pursuant to Title 10, Code of Federal Regulations, requires that each use of radioactive material be reviewed and approved by the JSC Radiation Safety Committee for compliance with NASA and JSC health and safety issuances, the Code of Federal Regulations, and other applicable statutes.

The type and degree of protection referred to in paragraph 4 will be dependent upon the amount of luminescent material and the design and location of the device.

G-41 [Reserved]

G-42 [Reserved]

G-43 [Reserved]

G-44 Attitude Control Authority

STATEMENT OF STANDARD

Spacecraft automatic attitude control circuitry shall be designed so that the crew can assume manual attitude control at all times.

REMARKS

This revision increases the scope of the standard to require capability for manual takeover of the automatic attitude control circuitry during all phases of the mission.

G-45 Solid Propellant Rocket Motors

STATEMENT OF STANDARD

Solid propellant rocket motors shall be designed with the capability to ignite without a seal, or with a nozzle seal failure, up to the highest altitude and maximum elapsed time at which ignition is required.

REMARKS

Nozzle covers (seals) are required to protect the grain from the environments but the motor should be capable of being lit when necessary even in the event of a seal failure.

REFERENCES:

See G-28, Sealing – Solid Propellant Rocket Motors.

G-46 Separation Sensing System – Structural Deformation

STATEMENT OF STANDARD

Separation sensing systems designed to detect separation of stages or modules of space vehicles shall not inadvertently actuate separation sensors due to structural deformations or vibrations less severe than those associated with the structural failure of the vehicle.

Separation sensing systems that are designed to initiate subsequent steps in a sequence of events shall be designed so that the failure or actuation of a single sensor will not initiate the sequence of events.

Separation sensing systems shall be designed not to initiate a sequence of events unrelated to space vehicle separation.

REMARKS

Separation sensors have erroneously given signals of spacecraft module separation because of structural deformation. On an uncrewed flight, high aerodynamic and vibrational loads caused structural deformation that resulted in an inadvertent firing of the launch escape tower.

Structural deformation must be considered during the installation design to locate separation sensors where relative motion of the structural elements is not excessive and where inspection of the sensor can be accomplished. The sensors should be selected to require actuation travel substantially greater than the maximum deformation anticipated between the structural elements at the point of installation.

G-47 Gyroscopes – Verification of Operational Status

STATEMENT OF STANDARD

Guidance, Navigation and Control subsystems utilizing gyroscopes shall provide continuous outputs during operation to verify that gyroscopes are operating within specified limits.

Gyroscopes shall be capable of providing operational readiness status prior to use.

Failures shall be detected within a timeframe that allows for corrective action prior to negative consequences resulting from the failure.

REMARKS

Optimum spacecraft operation and safety are dependent upon properly functioning gyroscopes. Failure detection and redundancy is desirable to mitigate the effects of gyroscope failures or off nominal operation.

G-48 Onboard Experiments – Required Preinstallation Checklist

STATEMENT OF STANDARD

Furnish analytical proof or conduct tests to demonstrate that proposed onboard experiments shall not impair the safety or effectiveness of the astronaut or jeopardize the functioning of spacecraft equipment under worst case conditions.

Examples include:

- Releasing solids, liquids, or gases.
- Producing temperature extremes or releasing thermal or ionizing radiation.
- Emitting electromagnetic radiation.
- Degrading external and internal visibility.
- Degrading internal auditory environment.
- Impeding crew ingress and egress.
- Jeopardizing the integrity of the spacesuit.
- Interfering with the operation of EVA or IVA controls.

- Jeopardizing the integrity of the spacecraft power system by transients or short circuits.
- Producing damage as a result of cabin decompression or recompression at maximum possible rate.
- Producing damage through loss of structural integrity during any spacecraft operation including land or water landings at maximum design conditions.
- Producing damage as a result of stored energy release.

REMARKS

Instances have occurred where materials that were prohibited from use in the spacecraft environment were planned for experimental use.

G-49 [Reserved]

G-50 Direct Procurement of Parts

STATEMENT OF STANDARD

The initiator of purchase requests and other applicable procurement documents for parts used in a spacecraft, space flight equipment, experiments, and ground support equipment shall specify on the procurement document that procurement must be made directly from the manufacturer or from distributors who can furnish certification of the following conditions:

1. The item was actually produced or assembled by the designated manufacturer.
2. The item conforms to the manufacturer’s current standards of performance and quality for items of the specified designation.
3. The distributor can furnish any traceability records or documentation required by the PR for materials control, process control, and limited life tracking. Traceability requires a configuration control system that includes drawing version control, fabrication records, and hardware serialization or lot tracking.

REMARKS

There have been cases of procurement of obsolete, out of tolerance, and improperly stored parts when lot control and serialization were not specified.

G-51 Flight Hardware – Restriction on Use for Training

STATEMENT OF STANDARD

Hardware and equipment that is scheduled as primary or spare equipment for flight shall not be used for training, unless all of the following conditions are met:

1. Training use is strictly limited to the prime and backup flight crews or a designated delegate.

2. Adequate crew familiarity with the characteristics of the actual flight equipment cannot be obtained from fabrication and use of flight-like training hardware or training models.

3. A record of all training use is documented per controlled hardware documentation requirements.

4. The equipment will subsequently be subjected to inspection and preinstallation acceptance tests prior to flight.

5. After such training use, the life remaining on all limited-life items will be adequate for completion of the mission.

REMARKS

October 2004 text modified to address crew availability during long-duration missions such as the International Space Station or exploration missions and hardware obtained specifically for training purposes.

G-52 Reuse of Flight Equipment

STATEMENT OF STANDARD

Flight equipment that has been previously used in flight may be reused in crewed flight if the following minimum conditions have been met:

1. Appropriate refurbishment, inspection, and testing have been accomplished between flights.

2. Any elements not replaced will be within all shelf-life limits, operational time or cycle life limits, and environmental (e.g., vibration) life limits at the end of the mission.

3. No evidence exists that the unit has been stressed beyond specification limits during previous use.

REMARKS

None.

G-53 Reverification

STATEMENT OF STANDARD

After successful completion of some or all of the verification program, changes may occur that dictate the need for reverification assessment. Such changes may include changes in design configuration, material, manufacturing or procurement sources, operating environments, etc. Baseline characterization data such as chemical and physical properties of materials including fluids as well as impurity composition and levels shall be collected during initial qualification such that any follow-on changes may be assessed relative to possible or anticipated impacts to equipment performance. When such changes as those identified below occur, a reverification assessment shall be performed to determine the need to repeat previously completed verification activities.

Qualification Reverification: If changes occur in any of the following, an assessment to determine the need to repeat any or all of previously completed qualification activities shall be performed and documented:

1. Design configuration or manufacturing process changes (e.g., bonding, soldering, welding, installation torques of fasteners, etc.)

2. Changes in fluids or lubricants; either in their specifications; procurement source, processing; transportation, or storage, or handling conditions.

3. Changes in materials or parts; either in their specifications; procurement source; manufacturer; or processing.

4. Changes to equipment, part, fluid, or lubricant manufacturer or manufacturing facility.

5. Inspection, test, mission change, or other data indicates that a more severe environment or operating condition exists than that to which the equipment was originally qualified.

6. Changes to flight software coding or capability.

When repeat of some or all of previously completed qualification activities is conducted due to such changes, a reverification report shall be written to formally document the reason for the reverification, justification for the degree of reverification performed, and the results of the reverification activity.

Acceptance reverification: If changes occur in any of the following, an assessment to determine the need to repeat any or all of previously completed acceptance activities shall be performed and documented:

1. Any change consistent with the above changes identified for qualification reverification.

2. A previously mated and verified interface has been demated.

3. Any modification, repair, replacement, or rework occurs on the equipment.

4. The equipment is subject to drift or degradation during transportation, storage, or handling.

REMARKS

This standard replaces information previously covered for qualification fluids in F-23 (1991).

G-54 Automatic Shutdown of Launch Vehicle Engine(s)

STATEMENT OF STANDARD

Automatic shutdown of launch vehicle engine(s) procedures/design shall maximize crew survival probability as part of the overall system.

The integrated system design shall incorporate:

- Shutdown commands initiated by engine controller(s).
- Shutdown commands initiated by the crew.
- Shutdown commands initiated by ground personnel.
- Crew escape capability from the vehicle on the pad.
- Launch abort/escape system capability while on the pad.
- Launch abort/escape system capability while in flight.
- Specific plans for non-catastrophic, imminently-catastrophic, and other engine failure mode categories.
- Early engine-out capability of the launch vehicle.
- Handling of multiple engine shutdown requests.
- Avoidance of catastrophic impact with ground or tower for loss of an engine(s).

REMARKS

Prior to structural separation from the pad (or free-standing liftoff), it is never too late to shut the engine(s) down and abort the mission. Once structural separation has occurred, the vehicle is essentially in flight, and a pad abort is generally considered unavailable.

Unless it can be demonstrated that shutting an engine down prior to T-0 umbilical separation, but after structural separation, will cause a trajectory transient that will result in the loss of vehicle, the engine should be allowed to shut down. If an engine is violating a redline shutdown limit, there are risks associated with running that engine. If it wants to shut down to avoid a catastrophic failure we should allow it to do so.

An example failure that drives an integrated system design solution is if an engine exhibits an imminently-catastrophic failure mode just after liftoff, but shutting down the engine will result in earth or tower impact. In such an instance vehicle destruction cannot be avoided. However, the option (shutdown or not) that provides the crew more time for launch escape than the alternative option is the preferred choice.

5.2 ELECTRICAL

E-1 Mating Provisions for Electrical Connectors

STATEMENT OF STANDARD

1. Electrical connectors, plugs, and receptacles which otherwise could be incorrectly mated shall be designed to prevent incorrect connection with other accessible connectors, plugs, or receptacles.

   The selection of the technique used shall be at the highest level of precedence in the following order:

   a. Use of constraints built into a cable or harness that locate similar connectors so they cannot be interchanged.

   b. Selection of different sizes or types of connectors to be located adjacent to each other.

   c. Selection of alternative polarization (alternative keying) of adjacent, similar connectors only if this requirement cannot be met with either method *a* or *b* above.

2. Permanent identification of mating connectors shall be provided on each side of each connector pair.

3. Ground connectors shall comply when they mate with flight connectors.

REMARKS

NASA-STD-3001, Vol. 2, NASA Space Flight Human-System Standard: Human Factors, Habitability, and Environmental Health, includes requirements to prevent connector mismating (paragraph 9.5.2.3, Incorrect Mating, Demating Prevention).

E-2 Protection of Severed Electrical Circuits

STATEMENT OF STANDARD

Electrical circuits which are to be severed in the normal course of mission events (e.g., vehicle separation) shall be protected against short circuiting or compromising other circuits during the remaining phases of the mission by deadfacing to remove all voltages.

REMARKS

For purposes of this standard, the term severed is defined as permanently separated by cutting conductors using guillotine devices. This standard does not address connector mate/demate using spring- or pyro-assisted mechanisms. Even small voltages could short and inadvertently power or ground the logic or control wiring resulting in adverse effects.

Spring-loaded separators may be used to physically separate bare ends of the individual wires in the cable after severing.

E-3 Electrical and Electronic Devices – Protection from Reverse Polarity and/or Other Improper Electrical Inputs

STATEMENT OF STANDARD

Electrical and electronic devices shall incorporate protection against improper electrical inputs during qualification, acceptance, and checkout tests if such inputs could damage the devices.

If it is impractical to incorporate adequate protection as a part of the device, protection shall be provided externally by the test equipment.

REMARKS

Damage of an incipient nature may remain undetected and later cause equipment failure in flight.

Examples of protective devices covered by this standard are diodes, capacitors, resistors, chokes, filters, etc., or combinations of devices included to protect electronic elements from such occurrences as unwanted transients, current reversals, short circuits, signal couplings, or wide deviations from desired operating conditions.

For verification and testing of protective devices, refer to standard E-16.

E-4 Electrical Connectors – Moisture Protection

STATEMENT OF STANDARD

Electrical connectors and wiring junctions to connectors shall be protected from moisture by methods which are demonstrated by test or analysis to provide adequate protection to prevent open and short circuits or a harmful unintended conductive current path. Shrink boots are not acceptable as moisture barriers.

Both external to and within the crew compartment, electronic and electrical equipment which is not hermetically sealed or otherwise positively protected against moisture shall not be cooled below the dew point of the surrounding atmosphere.

This requirement shall include test conditions (except for environmental qualification test articles) and all operating conditions, including flight, wherein condensation of moisture can occur either during equipment operation before equipment is brought up to operating temperature or after equipment is shut down.

REMARKS

The required composition and quality of the seal are dependent upon the environments to which the seal will be subjected. Examples include but are not limited to:

1. Rain, condensation, and other fluid environments on the launch pad

2. Condensation of cabin moisture during flight

3. Electrolytic corrosion

4. Manufacturing and storage environment

E-5 Electrical Connectors – Pin Assignment

STATEMENT OF STANDARD

Electrical circuits shall not be routed through adjacent pins of an electrical connector if a short circuit between them would constitute a single failure that would:

- cause injury to the crew or

- cause loss or degradation of a critical system.

REMARKS

In this standard, "adjacent" includes pins within reach of a bent pin.

E-6 Corona Suppression

STATEMENT OF STANDARD

Electrical and electronic systems and components susceptible to corona as dictated by the Paschen Curve shall be designed such that detrimental corona discharge will not occur under any operating conditions.

Where adverse corona effects are avoided by pressurizing or evacuating a component, the seals shall be capable of maintaining the required internal pressure throughout the intended mission. Pressure maintenance may be considered in lieu of seal demonstration.

Where corona effects are avoided by conformal coating and/or encapsulate, methods shall be provided to verify that conformal coating / encapsulate is free from trapped gases, voids, or fractures.

Where adverse corona effects are avoided in unsealed components by restricting operation to space vacuum conditions the ability of the equipment to reach the required vacuum in the planned time shall be demonstrated by test or analysis.

Components protected by potting, conformal coating, or by corona prevention design shall be tested to demonstrate no detrimental effects from corona or partial discharge. Tests shall be conducted under service conditions of worst-case voltage, over the full operational range of pressure and environment. Testing shall be done on energized sub-assemblies, lowest replaceable units, as well as cable runs, bus bars, and enclosures.

Corona testing shall be part of the component selection and component qualification process.

Test(s) or analysis shall be performed to demonstrate that the systems and components will remain protected for the intended length of the mission.

REMARKS

"Corona" is defined as an electrical discharge caused by ionization of gas in the vicinity of a conductor.

Ionization can occur on the surface of an insulated or uninsulated conductor as well as in voids and cracks within insulation.

Corona may be generally avoided or eliminated by lowering potential differences, increasing the gap or length of the current path between points of difference potential, increasing or decreasing the ambient gas pressure, or lowering the voltage stresses in gas spaces by selecting insulations with low dielectric constants.

Outgassing or inadequate venting can cause internal pressures to remain unsafe for some time after ambient pressures have reached safe values.

The possibility for corona near exposed conductors at voltage will be increased if local pressures are enhanced by nearby thruster operations, dumps, etc., particularly when extensive (e.g., reboost).

Corona prevention design techniques, such as the avoidance of sharp points and bends or the use of corona balls, should be employed.

Information on the Paschen Curve can be found in MSFC-STD-531.

E-7 Problem Electrical Components – Restrictions on Use

STATEMENT OF STANDARD

In the construction of spaceflight hardware, the following parts shall not be used in the applications specified. These part types and applications have known failure mechanisms which make them a reliability risk:

1. Silver cased wet slug Tantalum capacitors (CLR65).

2. Any non hermetically-sealed part that contains a fluid, such as an Aluminum electrolytic capacitor, used in a vacuum environment.

3. Solid Tantalum capacitors used in a low impedance application of less than 1 Ohm/Volt unless each part has been surge current tested to the test procedure defined in MIL-PRF-39003/10D w/Amendment 1.

4. Sealed parts with internal voltages greater than 200 Volts that are used in a vacuum environment and have a maximum leak rate which will allow the internal cavity pressure to reach 50 Torr over the part's mission life.

5. Parts with internal or external plating of greater than 97% Tin, unless a Program-approved mitigation plan is implemented.

6. Use of cartridge style fuses (example is FM08 & FM09) in a vacuum environment with greater than 50 Volts DC applied.

7. Switches, relays, bimetallic thermostats and other mechanical contact devices:

   a. Used in a voltage application for which they were not specifically qualified and proven.

   b. With higher rated contacts used in a low voltage or current application unless specifically recommended by the device manufacturer.

REMARKS

Remarks section below corresponds to each numbered part of this standard.

1. Silver-cased Tantalum capacitors are susceptible to internal dendrite growth between the Silver case and the tantalum anode when the capacitor is subjected to any negative voltage. This potential problem is eliminated by using a hermetic Tantalum cased (MIL-PRF-39006) capacitor instead.

2. Environmentally sealed parts that contain a gas, fluid, or gel should not be used in a vacuum environment. In the case of a non-hermetic wet capacitor the parts will begin to outgas and eventually begin overheating leading to accelerated outgassing and eventual failure.

3. Solid Tantalum capacitors have self-healing capability when they short if their circuit application provides 1 Ohm/Volt series impedance.

4. All hermetic devices have a definitive leak rate. Given enough exposure time in a vacuum environment a small cavity device will leak down below the critical pressure level of 50 Torr. If a part has 190 Volts or greater applied internally then a destructive corona event is very probable. (See MSFC-STD-531 for more detail)

5. High purity Tin plating propagates the growth of conductive Tin (Sn) whiskers that can lead to shorting and generation of conductive foreign object debris. (See JSC 49894, paragraph 2.12). Legislation passed by a number of countries in the world restricts the use of Lead (Pb) in electronic manufacturing processes. To comply with these laws electronic component manufacturers are removing Lead from the plating of their components. Although space, military, and certain industrial applications have been granted exceptions to compliance with these directives, the small market presence of these industries does not allow for much influence on component manufacturers. As a result, the vast majority of components will soon be available with only pure Tin plating. Soldering processes used with Tin/Lead solder do not fully mitigate the Tin plating issue because the entire termination is not covered during those soldering processes. The very small termination spacing on many current components further increases risk. Conformal coating reduces the risk of Tin whiskers migrating to other areas, but these whiskers can grow under or through it - possibly to adjacent terminations on the components. Replating terminations with Tin/Lead solder is a viable option if done by a qualified vendor who controls the thermal shock to the component.

   Additional caveats associated with Lead-free manufacturing processes:

   a. Lead-free solder compounds generally require higher reflow process temperature profiles than standard Tin/Lead solder. This adds additional stress to components, which may be damaged by these reflow temperatures.

   b. Alternative solders are also more brittle than Tin/Lead alloys. This may adversely affect product shock, vibration, or temperature cycle endurance.

6. In a vacuum environment a cartridge style fuse will leak because of its poor hermetic seal. If the internal fuse pressure falls between 50 torr and 10^{-3} torr during the same period that a circuit overload requires the fuse to open, testing has shown that 50 volts or greater across the fuse element can initiate a plasma arc between the poles of the fuse. The arc may propagate, consuming the fuse and attached conductors, until the arc's distance is exceeded or the upstream circuit protection is enabled. (See JSC 49894, paragraph 2.5.)

7. Explanation for mechanical contact devices:

   a. High voltage DC switches require a special design to assure reliability that includes a very fast snap-action contact movement and an arc suppression mechanism to immediately quench the contact-to-contact current flow. Qualification can be by the manufacturer or NASA. (An example of an inappropriate selection: 250 volt AC switch used in a 120 volt DC application)

b. Switch manufacturers often give maximum contact ratings but are silent on minimum ratings. It is often mistakenly thought that if a switch is rated for 5 amps it will work for a low current application (the bigger is better mentality). Manufacturers use special contact materials for various current and voltage configurations. Gold plated contacts are typically used in low current and/or voltage applications.

E-8 Electrical / Electronic Supplies and Loads – Verification Tests

STATEMENT OF STANDARD

Ground support equipment, facilities, and other equipment to be connected to a spacecraft system for operation, testing, checkout, or maintenance shall be designed so that routine verification tests can be conducted before each connection is made to ensure that each electrical and electronic input to the spacecraft is compatible with the spacecraft system.

Verifications test procedures shall be provided with the equipment.

REMARKS

Instances have occurred where spacecraft has sustained damage by inputs from equipment that was not checked and verified to be within acceptable limits before it was connected to spacecraft systems.

E-9 Electrical Circuits – De-energizing Requirement

STATEMENT OF STANDARD

Spacecraft electrical systems shall be designed so that all necessary mating and demating of connectors can be accomplished without producing electrical arcs that will damage connector pins or ignite surrounding materials or vapors.

Unless connectors are specifically designed and approved for mating or demating in the existing environment under the loads being carried, they shall not be mated or demated until voltages have been removed from the powered side(s) of the connector.

If the circuit breakers and switches normally provided in the power distribution system of the spacecraft do not provide a satisfactory means of complying with the intent of this standard in all planned flight and ground test operations, additional circuit interruption capability shall be provided as required.

REMARKS

Consideration in the design must be given to address the proper controls/inhibits in design features to avoid critical (two inhibits) and catastrophic (three inhibits) hazards (i.e., crew mate/demate of connectors for shock, molten metal & explosive environment hazards). Reference SSP 51700, Payload Safety Policy and Requirements for the International Space Station, Appendix E, JSC 18798B, Interpretations of NSTS/ISS Payload Safety Requirements, Section 4.3, Crew Mating/Demating of Powered Connectors (MA2-99-170); pages E-27 through E-35.

E-10 Cleaning of Electrical and Electronic Equipment

STATEMENT OF STANDARD

No method of cleaning electrical or electronic equipment shall be used unless it has been established that the method will not cause damage to, reduce the reliability of, or degrade the performance of any component or assembly being cleaned.

REMARKS

Typical cleaning processes include, but are not limited to, ultrasonic, chemical, electrochemical, aqueous-, and solvent-based cleaning systems.

E-11 Protective Covers or Caps for Electrical Receptacles and Plug

STATEMENT OF STANDARD

Electrical plugs and receptacles of flight equipment and ground equipment that connects with flight equipment shall be protected at all times.

Protective covers or caps shall be placed over electrical plugs and receptacles whenever they are not connected to the mating part. The protective covers or caps shall have the following characteristics:

1. Provide protection from moisture for the plugs and receptacles
2. Provide protection against damage to sealing surfaces, threads, and pins
3. Be made of conductive or dissipative materials that provide electrostatic discharge protection of components
4. Be resistant to abrasion, chipping, or flaking
5. Be positively marked by bright colors or streamers if they are to be removed prior to launch
6. Be maintained at a level of cleanliness equivalent to the plugs or receptacles on which they are used

7. Be made of material that is compatible with the connector material

8. Be provided with restraining devices or suitable storage areas if required for on-orbit activities. Pressure-sensitive tape shall not be used to satisfy this requirement.

REMARKS

Receptacles and plugs require restraining protection from mechanical damage, dust, dirt, and foreign objects. Incorrect practice has been to allow the disconnected parts to go unprotected.

E-12 Electrical Connectors – Disconnection for Trouble-Shooting and Bench Testing

STATEMENT OF STANDARD

Test equipment shall not be connected to spacecraft or spaceflight equipment circuits by insertion of meter probes directly into electrical connector sockets, by holding meter probes against connector pins, or by attachment of alligator clips to connector pins.

The appropriate mating connectors shall be used to minimize wear on spaceflight equipment connectors.

Connector savers and jumper cables with mating connectors may be installed and remain on the spaceflight equipment for bench tests up to the time of installation in the spacecraft.

Approved breakout boxes may also be used.

Shorting springs or shorting clips shall not be used in electrical or electronic connectors.

REMARKS

Insertion of meter probes in connector sockets and connection of alligator clips to connector pins can cause damage to these components.

Shorting springs or shorting clips are jumper wires that can be snapped or sprung into place to short connector pins to other connector pins. When installed, they do not form a reliable low impedance bond. Since spring tension or compression is all that holds them in place, mating and demating of connectors can result in breakage of the spring or clip, intermittent contact points, and resistance buildup in the circuit due to contaminants.

Test equipment with nonconducting probes (e.g., hall probes or proximity probes) may be used.

E-13 Bioinstrumentation Systems – Crew Electrical Shock Protection Standard

STATEMENT OF STANDARD

To limit electrical current that could flow through an instrumented crew member as a result of contact with available voltage sources to a safe level, bioinstrumentation systems shall be designed with sufficient resistance in series with each body electrode or conductive surface.

Examples of voltage sources include, but are not limited to, sources in crew bays, power cords, batteries, and extravehicular activity umbilicals.

REMARKS

This standard is in accordance with the international standard set forth by the IEC 60601-1.

Serious electrical shock currents can accidentally flow through a crew member instrumented with electrodes that are connected through a low impedance to power ground / power return. If contact is made with a voltage source having the same ground as the bioinstrumentation system, electrical shock may occur. The shock currents include those caused by unequal ground potentials in multiple-instrument systems.

Safety considerations must therefore be given a high priority in the design of bioinstrumentation systems. Adequate protection from electrical shock hazards to the instrumented person involves consideration of the total environment. Bioinstrumentation may be reliable and safe when used alone but may electrocute the person when used in combination with other instruments or equipment that is defective or marginal. The serious electrical shock hazard can be eliminated by adequately isolating the bioinstrumentation system from ground.

The maximum safe shock current levels for direct current (dc) and alternating current (ac) currents up to 1000 Hz are defined as 1.0 μA applied internally and 100 μA applied externally to the body.

Bioinstrumentation may be isolated from other power sources by the use of a photo-optical system or other suitable isolation method.

E-14 Electrical Wire Harnesses – Acceptance Testing

STATEMENT OF STANDARD

As a minimum, testing shall be performed on flight electrical wire harnesses prior to flight as defined in NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring, Paragraph 18.2, Testing:

1. Following fabrication and prior to installation

2. Post installation but prior to connection or reconnection to spacecraft components or devices

3. Prior to each flight for nonpermanently installed cables

Prior to performing dielectric withstanding testing, the dielectric strength of all connectors, wire, components, or devices attached to the harness shall be verified to be greater than the applied test voltage. The test voltage level shall be adjusted to prevent damage to the lowest rated item in the cable.

The individual leakage current readings shall be read and recorded for each test performed. Measurement shall have resolution to the nano (10^{-9}) range. The data shall be maintained and available for comparison as long as the subject cable is in service.

Initial and periodic testing for shorting and dielectric failures shall be performed on ground support cables that interface with flight hardware using the test criteria described above.

Any trend in dielectric strength degradation / fluctuation greater than one order of magnitude shall be evaluated to determine the cause and worst case effect.

REMARKS

Knowledge of an "out of family" reading that could indicate an impending dielectric problem can often be found in the documentation of all test measurements. Retention of the test data enables long-term trending that can provide insight into a potential insulation breakdown.

The use of subminiature connectors has led to dielectric breakdown failures during dielectric withstanding testing because the dielectric strength of the smaller connectors is often less than the required dielectric withstanding test voltages.

Values derived from dielectric withstanding voltage testing may be used to calculate the insulation resistance threshold.

E-15 Electrical Power Distribution – Overload Protection & Fault Propagation

STATEMENT OF STANDARD

Maximum operating temperatures for electrical power distribution circuit elements shall be established. Overload protection devices shall be designed, selected, and calibrated to protect all elements of the circuit. The protection provided shall include consideration of wire material properties/ratings and wire bundle derating factors that are necessary due to area environmental conditions.

Any circuit protection device shall be sized to support the maximum sustained load and to protect the smallest gauge wire to which it supplies power.

Protection device trip characteristics for branch circuits shall be designed so that combination of current and time required to isolate/remove an overloaded branch circuit will not be sufficient to cause upstream protection devices to act and remove power from other branches of the power system inadvertently.

Where circuit changes (such as the addition of splices or wiring) are made or where the environmental conditions surrounding the electrical system are changed in a manner that could adversely affect the power distribution system elements, the overload protection requirements shall be reevaluated to determine the adequacy of the protection provided.

Failure in an individual phase of a multiphase alternating current circuit shall not cause an unbalanced overload in the other phases of that circuit. Adequate protection shall be provided in each phase of the circuit supplying an item of equipment to prevent failure in other phases of that circuit or other branches upstream of the faulty equipment.

REMARKS

The requirements of this standard are directed toward the protection of circuit elements which, if overloaded, could be damaged or could cause damage to other elements through the generation of high temperature, flame, smoke, or noxious gases. For purposes of this standard, power distribution system elements are circuit elements such as wiring, wiring accessories, connectors, terminals, wire splices, and branch power distribution circuits.

Circuit protection devices have varied trip characteristic curves and the maximum values/times should be used in assessing downstream wire size/insulation (i.e., maximum blow/trip values in fuses range from 135% to 235% in some cases). Smart short current levels should be considered in selecting the wire gauge. Insulation temperatures should not exceed their maximum rating during a max short event.

E-16 Testing Protective Devices for Electrical and Electronic Circuits

STATEMENT OF STANDARD

Protective devices for electrical and electronic circuits shall be verified as functional after the environmental acceptance test of the circuit assembly and after any event, such as maintenance or handling mishaps, that could physically damage the circuit.

REMARKS

This test requirement is an important consideration during electronic circuit design where the verification should be performed without disassembly. Verification of the protective device should be accomplished by selecting test methods that do not require incorporation of special testing circuits.

Examples of protective devices covered by this standard are diodes, capacitors, resistors, chokes, filters, etc., or combinations of devices included to protect electronic elements from such occurrences as unwanted transients, current reversals, short circuits, signal couplings, or wide deviations from desired operating conditions.

For design requirements for protective circuits, refer to standard E-3.

E-17 Electrical and Electronic Piece Parts – Hermetic Construction

STATEMENT OF STANDARD

Hermetic packaging shall be used for parts exposed to any pressure environment (high or low/vacuum) if such exposure would adversely affect the function of those parts or mission reliability.

Hermetic packaging shall be used for parts exposed to pressure changes during any phase of space flight if such changes would adversely affect the function of those parts or mission reliability.

REMARKS

Some examples are piece parts that can be affected by injections of debris and moisture during vehicle descent. Another example of the need for hermetic parts is the quenching effect (arc suppression) of the nominal atmospheric air mixture for contacts in relays and switches.

Long-term storage of electronic parts is usually most successful if the part has a hermetic case or, as a minimum, is stored in a vapor proof container.

Environmentally (non-hermetic) sealed parts such as an aluminum electrolytic capacitor can begin to leak around its seals when subjected to a vacuum, leading to the loss of electrolyte. This loss accelerates over heating that increases internal pressure which increases the outgassing of electrolyte. It is a vicious cycle which eventually will lead to part failure.

If procedures for powering down those parts or other procedures will provide the necessary protection from damage such as corona, the parts need not be hermetically sealed.

E-18 [Reserved]

E-19 Equipment Design – Power Transients

STATEMENT OF STANDARD

Electrical and electronic equipment and circuits shall be designed and tested to ensure a compatible power bus transient environment.

Design factors shall include the following:

1. Specifying the bus transient environment

2. Limiting the transient generation characteristics of equipment to specified levels in both amplitude and time duration

3. Ensuring that the equipment is not susceptible to transients of the specified amplitude and time duration with a specified margin of safety and functionality.

System tests shall be performed using flight configuration hardware or electrically equivalent to flight equipment to demonstrate that power bus transients are within specified amplitude and time duration constraints during the worst cases of loading, switching, and power source impedance. Flight electrically equivalent equipment shall have identical steady-state and transient electrical response and characteristics as the actual flight hardware.

Ground equipment connected to a spacecraft power bus shall also comply with the requirements of this standard.

REMARKS

A bus environment is the baseline voltage and frequency of the bus plus the aggregate electrical feedback of equipment powered from the bus or coupled with it electrically.

E-20 Electrostatic Discharge Protection of Electronic Equipment

STATEMENT OF STANDARD

Electronic equipment including subassemblies and assemblies shall be designed to provide ESD protection from damage or fault for Electrostatic Discharge Sensitive (ESDS) parts used in the design. The minimum requirement for subassemblies and assemblies is 2,000 volts, and the minimum requirement for equipment is 4,000 volts. These requirements specifically relate to the direct contact during non-operating conditions to input, output, and interface connections to subassembly/assembly. These requirements shall be satisfied either by test or analysis.

Any hardware in its normal flight configuration, operating or non-operating, shall be immune to upset or damage to a human body model discharge of 16,000 volts from direct contact to operator accessible points and exposed surface areas of the equipment. This requirement shall be satisfied by test or analysis.

REMARKS

This standard does not apply to electrically-initiated explosive devices.

A subassembly or assembly is a configuration that cannot be normally operated independently of other, companion subassemblies or assemblies (e.g. a circuit card).

Equipment is a configuration of subassemblies or assemblies (e.g., an avionics box).

Either the body/finger or hand/metal Human Body Model (HBM) test methods may be utilized at the subassembly or assembly levels. The hand/metal HBM test method shall be utilized at the equipment level. Guidance for the selection of test methods at the subassembly and assembly levels can be located in IEEE STD C62.38, IEEE Guide on ESD: ESD Withstand Capability Evaluation Methods (for Electronic Equipment Subassemblies). Acceptable test methods may be located in ANSI C63.16, American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment, or IEC 61000-4-2, Electromagnetic Compatibility (EMC) – Testing and Measurement Techniques – Electrostatic Discharge Immunity Test.

Two documents recommended for use when establishing an ESD control program are:

- MIL-STD-1686, Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

- ANSI/ESD S20.20, For the Development of an ESD Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices).

E-21 [Reserved]

E-22 Ionizing Radiation Effects on Electronics

STATEMENT OF STANDARD

Spacecraft electronics shall meet performance and operability requirements while in the natural ionizing radiation environment of the mission. Proof of the ability to meet the performance and operability requirements shall be established by mean time between failure (MTBF) estimations at the box or system level. These MTBF estimations shall be based on actual test data. Proper test data acquired from other tests, including vendor data that shows radiation tolerance, may be used where appropriate. All radiation effects, such as Total Ionizing Dose (TID) and Single Event Effects (SEE) including upsets, latch ups and burn outs, shall be considered.

Radiation testing may be done at the part, board, or box level. The minimum radiation testing level required to establish performance and reliable operation capability shall be by exposure of the test article to either:

1. 200 MeV (+/- 10 MeV) protons to a fluence of 1e10 protons/cm^2 or

2. Heavy ions producing Linear Energy Transfer (LETs) of from 1 MeV/ (mg/cm^2) to 14 MeV/ (mg/cm^2) in appropriate steps of LET to a fluence of 1e6 ions/cm^2.

Testing past the minimum shall be with heavy ions to extend the maximum test LET beyond 14 MeV/ (mg/cm^2).

Because the minimum test is not as complete as advanced testing with heavy ions past 14 MeV/ (mg/cm^2), an MTBF of 10 years shall be assigned for errors such as destructive latchups NOT seen in the minimum test. The compatibility of the 10-year MTBF with the mission needs shall be proven for all systems using the “minimum testing” criteria. Additional testing with heavy ions to achieve LETs greater than 14 MeV/ (mg/cm^2) may be required if a 10 year MTBF is not sufficient for the mission or the application is such a critical nature that additional assurance is deemed necessary.

If similarity is to be used to establish the radiation susceptibility of a microelectronic part by comparison to a "similar" microelectronic part that has known radiation susceptibility characteristics, all of the following criteria shall be satisfied:

1. Both microelectronic parts must be the product of the same Qualified Parts List, Qualified Manufacturers List, and/or ISO 9000 manufacturer.

2. Both parts must have been manufactured on the same line.

3. The processing of both parts must have been identical, especially the critical parameters of rate of oxide growth, temperature of the oxide growing process and final oxide thickness.

4. The two parts must be similar in function and identical in technology including the same mask design, identical feature size, deposition, and doping.

5. The same foundry must have produced both wafers.

REMARKS

Modern microelectronic components are continuously being improved with faster operating speeds, smaller feature sizes, increased density, and reduced power requirements. These improvements, while providing superior performance in ordinary terrestrial environments, tend to increase the component’s susceptibility to the effects of ionizing radiation. There are also limited offerings of parts designed specifically for use in the space environment and the performance of these parts tends to lag technology capability by some 5 to 10 years. The overall result is that the vast population of modern microelectronic components is comprised of “commercial off the shelf” (COTS) parts designed for use on Earth. The use of these COTS parts in the radiation environment of space involves risks, both from tolerance to total ionizing dose (TID) and from susceptibility to single event effects (SEE). These risks must be quantified as part of a system design.

Rationale for testing: Essentially all microelectronics flown today has a probability of failing in some fashion due to ionizing radiation. For the case of total ionizing dose (TID), this failure is characterized by a system that degrades over time or totally ceases to function. Exposing the hardware to a TID that represents the expected mission exposure multiplied by a safety factor will demonstrate via test that the hardware functions after such an exposure. This total dose exposure can be accomplished during the testing for SEE with high-energy protons.

Rationale for the assigned 10 year MTBF: The minimum radiation test with protons or with heavy ions to 14 MeV/ (mg/cm^2) does not cover the on orbit deposited energy spectrum completely. The portion of the spectrum not covered is that of the higher LETs. Fortunately this high-LET region has considerably less population (particles per unit area per unit time), which lowers the chance for errors to be generated. However, this portion of the spectrum still offers the opportunity for failure modes to occur that won't be seen in the basic test. NASA/JSC modeling work indicates that a 10-year MTBF must be used to account for this somewhat truncated energy deposition (LET) region in the minimum test regimen.

Rationale for similarity restrictions: The "market life" of an electronic part today ranges from 6 months to three years and then a replacement part, generally with better performance, is offered in the market place. Even during the lifetime of a part, process changes can be made that might have catastrophic effects on the performance in the radiation environment. Even consecutive lot numbers or date codes will not guarantee similar radiation performance.

E-23 [Reserved]

E-24 Electrical Wire and Cable Acceptance Tests

STATEMENT OF STANDARD

Spacecraft electrical wire and cable, including wiring used within containerized electrical/electronic assemblies ("black boxes") shall be procured and acceptance tested to the appropriate flight hardware wire and cable specifications listed below:

- Cable specification ANSI/NEMA WC 27500, Standard for Aerospace and Industrial Electrical Cable.
- Cable specification MIL-DTL-17, Cables, Radio Frequency, Flexible and Semirigid.
- Wire specification SAE AS22759, Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy.
- Wire and cable defined in SSP 30423, Space Station Approved Electrical, Electronic, and Electromechanical (EEE) Parts List.

Other wire procurement specifications may be authorized by the procuring agency. Spacecraft wire and cable shall also comply with applicable program materials and process requirements.

If the wiring used in any spacecraft application is unknown, as it may be in the case of off-the-shelf equipment, pig-tailed components, heater strips, etc. and if the application is non-critical, the assembly is required only to meet applicable program materials and process requirements.

Two methods for certifying wire are:

1. As required by the procurement specification, Government Source Inspection shall certify that the test specified below has been performed by the wire manufacturer on the length of wire procured. In addition to meeting the requirements of the appropriate procurement specification, each shipment shall be accompanied by the manufacturer's test report.

2. Wire certification can also be performed by a NASA-approved test facility.

In either case, testing shall consist of the tests below.

Testing for insulation flaws of cable's basic wires shall be done prior to cable assembly.

100-Percent Testing

1. Insulated single conductor wires and cable basic wires

    a. Impulse dielectric test (no greater than 80% of military specification)

2. Cable

    a. Dielectric withstand of component wires

    b. Jacket flaws for shielded cables

Sample Testing

As a minimum, a sample or samples of each lot of wire/cable shall be subjected to the following applicable quality conformance inspections. (Applicability is determined by the specifications cited above).

1. Insulated single-conductor wires and cable basic wires

    a. Conductor resistance

    b. Wrap test

    c. Shrinkage (heat resistance)

    d. Cold bend followed by wet dielectric

    e. Visual and mechanical examination (finished wire o.d., identification of product, conductor diameter, strand diameter, conductor stranding, wire base metal, and the plating material)

    f. Polyimide cure test (applicable to modified aromatic polyimide coatings only)

    g. Crosslink proof testing for crosslinked insulation materials

2. Cable

a. Shield coverage

b. Identification of product

c. Jacket wall thickness

d. Cold bend

e. Thermal shock

f. Stress-Crack Resistance testing (MIL-DTL-17 cable only)

Any failure during sample testing shall be cause for immediate rejection of the entire lot.

Certification Processes

Certification of a NASA-approved test facility is done by an audit team with representatives from the S&MA and Engineering Directorates, or their representatives.

The team shall assure the test lab is qualified to perform the test methods referenced in this standard.

At the using installation, before placing wire/cable into bonded storage, representatives from the Engineering team and/or receiving inspection function shall verify that the test report indicating conformance with all applicable procurement specification requirements accompanies each lot shipped.

Storage shelf life: Silver plated wire and cable that has exceeded a shelf life of 10 years from its manufacturing date shall be downgraded to non-flight status and not be used on flight hardware.

This standard does not apply to non-flight wire and cable.

REMARKS

The primary reason for downgrading silver plated wire after 10 years of age is to control increased solderability problems with silver and the potential for Red Plague for wire stored in a high moisture environment.

Additional requirements for processing and dispositioning wire/cable lots are defined in JSC 49879, JSC Wire & Cable Integrity Compliance Program.

E-25 Protecting Electrical Wires, Cables, Bundles, and Harnesses

STATEMENT OF STANDARD

Electrical wire(s), cables, bundles, and wire harnesses shall be:

- designed and installed to withstand anticipated stresses induced by ground handling and flight operations,

- adequately protected to prevent insulation damage from such causes as chafing, abrasion and cold flow when passing through or touching any structure or panel;

- verified during qualification to withstand the anticipated environments.

REMARKS

Cold flow of Teflon®, and other “soft” polymer wire insulation materials, is the physical movement of the insulator under a compressive/directional load, and is often considered a latent reliability concern for electronic assemblies using wiring harnesses and cables. Cold flow only becomes a reliability issue affecting performance, if the insulation displacement becomes significant enough to thin the insulation jacket below the minimum isolation/electrical separation limit.

Panel and chassis hole edges should be properly chamfered and protected by a resilient-material grommet or non-conductive tape, e.g., Kapton®

Multiple broken wires have been detected in wire bundles at connectors. These breaks were caused by a stiff, hard coating on the bundles which did not allow sufficient flexing of the enclosed wires creating stress concentrations. Example causes include untapered tape or heatshrink tubing.

Problems have been caused by normal handling, thermal cycling, operating deformations, inadequate stress relief, vibration, and inadequate service loops.

5.3 FLUIDS

F-1 Restriction Requirements – Pressurized Components

STATEMENT OF STANDARD

Where pressurized components could fail in such a way that the total gas supply dumped directly into a compartment would be greater than the compartment relief valve or venting could handle without overpressurization of the compartment, necessary flow restrictions shall be incorporated to restrict the mass flow to a level that can be handled by the relief valve and/or venting.

For pressurized oxygen systems, flow restrictions shall be designed in accordance with ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance, to prevent flow-induced ignition hazards.

REMARKS

Pressurized components could fail in such a way that the total gas supply would be dumped directly into the compartment. If the pressure relief valve of the compartment were unable to handle the resulting pressure increase, compartment structural failure could result.

Relief valves in compartments are normally designed to maintain a preestablished pressure within the compartment during launch and reentry or in the event of a pressure regulator failure. They are not designed to maintain pressure in the event of a break or rupture of a pressure line or vessel.

High velocity oxygen flow can pose ignition hazards in improperly designed flow restrictors and terminations.

F-2 Water Separators in a Zero-Gravity Environment

STATEMENT OF STANDARD

In the design of water separators for use in gas streams under zero-gravity conditions, if the design includes a condensing heat exchanger and a downstream liquid/gas separator:

1. The liquid collection components and plumbing upstream of the separator shall be designed to preclude the collection of large quantities of liquid that could accumulate and be carried to the separator as a slug. If this cannot be assured then the design shall accommodate liquid entering the separator as a slug.

2. The hardware shall accommodate the expected proportions of liquid and gas that the separator will have to process (see #5 in Remarks).

3. Atmospheric debris shall be prevented from entering the separator to prevent clogging of small openings or channels.

4. Cabin trace contaminants shall not reduce the functionality of the heat exchanger coating below the required separator performance.

REMARKS

Design considerations include:

1. The behavior of water droplets changes once the influence of gravity is removed. Droplets tend to cling to surfaces more in zero-gravity.

2. In zero-gravity the extent to which the droplet beads up on a hydrophobic surface is more pronounced than in one-gravity. If the surface is hydrophobic, the droplet can bead up and be stripped away by the air stream. If the surface is hydrophilic, the droplet will spread out into a thin layer. Over time, metabolically-produced trace contaminants tend to coat surfaces, altering the hydrophobic or hydrophilic properties of surfaces or membranes. Separator designs that rely on the hydrophillic or hydrophobic nature of surfaces or membranes may lose that property with time. This may cause blockage or liquid carryover.

3. Liquid carryover from the separator can result from degradation of hydrophilic coatings, the separator not being designed for the liquid/gas proportions that it has to accommodate, a slug that is larger than the separator is designed to handle, or from a blockage of flow channels from debris.

4. Design verification of a liquid/gas separator can only be satisfactorily completed in a zero-gravity environment that has a long enough duration to experience the range of liquid/gas processing phases that will be expected on-orbit. Experience has shown that testing in a zero-gravity aircraft, which produces, at most, 20 seconds of micro-gravity is not always sufficient to identify problems with slugging or carryover. Results may even be misleading, since a period of increased gravity follows each 20 second micro-gravity interval. Testing for an extended period of zero-gravity is essential to verify the design of a liquid/gas separator.

5. Separators that have to process mostly liquid in a gas stream will have a different design than those that have to process mostly gas in a liquid stream.

F-3 Service Points – Positive Protection from Interchangeability of Fluid Service Lines

STATEMENT OF STANDARD

Service points for spacecraft fluid systems shall be designed with positive protection by location, connector size, or type to prevent connection to incorrect fluid service lines.

REMARKS

None.

F-4 Ground Service Points – Fluid Systems

STATEMENT OF STANDARD

Ground service points for fluid systems including those for filling, draining, purging, or bleeding shall be accessible from the exterior of the spacecraft or element.

Gas purge or bleed fittings shall exhaust outside the spacecraft or element.

Portable fluid systems and systems that are located entirely within the pressurized compartment(s) of the spacecraft are excluded from the above requirements.

REMARKS

Here, accessible means that the service points can be behind a door or access panel

A dry hose may be attached to the interior of the spacecraft for servicing by GSE.

Servicing of fluid systems from inside compartment(s) may result in the following:

1. Exposure of equipment to fluid spillage
2. Damage of service points due to inaccessibility
3. Unnecessary traffic in the compartment

F-5 Fluid Lines – Separation Provision

STATEMENT OF STANDARD

For separation of space-vehicle modules where one is being discarded, fluid lines that are required to be disconnected or severed on separation shall be designed such that any breakage resulting from failure of the disconnecting device to function will occur on the discarded side of the disconnect. The check valve or shutoff valve, used on the retained side of the disconnect for preventing unacceptable loss of fluid after disconnection, shall be a type that will function (i.e., that will close) in spite of such a failure.

For separation of space-vehicle modules where both need to function after separation and are intended for subsequent reconnection, fluid lines that are required to be disconnected on separation shall be designed to preclude unacceptable loss of fluid after disconnection and shall include provisions to enable successful reconnection.

REMARKS

None.

F-6 Temperature and Pressure Monitoring Requirements for Potentially Hazardous Reactive Fluids

STATEMENT OF STANDARD

All spacecraft systems and ground support servicing equipment requiring storage of reactive fluids (e.g., hydrogen peroxide, oxidizers, and monopropellants) shall be designed to include devices for monitoring temperature and pressure.

REMARKS

This approach permits accurate determination of the rates of decomposition of the fluids contained in their respective systems.

These monitoring devices will provide time for corrective action in the event that abnormal decomposition of fluids is initiated.

Transfer lines and pumps should be considered as part of the overall monitoring effort but not necessarily individually instrumented.

This standard combines G-49 and F-6 into single standard.

F-7 Capping of Fluid Servicing and Test Ports Not Required to Function in Flight

STATEMENT OF STANDARD

Fluid servicing and test ports, not required to function in flight, shall be designed so that they can be capped immediately after servicing or test in order to preclude leakage in flight.

The method and material used for capping shall be compatible with the applicable spacecraft subsystem and the expected environment.

REMARKS

Capping of these ports is necessary to prevent leakage of the applicable subsystem.

F-8 Fluid Systems Components Whose Function Is Dependent on Direction of Flow – Protection Against Incorrect Installation

STATEMENT OF STANDARD

The following positive measures shall be taken to prevent incorrect installation of fluid system components whose function is dependent on direction of flow:

1. The direction of fluid flow shall be indicated with permanent markings on the exterior of the component and on the parts and lines to be mated with the component.

2. A flow check shall be performed after each installation or change.

3. Where flow checks cannot be made, provisions shall be incorporated in the fluid line components' design, end fittings, or connections to preclude incorrect installation.

REMARKS

In a complex plumbing installation, it is difficult for fabrication or assembly personnel to know the direction of flow.

F-9 Spacecraft Venting-Induced Perturbing Forces

STATEMENT OF STANDARD

Sources of venting that could occur during the mission shall be identified and an analysis made to ensure that the total vent condition is designed to be compatible with vehicle and/or mission control capabilities. Impingement of vent plumes on spacecraft shall be analyzed.

Nonpropulsive vent concepts, opposed venting, operational procedures, or similar methods shall be used to eliminate the undesirable effects of perturbing forces resulting from such vents.

REMARKS

Typical sources of planned or expected overboard venting include water boilers, cabin relief valves, fuel cell purges, waste disposals, dryers, waste compartments, and air locks.

Such venting is a major cause of error in spacecraft precision control and navigation. In addition, venting may be a major source of exterior contamination of precision optical and electromagnetic instruments on spacecraft.

F-10 Nozzles and Vents – Protection Prior to Launch

STATEMENT OF STANDARD

All nozzles and vents used in crewed spacecraft systems, such as those of the reaction control system and environmental control system, shall be protected from entrance of rain, debris, or other contaminants prior to launch. (This standard applies throughout assembly, testing, shipment, and checkout of the spacecraft and its systems).

Protective covers for nozzles or vents located within a payload bay shall be designed to be readily removable during the countdown before launch or before final closure of payload bay doors.

Covers shall be designed so that removal can be accomplished without risk of dumping accumulated debris into the nozzle or vent, damaging nozzle radiation coatings or generating debris that poses a risk to the vehicle.

Covers shall be designed so that failure to remove the cover will not cause failure of the system or any other subsystem.

REMARKS

Protection is advisable at all times and is particularly required whenever any nozzle axis is pointing substantially above the horizontal axis.

F-11 Fluid Supplies – Verification Test Provisions

STATEMENT OF STANDARD

Ground support equipment, facilities, fluid containers, and other equipment to be connected to a spacecraft system for operation, testing, checkout, or maintenance shall be designed so that routine verification tests can be conducted before each connection is made to ensure that each fluid input to the spacecraft will be compatible with the spacecraft system.

Procedures shall be provided to accomplish the verification tests with the equipment.

REMARKS

Instances have occurred where a spacecraft has sustained damage by inputs from equipment which was not checked to be within acceptable limits before it was connected to spacecraft systems.

F-12 Protection of Pressurized Systems from Damage Due to Pressurant Depletion – Support Equipment

STATEMENT OF STANDARD

Where maintenance of fluid pressure is critical to prevent major damage to a space vehicle component such as a propellant tank or fuel cell, the ground support equipment (GSE), airborne support equipment (ASE) or flight support equipment (FSE) shall be designed to provide sufficient pressure to the space vehicle component in the event of a failure of the pressurant source.

The GSE, ASE or FSE shall be designed such that recovery from failures of the pressurant source can be accomplished without damage to the space vehicle component.

The GSE, ASE or FSE shall be designed to monitor pressure (or pressure differential) both from the source and to the system.

REMARKS

Depletion of the GSE, ASE or FSE pressure source or line pressure drops resulting from fluid flow have resulted in serious equipment damage in operations where the requirements of this standard were not met.

Good practice is to use separate fluid pressure sources for purge or flushing.

See the G-14 Remarks section for definitions of GSE, ASE, and FSE.

F-13 Habitable Module Pressure – Venting Restriction

STATEMENT OF STANDARD

To prevent over-pressurization, all habitable pressurized elements shall have pressure relief venting systems.

Each pressurized element shall have its own vent system so that venting systems are not shared.

The venting system shall be capable of isolating the flow path from the ambient environment of the pressurized element to space vacuum, and the venting system shall be configurable to or already have online a secondary vent system in the event the primary vent fails.

REMARKS

Contamination control, fire control, and other emergency response procedures require that all pressurized elements of a spacecraft can be isolated from the other pressurized elements, and that each pressurized element can be independently vented.

Experience with Shuttle and ISS have demonstrated that vents can ice up in permanently open or closed positions. Vents can also become corroded by contact with vented products.

Vents should not be shared. Vents can fail and must be capable of isolation from the ambient environment by actions internal to the element and alternate vents should be configurable or concurrently available.

F-14 [Reserved]

F-15 Separation of Hypergolic Reactants

STATEMENT OF STANDARD

Oxidizer and fuel (both liquids and vapors) shall be positively separated using all-metal containment with mixing only allowed in the controlled combustion area.

REMARKS

Common pressurant gas supply for fuel and oxidizer should not be used.

F-16 Fluid Line Routing and Installation

STATEMENT OF STANDARD

Flight and GSE fluid line routing and installation shall meet the following requirements:

- Detailed drawings and procedures shall be provided for routing and installation of all fluid lines, including pressure-sensor lines.

- If temperature conditions are not within acceptable limits for the fluid involved, measures shall be taken to provide passive or active thermal control as appropriate.

- A design analysis shall be provided for each line installation to show that the temperature extremes to which it will be subjected (including storage, handling, transportation, and operations) are within acceptable limits for the fluid involved.

- Fluid lines installed external to spacecraft shall be Extravehicular Activity (EVA) compatible, if intended for future EVA maintenance or repair.

- Strain relief shall accommodate design loads, deflections, and thermal expansion.

- Fluid lines shall be restrained at intervals in accordance with the governing standard for the application.
- Fluid lines carrying oxygen shall not be configured with sharp bends that could pose a blunt flow impingement ignition hazard, in accordance with ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance.

REMARKS

EVA compatibility information is provided in JSC 26626A, EVA Hardware Generic Design Requirements Document.

F-17 Cleanliness of Flowing Fluid and Associated Systems

STATEMENT OF STANDARD

Spacecraft systems that will contain gases or liquids to be used or expended during the mission shall be maintained in the state of cleanliness required by the specification for the particular substance involved after factory assembly and up to and including final servicing prior to flight.

This requirement shall also apply to the gas- and liquid-handling systems of all servicing, maintenance, handling, testing, and checkout equipment.

Such systems fluids, as well as test fluids that enter spacecraft systems, shall be filtered or controlled such that the degree of cleanliness required by the specification for the particular substance is maintained.

Spacecraft systems that will contain such gases or liquids shall be designed so that required draining, flushing, drying, cold trapping, etc. can be accomplished with the spacecraft in its checkout or working attitude. The length of time to accomplish this task shall be presented for approval during design reviews.

Calibration fluids shall be furnished with analysis reports which are signed by the preparer and the source inspection agency

REMARKS

None.

F-18 Pressure Relief Valves – Standardization of Functional Testing

STATEMENT OF STANDARD

To provide consistency in initial and subsequent testing of pressure relief valves, the manufacturer shall specify values with tolerances for: crack and reseat pressure, mass-flow rates, pressures corresponding to full flow, and allowable leakage.

These values shall be specified for operation with the flight fluid and any other fluid recommended for test purposes.

Retest time intervals shall be specified for valves that are subject to deterioration with time.

REMARKS

Specific flow-rate values have been found necessary for verification of these valve characteristics with the precision required in preflight checkout.

F-19 Cleanliness Protection for Fluid Systems

STATEMENT OF STANDARD

Handling of flight and flight interface GSE fluid systems shall meet the following requirements:

1. Design drawings and/or process specifications shall designate the method of complying with this standard.

2. In each step of the manufacturing process and buildup, all ends of tubing, fittings, and components used in fluid systems shall be protected against damage and entry of contaminants. Equivalent protection shall be provided for tubing, fittings, and/or components when the subsystem is open to effect repair or replacement.

3. Protective caps shall meet the cleanliness requirement of the manufacturing specification. Protective cap material and design shall be compatible with the fluid.

4. All assemblies shall be cleaned and dried before packaging. For oxygen components, cleaning and packaging materials shall not pose residue or particle contamination hazards, in accordance with ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance.

5. Refill procedures shall provide the same protection against damage or contamination as the initial manufacturing procedures establish.

6. Protection devices for components to be installed external to spacecraft shall be Extravehicular Activity (EVA) compatible.

7. Tubing assemblies, fittings, or components that are stored or shipped shall be protected and sealed in a clean, transparent, moisture-proof bag with sufficient protective strength and thickness for the intended handling.

REMARKS

Open plumbing and components must be protected to avoid entrance of foreign material and to protect the sealing surfaces.

Additional protection and procedures may be required by the regulatory authority for the fluid in question.

EVA compatibility information is provided in JSC 26626A, EVA Hardware Generic Design Requirements Document.

Methods of protection to maintain cleanliness of the hardware include but are not limited to: bagging, handling in a clean room or flow bench, and clean gas purge during assembly.

F-20 Fluid Systems – Cleanliness

STATEMENT OF STANDARD

After manufacturing and after any subsequent exposure to the probable entry of contaminants, fluid systems and servicing equipment shall be cleaned by flushing to remove all contaminants which could be detrimental to the system.

The flushing fluid shall be compatible with the system materials and the working fluid to be used in the system. Cleanliness levels of the flushing fluid and the system maximum allowable contamination shall be specified. During flushing, the fluid entering the system shall be filtered to the same level of cleanliness or better than that of the working fluid to be used in the system.

Whenever it is necessary to verify the cleanliness level of a spacecraft fluid system or its servicing equipment, samples of the fluid leaving the system from draining, purging or flushing operations shall be analyzed to determine that particulate and/or chemical contamination are within specified limits.

The fluid sample shall be taken at the end of the draining, purging or flushing operation.

REMARKS

None.

F-21 Purge Gases – Dew Point Requirement

STATEMENT OF STANDARD

Gases used for purging propellant vapors or other vapors from space-vehicle compartments shall have a dew point low enough to preclude moisture condensation from the purge gas on the coldest surfaces that the purging gas will contact.

REMARKS

This standard does not apply to cryogenic system surfaces when in a supercold condition and does not preclude consideration of other problems, such as static electricity or equipment temperature requirements, that may be involved with selection of proper dew point.

Purge gases may become saturated with the vapor being purged. When the gases later come in contact with colder surfaces in the compartment, the absorbed vapor may be deposited on these surfaces.

Transfer of the liquid from the point where it is being absorbed to other locations in the compartment may be dangerous.

F-22 Pressure Garments – Protection Against Failure Propagation

STATEMENT OF STANDARD

Systems which supply pressure to crew pressure garments shall be designed so that a major failure of one crew member's garment or garment pressure supply will not cause loss of life to other crew members.

REMARKS

Systems supplying gas to pressure suits should be so designed that an abrupt decompression of the suit of one crew member (such as might result from a rip in the fabric or a broken or unlatched faceplate) will not result immediately in a similar rapid loss of pressure in the suits of the other members or in a sudden total depletion of the gas supply.

The time available before the loss of pressure occurs in the other suits or before a critical depletion of the gas supply occurs should be sufficient to allow:

1. time for reasonable attempts to aid the decompressed crew member (e.g., by closing an unlatched faceplate) and

2. time to shut off flow to the open suit in the event the damage is beyond repair and the crew member cannot be saved.

F-23 [Reserved]

F-24 Fluid Systems – Design for Flushing and Draining

STATEMENT OF STANDARD

Spacecraft fluid systems and related servicing equipment shall be designed to permit complete flushing and draining during ground and on-orbit servicing operations.

The following conditions shall be satisfied, as a minimum:

1. The systems shall be free from dead-ended piping or passages through which flushing fluid cannot be made to flow.

2. Drain and bleed ports shall be provided for attitudes anticipated during ground servicing of the systems.

REMARKS

This standard is to clarify that the design requirements pertain to on-orbit as well as ground servicing operations.

F-25 Toxicity – Fluids Contained in Systems in the Crew Compartment

STATEMENT OF STANDARD

Fluids capable of producing toxic fumes shall not be used in systems within the crew compartment if a nontoxic substitute with equivalent performance exists.

Where no satisfactory substitute for the fluid exists, tests shall be performed to ensure that the total leakage is less than the concentration which would result in a level of toxicity that would impair crew health and safety.

REMARKS

None.

F-26 Atmospheric Pressure and Composition Control

STATEMENT OF STANDARD

Spacecraft and habitable modules shall be designed and operated so that atmospheric pressure and composition control systems maintain a habitable environment under all nominal and contingency operational scenarios.

Provisions shall be made to monitor and control oxygen, nitrogen, carbon monoxide, carbon dioxide, partial and total atmospheric pressure, and credible atmospheric contaminants.

Crew compartments shall be designed with forced ventilation to prevent stagnant air pockets from forming in crew-habitable areas of the compartment.

REMARKS

Nominal and contingency operational scenarios include, but are not limited to: nominal operations, planned or inadvertent fluid system venting into the crew compartment, planned or inadvertent crew compartment venting to space, fluid system leakage into a crew compartment, and crew compartment leakage to space.

Credible contaminants may be organic, inorganic, or biological. Refer to MP-9 for additional information.

In the absence of natural convective air circulation in a microgravity environment, stagnant pockets may accumulate in areas without forced ventilation. Pockets of crew-generated carbon dioxide pose a toxicity hazard to the crew.

Planned or inadvertent venting of inert gas into a crew compartment may reduce oxygen concentration to a level that could pose a confined space hazard.

Planned or inadvertent venting of oxygen into a crew compartment may increase oxygen concentration to a level that poses a fire hazard. Refer to ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance, for guidance on proper selection of crew cabin materials for oxygen-enriched environments.

F-27 Verification of Liquid or Gas Properties

STATEMENT OF STANDARD

The contents of each individual liquid or gas container to be used in flushing, testing, checkout, or operation of spacecraft and/or life support systems shall be shown by laboratory analysis to conform to specified requirements, at a minimum, prior to introduction into the system.

REMARKS

To prevent system contamination and to verify implementation of hazard controls, it is necessary to determine when and where in the process it is most critical to verify liquid or gas properties meet requirements, for example just prior to introduction into the system, at a point of interface with a human, or both.

Instances have occurred where incorrect labeling of containers has caused application of incorrect fluids to subsystems. In other cases, the contents of the container have failed to meet the specified standards of purity. Inspection of shipments by sampling some of the containers has proven unsatisfactory for determining impurities in the entire shipment.

Instances have occurred where de-ionized water that had been laboratory analyzed prior to use, did not meet requirements at the point of use (i.e. introduction into the system) and subsequently contaminated flight equipment. For systems involving purified water and that are flown dry, a best practice is to have a second laboratory analysis after the purified water has been introduced into the system to ensure specified requirements were maintained during the interval of time from the original analysis through introduction into the system.

F-28 [Reserved]

F-29 Filter Protection of Sensitive Fluid Components

STATEMENT OF STANDARD

Fluid system components subject to malfunction from particulate contamination in zero-gravity or reverse flow situations shall be protected by filters from particulates which might enter from either flow direction.

Filters shall be designed either to accommodate the worst expected conditions of service for their entire expected service life or to be cleaned and/or replaced as a standard maintenance item.

REMARKS

Components subject to malfunction from particulate contamination should be protected on their inlet and outlet by filters.

This applies to both mechanically active (e.g., regulators, solenoid valves, and check valves) and mechanically passive (e.g., porous plate sublimators and membrane separators) components.

F-30 Pressure Relief for Pressure Vessels/Systems

STATEMENT OF STANDARD

Pressure relief capability shall be provided for pressure vessels/systems where the contents, system design, environment or operation may cause an increase in internal pressure above the maximum design pressure (as defined below).

For pressure vessels/systems where pressure can fluctuate only because of external ambient temperature, a mechanical relief device shall not be required provided the fluctuations cannot cause the maximum design pressure to be exceeded.

All flight pressure vessels/systems shall be protected during servicing, either on the ground or in flight, by relief valves in the servicing equipment. The relief valves shall be sized for sufficient mass flow to protect the pressure vessel/system in the event of servicing pressure regulator failure. Such a failure shall not cause the pressure vessel/system to exceed the maximum design pressure.

Where mechanical relief devices are required, they shall be sized for sufficient mass flow to protect the pressure vessel/system from exceeding the maximum design pressure.

The effects of thrust or torque imparted to the pressure vessel or associated equipment by actuation of the relief device shall be considered. The effects of thrust or torque imparted to the spacecraft by actuation of the relief device shall also be considered.

Pressure rise in the compartment where the relief device vent is located shall be assessed at relief device maximum flow conditions.

REMARKS

The Maximum Design Pressure (MDP) for a pressurized system is the highest pressure defined by the maximum relief pressure, maximum regulator pressure, maximum temperature and transient pressure excursions based on two credible system failures.

The pressure vessel/system includes all pressurized hardware (e.g. tankage, lines, fittings, and components).

Portions of fluid systems that can trap fluids (become locked-up) shall be specifically evaluated for the need of relief capabilities.

5.4 MATERIALS AND PROCESSES

MP-1 Materials and Processes Control

STATEMENT OF STANDARD

Materials used in the fabrication and processing of flight hardware shall comply with NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft.

Applicability to GSE is specified in NASA-STD-6016.

REMARKS

JSC 27301, Materials and Processes Selection, Control, and Implementation Plan for JSC Flight Hardware is used to implement the requirements of NASA-STD-6016 for JSC in-house flight hardware.

Selection of materials is based on the worst-case operational requirements for the particular application and the design engineering properties of the candidate materials.

The operational requirements include, but are not limited to, operational temperature limits, loads, contamination, life expectancy, moisture or other fluid media exposure, and vehicle-related induced and natural space environments.

Properties to be considered in material selection include, but are not limited to, mechanical properties, fracture toughness, flammability and offgassing characteristics, corrosion, stress corrosion, thermal and mechanical fatigue properties, vacuum outgassing, fluids compatibility, microbial resistance, moisture resistance, fretting, galling, susceptibility to electrostatic discharge (ESD).

Conditions that contribute to deterioration of hardware in service receive special consideration.

MP-2 [Reserved]

MP-3 [Reserved]

MP-4 [Reserved]

MP-5 [Reserved]

MP-6 [Reserved]

MP-7 [Reserved]

MP-8 [Reserved]

MP-9 Mercury Limitations in Breathable Atmospheres

STATEMENT OF STANDARD

Direct inhalation breathing systems shall not contain any sources of mercury. Examples include but are not limited to: spacesuits, launch entry suits, underwater breathing systems, environmental chambers, and auxiliary life support systems.

Closed habitable atmospheres shall not contain sources of mercury that could lead to unsafe levels of contamination as determined by the JSC Toxicologist for spaceflight equipment and the Industrial Hygienist for ground support equipment.

REMARKS

If mercury sources are identified, the mercury should either be removed, or a waiver from JSC environmental health should be obtained. If a waiver is obtained and a source of mercury remains in the system, a test of the air will be conducted using calibrated analytical instruments capable of detecting concentrations of mercury less than 0.005 mg/m^3. The minimum temperature of a system while undergoing testing will be 20 degrees C (68 degrees F).

JSC 20584, Spacecraft Maximum Allowable Concentrations (SMAC) for Airborne Contaminants, defines the limit for continuous exposure to mercury.

JPR 1700.1, JSC Safety and Health Handbook, Section 9.1.16 cites 40 C.F.R. 61, National Emission Standards for Hazardous Air Pollutants (NESHAP), and lists mercury as a restricted substance at JSC.

MP-10 [Reserved]

MP-11 Pressure Vessel Documentation

STATEMENT OF STANDARD

Manufacturing, processing, and pressurization histories shall be maintained for each spaceflight pressure vessel. The minimum data required are:

1. Material certification and composition
2. Actual fabrication and processing sequence
3. Fluid exposure and temperature during fabrication and testing
4. Actual chronological tests and checkout history including all proof, leak, and cycling data along with the magnitude of pressure, type of pressurant, and number of pressure cycles to which the tank was subjected
5. Discrepancy history
6. Inspection Plan
7. Damage Control Plan for Composite Overwrapped Pressure Vessels (COPVs)
8. Fracture Control Summary
9. Certification Report

REMARKS

Histories may include manufacturing, processing, and pressurization information on pressure vessels, including those used for qualification and other tests. The data should be comprehensive and enable an assessment of the similarity of production units to those subjected to qualification and other nonproduction testing.

Because of the high sensitivity of pressure vessels to structural degradation, which can occur during manufacturing, shipping, handling, and testing, conditions can develop which have not been demonstrated to be acceptable by the qualification test. Documentation should be available to assess the overall condition of each pressure vessel.

In addition to the above minimum requirements, it is desirable to maintain any pertinent backup data that would facilitate an investigation in the event of an unanticipated failure or problem related to the pressure vessel material or related components.

For the purposes of this standard, a pressure vessel is as defined in AIAA S-080-1998, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure

Components, and AIAA S-081A-2006, Space Systems – Composite Overwrapped Pressure Vessels (COPVs) (see standard MP-13).

MP-12 [Reserved]

MP-13 Pressure Vessel / Special Pressurized Equipment Design and Certification

STATEMENT OF STANDARD

The design, manufacture, test, inspection, qualification, and use of space systems pressure vessels and special pressurized equipment shall meet the requirements of:

1. AIAA S-080-1998, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components

2. AIAA S-081A-2006, Space Systems – Composite Overwrapped Pressure Vessels (COPVs)

NASA-contracted ground support equipment (GSE) pressure vessels shall meet Center requirements (such as JPR 1710.13, Design, Inspection, and Certification of Ground-Based Pressure Vessels and Pressurized Systems) or the pertinent requirements of The American Society of Mechanical Engineers (ASME) Boiler and Pressure Code for Unfired Pressure Vessels, Section VIII.

In addition, GSE pressure vessels shall have demonstrated resistance to environmentally-induced flaw propagation sufficient to preclude degradation of the tank under expected use conditions.

REMARKS

Examples of special pressurized equipment include, but are not limited to: dewars, heat pipes, and certain batteries.

MP-14 [Reserved]

MP-15 [Reserved]

MP-16 [Reserved]

MP-17 [Reserved]

MP-18 [Reserved]

MP-19 [Reserved]

MP-20 [Reserved]

MP-21 [Reserved]

MP-22 [Reserved]

MP-23 [Reserved]

MP-24 [Reserved]

MP-25 [Reserved]

MP-26 [Reserved]

5.5 MECHANICAL AND STRUCTURAL

MS-1 Equipment Containers – Design for Rapid Spacecraft Decompression

STATEMENT OF STANDARD

Equipment containers or enclosures for use within pressurized compartments of spacecraft shall be designed to withstand rapid decompression of the spacecraft without yielding, fracturing, or sustaining damage.

REMARKS

Rapid decompression is defined as that decompression rate associated with the sudden opening of the largest inlet or outlet which vents to the space environment.

MS-2 Alignment, Adjustment, and Rigging of Mechanical Systems

STATEMENT OF STANDARD

Mechanical systems requiring accurate alignment, adjustment, or rigging of the system or system components shall incorporate provisions allowing for such alignment, adjustment or rigging to be made without the removal of the system, any of its components, or any neighboring hardware.

Where the actual alignment, adjustment, or rigging equipment is not incorporated into the flight hardware, provisions for mounting and using the necessary alignment, adjustment or rigging equipment shall be incorporated into the flight system.

Where in-flight alignment, adjustment, or rigging is required, such capability shall be incorporated into the flight hardware. If in-flight alignment, adjustment, or rigging requires tooling, the tools shall be standard tools.

REMARKS

None.

MS-3 [Reserved]

MS-4 Crew Hatches

STATEMENT OF STANDARD

Crew hatches shall meet the following requirements.

1. OPERATION

   a. Hatches and associated hardware (hinges, latches, actuators, attenuators, seals, etc.) shall be designed for repeated operation.

   b. Hatches shall be designed to be operable on the ground with the vehicle in any ground processing orientation.

   c. Hatches shall be capable of one-handed operation under zero-g conditions.

   d. Hatches shall be capable of being manually closed and opened from both sides.

      (1) Internal hatches shall have in-place provisions for latch-unlatch and opening operations from either side of the hatch.

      (2) External hatches shall have in-place provisions for latch-unlatch and opening operations from the interior of the hatch, and shall have provisions for latch-unlatch and opening operations from the exterior of the hatch.

   e. Hatch latch actuation shall require two (2) separate and distinct operations to unlatch.

   f. The hatch latch mechanism shall have an indicating system to display hatch latch locked and safe.

   g. Internal hatches shall have a means of pressure equalization and display of pressure delta across the hatch on each side of each hatch.

h. Opening assist devices shall be provided to break the seals of the hatch to allow the differential pressure across the hatch to reduce to an acceptable level before releasing the hatch to the fully open position.

2. MAINTENANCE

   a. Hatches and associated hardware (hinges, latches, actuators, attenuators, seals, etc.) shall be designed to allow for inspection.

   b. Hatches shall have provisions for ease of removal.

   c. All associated hatch hardware (hinges, latches, actuators, attenuators, seals, etc.) shall be designed to be repairable, replaceable, or both on the ground. If operated during flight, all associated hardware shall be designed to be repairable, replaceable, or both during flight.

3. SEAL INTEGRITY

   a. The capability shall be provided to leak check between redundant pressure seals without pressurizing/depressurizing the adjacent pressure volumes.

   b. The capability for verification of hatch seal integrity shall be provided on both sides of the hatch.

4. THERMAL AND STRUCTURAL LOADS

   a. Hatches and associated mechanisms shall not be designed to carry primary structural loads.

   b. The design of the structure surrounding hatches used in escape operations shall consider provisions to minimize the probability of jamming which would prevent crew egress following emergency landing or ditching.

   c. Hatches and associated mechanisms shall allow for differential movement between structural frame and the hatch as well as maintain compartment sealing under these conditions.

5. VISIBILITY

   a. Hatches shall incorporate a window.

REMARKS

See MS-8, Penetration of Inhabited Spacecraft Compartments, for hatch requirements related to ground and emergency operations.

See G-9, Shatterable Material – Exclusion, and MS-7, Windows and Glass Structure, for glass requirements.

See G-37, Verification of External Visibility, for visibility verification requirements.

MS-5 Threaded Fasteners

STATEMENT OF STANDARD

Threaded fasteners shall meet the requirements of NASA-STD-5020, Requirements for Threaded Fastening Systems in Spaceflight Hardware.

Additionally, threaded fasteners used in EVA activity shall meet the requirements of JSC 28918, EVA Design Requirements and Considerations, Section 4.17, EVA Operable Fasteners.

REMARKS

See G-5, Prevention of Debris – Electrical & Mechanical Systems, for foreign object debris prevention requirements.

MS-6 [Reserved]

MS-7 [Reserved]

MS-8 Penetration of Inhabited Spacecraft Compartments

STATEMENT OF STANDARD

Inhabited spacecraft compartments shall be so designed that all penetrations shall take advantage of normal pressure-induced forces to aid in maintaining vessel structure and cabin pressure integrity.

The primary flight crew ingress/egress hatch used during ground operations shall be designed to be outward opening from the pressurized spacecraft compartment. For designs where it is impractical to have an outward opening hatch, provisions shall be made to rapidly equalize the pressure across the hatch.

Reliable, redundant safety devices shall be provided to prevent inadvertent opening or rapid depressurization on orbit.

REMARKS

Penetrations include ingress/egress and manufacturing access hatches.

The purpose of the outward opening feature specified is to enable rapid egress of the crew from the spacecraft.

MS-9 Positive Indication of Status for Mechanisms

STATEMENT OF STANDARD

All movable mechanical systems shall provide positive indication that the mechanism has achieved its desired position.

REMARKS

Examples of desired position include ready-to-latch, latched, locked, stowed, deployed, etc.—any state in which a failure to achieve this state results in a failure of the mechanism to perform its function.

MS-10 [Reserved]

MS-11 Meteoroid and Orbital Debris Protection Levels for Structures

STATEMENT OF STANDARD

Protection levels against impacts from micrometeoroids and orbital debris (MMOD) for spacecraft structures shall be determined by hypervelocity impact tests and analysis.

The risks for loss of crew, loss of vehicle, and loss of mission from MMOD shall be established. Such risks shall be equal to or better than MMOD risks for previous spacecraft programs.

The MMOD risk assessments shall be updated as the MMOD environment definitions change.

Actual damage from MMOD impacts shall be identified and compared to predictions in order to track and trend MMOD effects on the spacecraft.

REMARKS

Empirical equations have been derived from hypervelocity impact testing on a variety of single-sheet or multi-sheet structures. When the structural configuration differs significantly from the test specimen configurations from which the equations were derived, the equations cannot be considered accurate. For example, if multilayer insulation is added, the equations are likely to be invalid; or if a honeycomb core joins the MMOD bumper to the main structural shell, the protection level may be significantly altered.

Hypervelocity impact tests are considered to be the most accurate method of determining the protection levels of spacecraft structures. Current impact test capabilities are limited in velocity such that tests cover only a portion of the MMOD threat. The mass of test particles should be determined by test at the ballistic limit (or failure limit) of the structure in question as a function of impact velocity, angle and particle density, and extended by analytical means to cover all MMOD impact conditions. The resulting ballistic limit equations are used in probability analysis to assess MMOD risks for the spacecraft.

Suggested references:

1. NASA TP-2003-210788, Meteoroid/Debris Shielding
2. NASA TM-2009-214785, Handbook for Designing MMOD Protection
3. NASA TP-2014-217370, NASA Orbital Debris Engineering Model (ORDEM) 3.0 - User's Guide
4. MEM R2, NASA Meteoroid Engineering Model (MEM) Release 2.0 – User's Guide

The Program will establish requirements for MMOD protection that provides for crew safety, vehicle survivability and mission success. Different levels of allowable MMOD risk have historically been specified for loss-of-crew (LOC), loss-of-vehicle (LOV), early mission termination/loss-of-mission (LOM), and functional failure for equipment and systems that can degrade mission success. Future crewed spacecraft should be designed to meet or exceed levels of MMOD protection provided by previous spacecraft, in particular the Apollo Program, the International Space Station (ISS), and the Space Shuttle.

Risks from MMOD impact can be mitigated by a combination of design and operational options including but not limited to: advanced low-weight shielding, leak stop or self-sealing materials in the shielding, leak detection/damage detection sensors and repair procedures, collision avoidance maneuvers from trackable orbital debris, and flying low-MMOD risk attitudes.

The orbital debris environment and to a certain extent meteoroid environment definition models are subject to change. Spacecraft MMOD risk assessments must be updated with the latest MMOD environment definitions that have been officially released and accepted by NASA.

Actual MMOD impact damage to the spacecraft should be monitored during the life of the program to trend MMOD damage to the spacecraft, to compare actual damage to predictions, and to identify any potential near-misses for potential corrective action to reduce MMOD risk.

MMOD damage can be monitored through photo evaluation on-orbit or by examination of returned surfaces on ground.

MS-12 Spacecraft Recovery Hoist Loops

STATEMENT OF STANDARD

Spacecraft recovery hoist loops shall be provided on all recoverable spacecraft.

Design of the spacecraft recovery hoist loop(s) shall be based on the following minimum requirements:

1. Before retrieval, a minimum open area equivalent to that of a 10-inch diameter circle shall be deployed. When the spacecraft is in its normal flotation or upright attitude, the loop shall be visible and accessible to retrieval personnel. The loop shall be located with respect to the spacecraft center of gravity such that the spacecraft may be readily carried and/or placed aboard the recovery vessel, vehicle, aircraft, etc. in a stable position.

2. The load envelope for the hoist loop and backup structure shall be derived from an analysis which considers the dynamic load resulting from relative motion of the spacecraft and the recovery vessel, vehicle, or aircraft. Factors to be considered in this analysis shall be defined for each particular case. In general, the minimum factors to be included in the analysis shall be:

    a. Spacecraft weight, including the effect of trapped water, unspent fluids, and cargo

    b. The relative motion of the spacecraft and the recovery vessel, vehicle, or aircraft resulting from worse case conditions in the recovery area

    c. Retrieval winch in-haul speed

    d. Stiffness characteristics of the retrieval line

3. The recovery hoist loop shall be adequate to withstand the environment experienced when the spacecraft is carried externally by a recovery vessel, vehicle, or aircraft.

REMARKS

The environment to be considered shall be defined for each particular case.

Hoisting weights and accelerations vary considerably from one spacecraft type to another.

Spacecraft	Spacecraft dry weight	Spacecraft hoisting weight
Mercury	1,088.6 kg (2,400 Ib)	4,535.9 kg (10,000 Ib) (including water trapped in landing attenuation bag)
Gemini	1,769 kg (3,900 Ib)	2,268 kg (5,000 Ib)

MS-13 [Reserved]

MS-14 Structural Analysis

STATEMENT OF STANDARD

Structural analysis shall be performed on all spacecraft structures, including pressure vessels, to show that all elements of the design such as the strength, stiffness, structural stability, and life meet all specified criteria for the anticipated loads and environments.

The analyses shall include stress analyses, fatigue or fracture analyses, loads and environmental data, and the appropriate references for the purpose of certifying the flightworthiness of structures.

The analyses shall be compiled and documented as part of certification of the flightworthiness of the structure.

The analyses shall comply with NASA-STD-5001, Structural Design and Test Factors of Safety for Spaceflight Hardware.

REMARKS

None.

MS-15 Fluid Systems – Method of Joining Metallics

STATEMENT OF STANDARD

Metallic vessels, tubing, and fittings used in fluid systems (pressurized / non-pressurized) shall be joined by brazing or welding except where:

1. mechanical disconnects are required for replacement or servicing,
2. components would be adversely affected by brazing or welding, or
3. brazing or welding cannot be performed or verified.

REMARKS

Welding and brazing are considered more reliable methods for joining metallic vessels, tubing, and fittings in order to prevent leaks.

Fluid systems in this context refer to both liquid and gas.

MS-16 Pressure Vessels – Negative Pressure Damage

STATEMENT OF STANDARD

Pressure vessels shall be evaluated for susceptibility to damage by negative pressures that could occur during fabrication, testing, installation, transportation, storage, servicing, operation, and maintenance.

Those vessels identified as susceptible to damage shall be appropriately tagged and protected against negative pressure during the life cycle of the tank, particularly during manufacturing and testing, by detailed formal procedures or protective devices.

Where such protection is not required in flight, the protection shall be provided as part of the ground equipment.

REMARKS

For the purposes of this standard, "negative pressure" exists when the external pressure exceeds the internal pressure of the vessel.

Thin-walled pressure vessels and tanks designed for use in space vehicles are often vulnerable to very costly damage by relatively small negative pressure differentials. This problem is particularly prevalent during initial manufacture and ground testing on new programs. The intent of this standard is to have all vessels reviewed early in the program to identify those vessels susceptible to this type damage so protective measures can be taken in all phases of the vessel life cycle. The preventive measure selected for specific vessels will vary with programs and considerations of safety, initial cost of vessel, cost of protection, and time required for and cost of replacement or repair of the vessel.

Typical sources of negative pressure damage to pressure vessels include the following:

1. Premature closure of manually operated vent during draining.

2. Rupture of a service line, allowing vessel to drain without venting. Check valves in the vent line or insufficient venting through a vent not designed for this contingency has contributed to this problem.

3. Use of a vacuum hose to remove cutting chips from a service line connected to a vessel that was not vented.

4. Failure of vents to compensate for rate of descent of aircraft during air transportation.

5. Undetected leakage of internal pressure during altitude chamber testing when the chamber is repressurized

5.6 PYROTECHNICS

P-1 Pyrotechnic Devices

STATEMENT OF STANDARD

Pyrotechnic devices shall meet the requirements of JSC 62809, Human Rated Spacecraft Pyrotechnic Specification.

REMARKS

JSC 62809 is a comprehensive pyrotechnic specification that incorporates all of the pyrotechnic requirements formerly included in JSC-08080-2A and its predecessors.

For the Orion/MPCV Program the correct set of requirements for human spaceflight are defined in CxP 70199, Constellation Spacecraft Pyrotechnic Specification.

P-2 [Reserved]

P-3 [Reserved]

P-4 [Reserved]

P-5 [Reserved]

P-6 [Reserved]

P-7 [Reserved]

APPENDIX A REQUIREMENT GUIDELINES

Here are some guidelines for writing JSC-08080-2 requirements:

- Capture lessons learned and best practices for the development and operation of human spaceflight equipment
- Be complete, addressing all technical disciplines
- Be unique, referencing lessons learned and best practices from other standards (versus duplicating them)
- Be specific to JSC, capturing how JSC does business
- Include rationale when available
- Be technically correct and current

APPENDIX B REFERENCE DOCUMENTS

These documents are referenced in the Remarks section of individual requirements. The referencing requirements for each reference document are listed in parenthesis following the document name. Documents are grouped as in Section 4.5. Some of these documents also appear in Section 4.5.

40 C.F.R. 61, National Emission Standards for Hazardous Air Pollutants (NESHAP) (MP-9)

48 C.F.R. § 1852.246-73, NASA Federal Acquisition Regulations Supplement, Human Space Flight Item (1997) (G-11)

JPR 1700.1, JSC Safety and Health Handbook (MP-9)

JPR 1281.8, Product Identification and Traceability (G-22)

JPR 1281.10, Inspection and Testing (G-14)

JPR 8500.3, Serial and Lot Numbers for Certain Items of Government-Furnished Equipment (G-22)

JPR 8500.4, Engineering Drawing System Manual (G-22)

NPR 8705.2 Human-Rating Requirements for Space Systems (G-29)

JSC 18798B, Interpretations of NSTS/ISS Payload Safety Requirements (E-9)

JSC 20584, Spacecraft Maximum Allowable Concentrations for Airborne Contaminants (MP-9)

JSC 26626A, EVA Hardware Generic Design Requirements Document (F-16, F-19)

JSC 27301, Materials and Processes Selection, Control, and Implementation Plan for JSC Flight Hardware (MP-1)

JSC 49879, JSC Wire & Cable Integrity Compliance Program (E-24)

JSC 49894, Electronic Part Selection and Design Guidelines for Low Criticality Space Flight Payloads (E-7)

MEM R2, NASA Meteoroid Engineering Model (MEM) Release 2.0 – User's Guide (MS-11)

MSFC-STD-531, High Voltage Design Criteria (E-6, E-7)

NASA TM-2009-214785, Handbook for Designing MMOD Protection (MS-11)

NASA TP-2003-210788, Meteoroid/Debris Shielding (MS-11)

NASA TP-2014-217370, NASA Orbital Debris Engineering Model (ORDEM) 3.0 - User's Guide (MS-11)

NASA-STD-3001, NASA Space Flight Human-System Standard, Vol. 2, Human Factors, Habitability, and Environmental Health (E-1)

NASA-STD-6016, Standard Materials and Processes Requirements for Spacecraft (G-5)

SSP 51700, Payload Safety Policy and Requirements for the International Space Station (E-9)

MIL-HDBK-340A, Test Requirements for Launch, Upper-Stage, and Space Vehicles, Vol I, Baselines (G-14)

MIL-PRF-39006, Capacitor, Fixed, Electrolytic (Nonsolid Electrolyte), Tantalum, Established Reliability, General Specification for (E-7)

MIL-STD-1686, Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (E-20)

AIAA S-080-1998, Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components (MP-11)

AIAA S-081A-2006, Space Systems – Composite Overwrapped Pressure Vessels (COPVs) (MP-11)

ANSI / ESD S20.20, For the Development of an ESD Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (E-20)

ANSI C63.16, American National Standard Guide for Electrostatic Discharge Test Methodologies and Criteria for Electronic Equipment (E-20)

ASTM Manual 36, Safe Use of Oxygen and Oxygen Systems: Handbook for Design, Operation, and Maintenance (F-26)

IEC 60601-1, [Safety Standard for] Medical Electrical Equipment (E-13)

IEC 61000-4-2, Electromagnetic Compatibility (EMC), Testing and Measurement Techniques, Electrostatic Discharge Immunity Test (E-20)

IEEE STD C62.38, IEEE Guide on ESD: ESD Withstand Capability Evaluation Methods (for Electronic Equipment Subassemblies) (E-20)