Materials and Processes Selection, Control, and Implementation Plan for JSC Flight Hardware

Engineering Directorate

Structural Engineering Division

November 2005

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center

PREFACE

This Materials and Processes Selection, Control, and Implementation Plan defines the implementation of the materials and processes (M&P) requirements for all new flight hardware developed by the NASA Johnson Space Center (JSC). Space Shuttle GFE, International Space Station GFE, Constellation Program GFE, and JSC-developed payload hardware are to be designed and manufactured in accordance with this plan. The plan describes the implementation of the M&P requirements in JSC 49774A, Manned Spacecraft Requirements for Materials and Processes; SSP 30233, Space Station Requirements for Materials and Processes; SE-R-0006, General Specification Space Shuttle System Requirements for Materials and Processes; and JPR 8080.5A, JSC Design and Procedural Standards.

This plan defines the responsibilities of the JSC Materials & Processes Branch and JSC contractors for flight hardware M&P requirements implementation and verification, and includes modifications of Space Shuttle, ISS, and Crew Exploration Vehicle requirements for flight hardware. The contents of this document are consistent with the tasks performed for the ISS as defined in SSP 41000, System Specification for the International Space Station.

This flight hardware Materials and Processes Selection, Control, and Implementation Plan shall be implemented on all new contracts for the procurement of JSC flight hardware, and shall be included in existing contracts through contract changes. This document is under the control of the JSC Structural Engineering Division (JSC Code ES), and any changes or revisions shall be approved by the same organization.

MATERIALS AND PROCESSES SELECTION, CONTROL, AND IMPLEMENTATION PLAN FOR JSC FLIGHT HARDWARE

Signature on File
Prepared By: ES4/Michael D. Pedley

Signature on File
Approved By: ES4 /Bradley S. Files
Chief, Materials and Processes Branch

REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version (Materials Control Plan for JSC Space station Government-Furnished Equipment)	3/96
A	Retitled and revised to address all JSC flight hardware; numerous minor technical revisions, including reference document updates	7/16/99
B	Added requirement for oxygen system hardware exposure to pressurized oxygen before flight (Section 5.1.4.1)	3/9/00
C	Added ISS alcohol usage control (VUAs); added requirements for precision-cleaned hardware; revised author; incorporated administrative changes for division reorganization; numerous minor technical revisions, including reference document updates	1/29/02
D	Clarified requirement on low earth orbit environment survivability (Section 5.3.7); added related requirement on external use of silver-plated fasteners (Section 5.6.5.2)	2/26/02
E	Revised and retitled document to make compliant with JSC 49774A, Standard Manned Spacecraft Requirements for Materials and Processes	11/05

Verify correct version before use

TABLE OF CONTENTS

APPENDICES

APPENDIX **PAGE**

1.0 INTRODUCTION

This plan documents the methods by which the NASA Johnson Space Center (JSC) will implement materials and processes control for flight hardware developed by JSC. The plan addresses the detailed requirements in JSC 49774A, Standard Manned Spacecraft Requirements for Materials and Processes, as required by JPR 8080.5A, JSC Design and Procedural Standards. Flight hardware under JSC control shall be designed and fabricated in accordance with this plan. The plan does not apply to program hardware developed by a program contractor as contractor-furnished equipment (CFE).

This plan also implements for JSC flight hardware the Materials and Processes (M&P) requirements contained in SSP 30233, Space Station Requirements for Materials and Processes and SE-R-0006, General Specification Space Shuttle System Requirements for Materials and Processes. The plan tailors the requirements in JSC 49774A, SSP 30233, and SE-R-0006 for JSC in-house hardware; in the event of a conflict between these three documents and this implementation plan, this plan shall take precedence.

Note: Exceptions to JSC 49774A are identified in Appendix F.

This document shall be incorporated as a general materials control specification in end-item specifications for JSC flight hardware procurements. It shall be implemented on all new contracts for procurement of JSC flight hardware, and shall be included in existing contracts through contract changes.

Note: This plan does not address fracture control. Fracture control for JSC flight hardware structures, including pressure vessels, is implemented in accordance with JSC 25863A, Fracture Control Plan for JSC Flight Hardware. However, the Materials and Fracture Control Certification generated to verify compliance with this plan (see Section 4.6) includes certification of compliance with fracture control requirements and any flight limitations determined by the fracture control analysis. The JSC Materials & Processes Branch monitors and reviews the fracture control program and evaluates the fracture control analysis.

1.1 SCOPE

This document defines the implementation of the materials and processes (M&P) requirements for all new flight hardware developed by the NASA Johnson Space Center (JSC), including International Space Station GFE, Space Shuttle GFE, Constellation Program GFE (including GFE for the Crew Exploration Vehicle (CEV)), and payload hardware. Ground Support Equipment (GSE) supplied as JSC-controlled hardware shall comply with this plan where GSE hardware can adversely affect flight hardware.

2.0 DOCUMENTS

The following documents include specifications, standards, handbooks, and other special publications. They are applicable to the extent specified herein. In the event of a conflict between these documents and this plan, this plan shall take precedence.

2.1 APPLICABLE DOCUMENTS

2.1.1 VOLUNTARY CONSENSUS STANDARDS

DOCUMENT NO.	TITLE
ANSI EOS/ESD S20.20	Development of an Electrostatic Discharge Control Program: Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
Reference	5.7.11
ANSI/IPC-J-STD-001C	Requirements for soldered electrical and electronic assemblies
References	5.7.6.2, 5.7.8
ASTM-E595-93	Total Mass Loss and Collected Volatile Condensable Materials From Outgassing In A Vacuum Environment
Reference	5.3.7
AWS C-3.3-2002	Design, Manufacture, and Inspection of Critical Brazed Components, Recommended Practices for
Reference	5.4.5
AWS C-3.4-1999	Torch Brazing
Reference	5.4.5
AWS C-3.5-1999	Induction Brazing
Reference	5.4.5
AWS C-3.6-1999	Furnace Brazing
Reference	5.4.5
AWS C-3.7-1999	Aluminum Brazing

Reference	5.3.5
SAE-AMS-H-6875A	Heat Treatment Of Steel Raw Materials
Reference	5.2.2.1
SAE-AMS-STD-401	Sandwich Constructions and Core Materials; General Test Methods
Reference	5.6.2
SAE-AMS-STD-1595	Qualification Of Aircraft, Missile and Aerospace Fusion Welders
Reference	5.4.4
SAE-AMS2175	Castings, Classification and Inspection Of
Reference	5.4.2
SAE-AMS 2488D	Anodic Treatment - Titanium & Titanium Alloys, Solution pH 13 or Higher
Reference	5.2.3.3
SAE-AMS 2491D	Surface Treatment, Polytetrafluoroethylene, Preparation for Bonding
Reference	5.7.7
SAE-AMS 2759C	Heat Treatment of Steel Parts, General Requirements
Reference	5.2.2.1
SAE-AMS 2759/9B	Hydrogen Embrittlement Relief (Baking) of Steel Parts
Reference	5.2.2.1
SAE-AMS 2770G	Heat Treatment of Wrought Aluminum Alloy Parts
Reference	5.2.1
SAE-AMS 2772C	Heat Treatment of Aluminum Alloy Raw Materials
Reference	5.2.1

SAE-AMS 2774A	Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts
Reference	5.2.9.1
SAE-AMS-H-81200A	Heat Treatment of Titanium and Titanium Alloys.
Reference	5.2.3.1
SAE-AS7928	Terminals, Lug: Splices, Conductors: Crimp Style, Copper, General Specification For
Reference	5.7.9
IPC-CM-770E	Component Mounting Guidelines For Printed Boards.
Reference	5.7.6.2
IPC-2221A	Generic Standard on Printed Board Design
Reference	5.7.5
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards
Reference	5.7.5
IPC-6011	Generic Performance Specification for Printed Boards
Reference	5.7.5
IPC-6012B	Quality and Performance Specification for Rigid Printed Boards
Reference	5.7.5

2.1.2 GOVERNMENT AND MILITARY STANDARDS

DOCUMENT NO.	TITLE
DOT/FAA/AR-MMPDS-01	Metallic Materials Properties Development and Standardization (MMPDS)
Reference	4.5, 5.3.4
MIL-H-81200B	Heat Treatment of Titanium and Titanium Alloys
Reference	5.2.3.1
MIL-HDBK-17/1F,2F,3F	Polymer Matrix Composites

Reference	4.5
MIL-HDBK-6870A	Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts
Reference	5.5.1
MIL-PRF-31032A	Printed Circuit Board/Printed Wiring Board, General Specification for
Reference	5.6.5
MIL-HDBK-454A	General Guidelines for Electronic Equipment
Reference	5.3.9
MIL-STD-810F	Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
Reference	5.3.9
MIL-STD-889B	Dissimilar Metals
Reference	5.6.4

2.1.3 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DOCUMENT NO.	**TITLE**
NASA-STD-6001 (formerly NHB-8060.1C)	Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion
References	5.1, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5
NSTS 1700.7B (including ISS Addendum)	Safety Policy and Requirements for Payloads Using the Space Transportation System
References	3.4, 5.1.3
NASA-TM-86556	Lubrication Handbook For the Space Industry, Part A: Solid Lubricants, Part B: Liquid Lubricants
Reference	5.3.5

NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
References	5.7.3, 5.7.9, 5.7.10
NASA-STD-8739.5	Fiber Optic Terminations, Cable Assemblies, and Installation
References	5.7.4
NASA-STD-8739.1	Workmanship Standard for Surface Mount Technology
References	5.7.6.1
NASA-STD-8739.2	Requirement for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
References	5.7.6.1, 5.7.6.2

2.1.4 JOHNSON SPACE CENTER / SPACE STATION PROGRAM

DOCUMENT NO.	TITLE
JSC 20584	Spacecraft Maximum Allowable Concentrations for Airborne Contaminants
Reference	5.1.2
JSC 25863 (Latest revision)	Fracture Control Plan for JSC Flight Hardware
Reference	1.0
JPR 8080.5	JSC Design and Procedural Standards Manual
References	1.0 and 6.0
JPR 8500.4	Engineering Drawing System Manual: Drawing Format, Requirements, and Procedures
References	3.0, 4.2
SE-R-0006D	Space Shuttle Program Requirements for Materials and Processes
References	3.1.1, 3.4

SSP 30233G	Space Station Requirements for Materials and Processes
Reference	3.1.1
SSP 30234F	Instructions for Preparation of Failure Modes and Effects Analysis and Critical Items List for Space Station
References	3.2.1, 3.2.2
SSP 30426D	Space Station External Contamination Control Requirements
Reference	5.3.7
SSP 50431A	Space Station Program Requirements for Payloads
Reference	3.2.1

2.1.5 MARSHALL SPACE FLIGHT CENTER

DOCUMENT NO.	TITLE
MSFC-SPEC-250A	Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for
Reference	5.6.4
MSFC-SPEC-445A	Adhesive Bonding, Process and Inspection, Requirements for
Reference	5.4.3
MSFC-SPEC-504C	Welding, Aluminum Alloys
References	5.4.4.3, 5.4.4.5
MSFC-STD-3029A (formerly MSFC-SPEC-522B)	Guidelines for Selection of Metallic Materials for Stress-Corrosion-Cracking Resistance in Sodium Chloride Environments
Reference	5.6.3
MSFC-SPEC-560A	The Fusion Welding of Steels, Corrosion and Heat Resistant Alloys
Reference	5.4.4.4

MSFC-STD-557A	Threaded Fasteners, 6 Al-4V Titanium Alloy, Usage Criteria for Spacecraft Applications
Reference	5.6.5
MSFC-SPEC-766	Specification: Fusion Welding Titanium and Titanium Alloys
Reference	5.4.4.5
MSFC-PROC-404A	Procedure: Gases Drying and Preservation, Cleanliness Level and Inspection Methods
Reference	5.1.4.1

2.1.6 JOHNSON SPACE CENTER MATERIALS AND PROCESSES BRANCH

PRC-0001	Manual Arc Welding of Aluminum Alloy Flight Hardware
Reference	5.4.4.3
PRC-0004	Manual Arc Welding of Titanium Alloy Flight Hardware, Process Specification for
Reference	5.4.4.5
PRC-0006	Manual Arc Welding of Steel and Nickel Alloy Flight Hardware
Reference	5.4.4.4
PRC-0008	Qualification of Manual Arc Welders, Process Specification for
Reference	5.4.4.5
PRC-1001	Adhesive Bonding
Reference	5.4.3
PRC-5002	Passivation and Pickling of Metallic Materials
Reference	5.6.4.1
PRC-6001	Composite Laminate Prepreg. Parts, Process Specification for the Manufacture of
Reference	5.3.4

PRC-6002	Sandwich Structures, Process Specification for the Assembly of
Reference	5.3.4
PRC-6003	Trimming and Drilling of Composites, Process Specification for
Reference	5.3.4
PRC-6501	Ultrasonic Inspection of Composites, Process Specification for the
Reference	5.3.4
PRC-7001	Soldering of Electrical Components
Reference	5.7.8
PRC-7002	Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
References	5.7.6.1 and 5.7.6.2
PRC-7003	Electrical Cables, Wiring, and Harnesses
Reference	5.7.3
PRC-7005	Printed Circuit Boards and Assemblies
Reference	5.7.5
ES SOP-004.5	Control of Weld and Braze Filler Materials, Electrodes, and Fluxing Materials
Reference	5.4.4.2
ES SOP-007.5	Materials and Processes Drawing Approval
Reference	4.1.2, 4.6.1
ES SOP-007.6	Materials and Fracture Control Certification
Reference	4.6

2.2 REFERENCE DOCUMENTS

DOCUMENT NO.	TITLE
ASTM G63-99	Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service
Reference	5.1.4
ASTM G88-90	Standard Guide for Designing Systems for Oxygen Service
Reference	5.1.4
ASTM G94-92	Standard Guide for Evaluating Metals for Oxygen Service
Reference	5.1.4
JSC 29353	Flammability Configuration Analysis for Spacecraft Applications
Reference	5.1.1
GSFC Supplement S-312-P003	Process Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses,
Reference	5.7.5

3.0 REQUIREMENTS IMPLEMENTATION RESPONSIBILITIES

Primary responsibilities for implementing the requirements in this plan are divided between the JSC Materials & Processes Branch and JSC contractors as outlined in this section. These and other responsibilities are discussed in further detail in other sections of this document. JSC contractors are divided into in-house contractors that design and fabricate flight hardware at JSC, using the JSC engineering drawing release system per JPR 8500.4, and outside contractors that design and fabricate flight hardware for JSC in accordance with a contractor drawing release system

3.1 "PLAN" AND "NON-PLAN" CONTRACTORS

The terms "plan" and "non-plan" JSC contractors are used only for the purposes of this plan, as follows:

3.1.1 "PLAN" CONTRACTOR

A "plan" flight hardware contractor is defined as a contractor that has a Materials and Processes Selection, Control, and Implementation Plan approved by the JSC Materials & Processes Branch as meeting the requirements of either this control plan or the applicable program materials and processes requirements document (such as JSC SE-R-0006 for Space Shuttle, SSP 30233 for ISS, and JSC 49774A for CEV). Only a few major contractors are required by contract by the JSC Materials & Processes Branch to provide a Materials and Processes Selection, Control, and Implementation Plan. (Refer to Section 4.1 of this plan for information on Materials and Processes Selection, Control, and Implementation Plans.) Plan contractors (and not the JSC Materials & Processes Branch) are responsible for certifying their flight hardware for materials and processes to JSC requirements, unless otherwise specified in the Materials and Processes Selection, Control, and Implementation Plan and/or the contract.

3.1.2 "NON-PLAN" CONTRACTOR

A "non-plan" flight hardware contractor is defined as a contractor that neither has, nor is required by contract to develop, a Materials and Processes Selection, Control, and Implementation Plan approved by the JSC Materials & Processes Branch. Consequently, a non-plan contractor cannot provide final materials certification for JSC flight hardware. The JSC Materials & Processes Branch shall provide Materials and Fracture Control Certification for JSC flight hardware provided by non-plan contractors.

3.2 NEW FLIGHT HARDWARE

Basic M&P responsibilities for new flight hardware are summarized in this section. Recertification of existing Shuttle and payload flight hardware provided to support ISS is addressed in section 3.4 of this plan. Further details on these and other M&P responsibilities are discussed in other sections of this plan.

3.2.1 JSC PLAN CONTRACTOR FLIGHT HARDWARE

JSC plan contractor flight hardware refers to flight hardware developed for JSC by a contractor with an approved Materials and Processes Selection, Control, and Implementation Plan (per Section 3.1.1). The plan contractor shall perform the following basic M&P functions:

- provide drawing review and approval for M&P

- provide a Materials Identification and Usage List (MIUL) (or an electronic searchable parts list) for all Criticality category 1 flight hardware. (Criticality categories are defined in SSP 30234.) Criticality categories 1R, 1S, 1SR and 1P are not included.

  Notes:

  1. The MIUL is required for payload criticality 1 hardware only if the payload is Class A or Class B per SSP 50431, Space Station Program Requirements for Payloads (or equivalent classes for other program payloads)

  2. For selected plan contractors, additional MIUL requirements may be specified in the contract.

- generate and approve Materials Usage Agreements (MUAs) and water-soluble Volatile Organic Compound Uasge Agreements (VUAs). However, final MUA/VUA approval shall be by the JSC Materials and Processes Branch.

- provide materials certification as specified in the Materials and Processes Selection, Control, and Implementation Plan and/or the contract.

3.2.2 JSC NON-PLAN CONTRACTOR FLIGHT HARDWARE (& FLIGHT HARDWARE DESIGNED BY JSC EMPLOYEES)

The above two types of flight hardware in the title are grouped together in this section because both types of flight hardware have M&P functions which shall be performed by the JSC Materials & Processes Branch, as shown below:

- provide drawing review and approval for M&P. This applies to drawings generated by JSC employees, and to most of the non-plan contractors who generate drawings in the "JSC engineering drawing system", with the following two exceptions:

  (a) A few non-plan contractors who generate flight hardware drawings in the JSC engineering drawing system have been selected by the JSC Materials & Processes Branch to sign their own JSC drawings for M&P (and also generate their own MIULs and MUAs).

  (b) The JSC Materials & Processes Branch does not approve contractor drawings generated per a contractor's own engineering drawing system, but does review such drawings to the extent necessary to insure compliance with M&P requirements.

- provide a Materials Identification and Usage List (MIUL) (or an electronic searchable parts list) for Criticality category 1 flight hardware.

  Notes:

  1. The MIUL is required for payload criticality 1 hardware only if the payload is Class A or Class B per SSP 50431, Space Station Program Requirements for Payloads (or equivalent classes for other program payloads)
  2. For selected plan contractors, additional MIUL requirements may be specified in the contract.

- provide assistance to flight hardware managers in the generation of Materials Usage Agreements (MUA)

- approve MUAs

- provide Materials and Fracture Control Certification

3.3 MATERIALS AND PROCESSES RECIPROCAL AGREEMENTS

NASA Centers (or other space agencies) with reciprocal agreements for Materials and Processes with JSC shall generate MUAs and materials certifications on hardware that they manage or manufacture. These reciprocal or intercenter agreements involve acceptance of each other's materials certifications and MUAs. Currently, NASA Centers that have reciprocal agreements with JSC include Glenn Research Center, Marshall Space Flight Center, Jet Propulsion Laboratory, and Goddard Space Flight Center. NASA also has M&P reciprocal agreements with the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the Russian space companies, Energia and Khrunichev. Copies of these agreements can be obtained from the JSC Materials & Processes Branch.

3.4 SPACE SHUTTLE GFE FOR ISS

JSC Shuttle GFE for ISS include JSC GFE provided by the Space Shuttle Vehicle Engineering Office and the EVA Project Office to support the ISS, and JSC Shuttle Payload GFE provided by the responsible JSC payload organizations for the ISS. JSC Shuttle GFE hardware certified prior to the release of this document is certified by the JSC Materials & Processes Branch as meeting the requirements of SE-R-0006, Space Shuttle Program Requirements for Materials and Processes, and NSTS 1700.7, Safety Policy and Requirements for Payloads Using the Space Transportation System. For previously approved hardware built to SE-R-0006 and NSTS 1700.7 and supplied as GFE to the ISS Program, Materials Usage Agreements (including Materials Stowage Codes) shall be reviewed by the JSC Materials & Processes Branch, or plan contractor, as applicable, to verify compliance with this plan.

4.0 GENERAL REQUIREMENTS

Materials used in the fabrication and processing of flight hardware shall be selected by considering the worst-case operational requirements for the particular application and the design engineering properties of the candidate materials. The operational requirements shall include, but not be limited to, operational temperature limits, loads, contamination, life expectancy, moisture or other fluid media exposure, and vehicle related induced and natural space environments. Properties that shall 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, and susceptibility to electrostatic discharge (ESD) and contamination. Conditions that could contribute to deterioration of hardware in service shall receive special consideration. Non-flight materials used in processing and testing of flight hardware shall not cause degradation of the flight hardware.

4.1 MATERIALS AND PROCESSES, SELECTION, CONTROL, AND IMPLEMENTATION PLAN

The contractor shall provide a Materials and Processes Selection, Control, and Implementation Plan when specified in the contract data requirements. This plan shall document the degree of conformance and method of implementation for each requirement in this standard, identifying applicable in-house specifications used to comply with the requirement. It shall also describe the methods used to control compliance with these requirements by subcontractors and vendors. The Materials and Processes Selection, Control, and Implementation Plan, upon approval by the procuring activity shall become the Materials and Processes implementation document used for verification. Only a few major contractors are required by contract to provide a Materials and Processes Selection, Control, and Implementation Plan. All other JSC flight hardware contractors not required by their contract to provide a Materials and Processes Selection, Control, and Implementation Plan shall use this document as their Materials and Processes Selection, Control, and Implementation Plan instead of developing a separate contractor plan.

The Materials and Processes Selection, Control, and Implementation Plan shall include the following:

4.1.1 COORDINATION, APPROVAL, AND TRACKING

The Materials and Processes Selection, Control, and Implementation Plan shall identify the method of coordinating, approving, and tracking all engineering drawings, engineering orders, and other documentation that establishes or modifies materials and/or processes usage.

4.1.2 APPROVAL SIGNATURE

The Materials and Processes Selection, Control, and Implementation Plan shall include a requirement that each engineering design drawing and drawing change be approved and signed by the responsible Materials and Processes organization prior to release. For designs produced by automated Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) systems, an equivalent level of review and approval shall be defined. The M&P drawing approval process shall comply with ES SOP-007.5, Materials and Processes Drawing Approval.

For non-plan contractors, the JSC Materials & Processes Branch shall review drawings to the extent necessary to insure compliance to M&P requirements.

4.1.3 PROCESS CONTROLS

The Materials and Processes Selection, Control, and Implementation Plan shall identify all process specifications used to implement specific requirements in this standard. All materials processes used in manufacturing shall be documented in process specifications and all applicable process specifications shall be identified on the engineering drawing. Each processing step in the process specification shall be identified in a level of detail that ensures the process is sufficiently repeatable to produce a consistent and reliable product. Qualification testing shall be conducted to demonstrate the repeatability of all processes where the quality of the product cannot be verified by subsequent monitoring or measurement. Process specifications shall be made available to support design review activities. Deviations from process specifications identified in the Materials & Processes Selection, Control, and Implementation Plan shall require approved MUAs per section 3.3 of this standard.

JSC in-house hardware (designed and fabricated using the JSC engineering drawing release system per JPR 8500.4) shall be designed and fabricated in accordance with JSC internal process specifications approved by the Materials & Processes Branch. These specifications (designated PRC-xxxx) are available on the JSC Quality Management System web page at http://stic.jsc.nasa.gov/dbase/iso9000/docs/ES/master.htm.

4.2 MATERIALS AND PROCESSES USAGE DOCUMENTATION

Materials and processes usage shall be documented in an electronic searchable parts list or separate electronic searchable Materials Identification and Usage List (MIUL) for all Criticality 1 flight hardware, except as specified in section 3. The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design. The system used shall be an integral part of the engineering configuration control/release system. A copy of the stored data shall be provided to NASA in a form compatible with the Materials and Processes Technical Information System (MAPTIS).

Note: For non-plan contractors, the JSC Materials & Processes Branch must be notified by CDR of all Criticality 1 flight hardware for which it is responsible for providing the MIUL and Materials and Fracture Control Certification (as well as any changes "to or from" a Criticality 1 status which might occur after CDR).

The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design.

The parts list or MIUL for Criticality 1 flight hardware shall identify the following applicable information:

- Detail drawing and dash number

- Next assembly and dash number
- Change letter designation
- Drawing source
- Material form
- Material manufacturer
- Material manufacturer's designation
- Material specification
- Process specification
- Environment
- Weight
- Material code
- Standard/commercial part number
- Contractor
- System
- Subsystem
- Maximum temperature
- Minimum temperature
- Fluid type
- Surface Area
- Associate contractor number
- Project
- Document title
- Criticality
- Line number
- Overall evaluation
- Overall Configuration test
- Maximum pressure
- Minimum pressure
- Test MUA Document
- Cure codes

The Materials and Processes Technical Information System (MAPTIS) shall be consulted to obtain material codes and ratings for materials, standard and commercial parts and components. New material codes shall be assigned by NASA Marshall Space Flight Center (MSFC).
A procedure shall be established to ensure that all vendor designed, off-the-shelf, and vendor furnished items are covered by the M&P requirements of this document. Where batch/lot testing is required, traceability of specific test reports for batch/lot used shall be provided. Wire, cable, and exposed surfaces of connectors shall meet the requirements of this document and be reported on the MIUL. All other standard and nonstandard Electrical, Electronic, and Electromechanical (EEE) Parts shall be exempt from these requirements and reporting on the MIUL. Materials used in hermetically sealed electronic containers are exempt from inclusion in the MIUL. Ground Support Equipment which is not used within 3 feet of flight hardware or does not have any operational, physical, or fluid system interfaces is exempt from inclusion in the MIUL.

A periodic review of plan contractors shall be conducted by the JSC Materials & Processes Branch to ensure compliance with Material and Processes requirements.

4.3 MATERIALS USAGE AGREEMENTS

The use of materials and processes that do not comply with the technical requirements of this standard may be technically acceptable if hardware reliability and vehicle safety are not affected. Material Usage Agreements (MUAs) shall be submitted for all materials and processes that are technically acceptable but do not meet the technical requirements of this standard, as implemented by the approved Materials and Processes Selection, Control, and Implementation Plan. A tiered MUA system with three categories shall be used.

4.3.1 CATEGORY I MUAS

Category I MUAs are those that involve material/processes usage that could affect the safety of the mission, crew, or vehicle or affect the mission success, but must be used for functional reasons. Category I flight hardware MUAs shall be approved by the hardware manager, the JSC Materials & Processes Branch Chief, and the applicable Program Office.

4.3.2 CATEGORY II MUAS

Category II MUAs are those that involve material/processes usage that fails a screening of Material and Processes requirements and is not considered a hazard in its use application but for which no Category III rationale code exists. Category II MUAs shall be approved by the hardware manager and the JSC Materials & Processes Branch Chief. (On selected MUAs, the Astronaut Office or Crew Training Office may also be required to concur.)

4.3.3 CATEGORY III MUAS

Category III MUAs are those that involve materials or processes that have not been shown to meet these requirements but have an approved rationale code listed in Appendix E. They are evaluated and determined to be acceptable at the configuration/part level.

The acceptance rationale is approved by the Materials and Fracture Control Certification. The rationale code shall be recorded in the backup information form for the JSC Materials and Fracture Control Certification, which is maintained by the JSC Materials & Processes Branch. (If an MIUL is required per Section 4.2, the rationale code shall also be reported in the MIUL, or electronic data system.)

4.3.4 MATERIAL USAGE AGREEMENT SUBMITTAL

Category I and II MUAs shall be submitted as appropriate for each usage of a material or process that does not meet the requirements of this document. These MUAs shall be approved as indicated in the categories above. The MUA shall include sufficient information to demonstrate that the application is technically acceptable. A typical MUA form is given in Appendix D page D-1.

Deliverable Ground Support Equipment (GSE) with operational, physical, or fluid system interfaces or which is used within 3 feet of flight hardware shall require the submittal of an MUA only when the requirements of NASA-STD-6001 or the Stress Corrosion Cracking requirements of paragraph 5.6.3 are not met, or cannot be accepted with a Category III MUA.

4.4 VOLATILE ORGANIC COMPOUND USAGE AGREEMENTS

Volatile Organic Compound Usage Agreements (VUAs) shall be submitted for hardware containing the following water-soluble volatile organic compounds (Section 5.3.11):

> Methanol; ethanol; isopropyl alcohol; n-propyl alcohol; n-butyl alcohol; acetone; ethylene glycol; propylene glycol.

The restrictions on water-soluble volatile organic compounds apply only to hardware used in the ISS habitable environment and hardware used in the Space Shuttle orbiter while docked to ISS with the hatch open. VUAs are not required for hardware used in the orbiter at other times.

A tiered VUA system with two categories shall be used. VUA forms shall be used for both categories. The standard JSC VUA form is shown in Appendix B.

4.4.1 CATEGORY I VUAS -- Category I VUAs are those that involve water-soluble volatile organic compound usage that could affect the safety of the mission, crew, or vehicle or affect the mission success, but must be used for functional reasons. Category I flight hardware VUAs shall be approved by the hardware manager, the JSC Materials & Processes Branch Chief, and the responsible ISS program control board (Vehicle Control Board, GFE Control Board, Payloads Control Board, or equivalent).

4.4.2 CATEGORY II VUAS -- Category II VUAs are those that involve water-soluble volatile organic compound usage that is not considered a hazard to safety or mission success in its use application. Category II VUAs shall be approved by the hardware manager and the JSC Materials & Processes Branch Chief. Category II VUAs are permitted only for those applications that do not raise the gas-phase water-soluble volatile organic compound generation rate significantly above the background level that results from normal materials offgassing.

4.4.3 VOLATILE ORGANIC COMPOUND USAGE AGREEMENT SUBMITTAL -- Category I and II VUAs shall be submitted as appropriate for each usage of a water-soluble volatile organic compound that does not meet the requirements of this document. These VUAs shall be signed by a member of the contractor M&P organization and approved as indicated in the categories above. The information required on the VUA form shall be provided as specified in the contract data requirement for the category I and II MUAs and must include sufficient information to assess these usages. A typical VUA form is given in Appendix D page D-3.

The VUA shall be submitted separately from any MUA submitted for the same hardware. Documentation of a VUA in the applicable MIUL is not required.

4.5 MANUFACTURING PLANNING

Materials and Processes organizations shall participate in manufacturing planning to ensure compliance with materials and process requirements.

4.6 RAW MATERIALS CERTIFICATION AND TRACEABILITY

All parts or materials used in manufacturing JSC flight hardware shall be certified as to composition and properties as identified by the procuring document. Noncritical commercial off-the-shelf hardware is exempted from this requirement. Materials used in critical applications such as life-limited materials, safety and fracture critical parts shall be traceable through all critical processing steps and the end-item application; processing records shall be retained for the life of the hardware.

4.7 MATERIAL DESIGN ALLOWABLES

Values for allowable mechanical properties of structural materials in their design environment shall be taken from DOT/FAA/AR-MMPDS-01, Metallic Materials Properties Development and Standardization (MMPDS) or MIL-HDBK-17B, Polymer Matrix Composites. When high-strength metallic materials are heat treated, the adequacy of the heat treatment process shall be verified by test (see Section 5.2).

Material "B" allowable values shall not be used except in redundant structure in which the failure of a component would result in a safe redistribution of applied load-carrying members.

DOT/FAA/AR-MMPDS-01 material ”S” allowables may be used in non-critical applications; the use of “S” allowables in primary structure or fracture critical hardware requires an approved materials usage agreement.

When design allowables for mechanical properties of new or existing materials are not available, they shall be determined by analytical methods described in DOT/FAA/AR-MMPDS-01. The hardware developer shall develop a plan describing their philosophy on how they will determine what material design properties will be used, and if those properties do not exist, how they will be developed including, but not limited to the statistical approaches to be employed. All mechanical and physical property data shall be made available to the JSC Materials & Processes Branch.

4.8 MATERIALS AND FRACTURE CONTROL CERTIFICATION PROCESS

Materials and Fracture Control Certification is required to document that hardware has been evaluated for compliance with the M&P requirements of this document. The Materials and Fracture Control Certification process includes drawing review and approval, and issuance of a Materials and Fracture Control Certification. The Materials and Fracture Control Certification process shall comply with ES SOP-007.6, Materials and Fracture Control Certification.

A Materials and Fracture Control Certification shall be issued by the JSC Materials & Processes Branch, or plan contractor, as applicable, after satisfactory completion of required materials analysis and/or testing, drawing review, fracture control analysis, MUAs, and VUAs. The Materials and Fracture Control Certification shall identify any MUAs or VUAs applying to the hardware and the reason for each MUA (use of flammable materials, stress corrosion sensitive materials, etc.). The Materials and Fracture Control Certification shall also indicate the vehicle locations (environments) for which the hardware is approved, any flight limitations, and any coded stowage conditions agreed to. A backup information form to the JSC Materials and Fracture Control Certification contains additional details, and is maintained within the JSC Materials & Processes Branch. Use of this hardware in a different application (even in the same environment) may require different materials to be used and/or a new Materials and Fracture Control Certification. A copy of the JSC Materials & Processes Branch Materials and Fracture Control Certification form is shown in Appendix C.

Plan contractors may use their own form, with the following information shown as a minimum:

(a) Top assembly drawing number

(b) Applicable M&P requirements documents

(c) Location / environment certified for

(d) Any MUAs or VUAs

(e) Any flight, EVA, or other limitations

4.8.1 M&P DRAWING APPROVAL

M&P approval is required for JSC flight hardware drawings, either by the JSC Materials & Processes Branch, or the plan contractor, as applicable. The M&P drawing approval process shall comply with ES SOP-007.5, Materials and Processes Drawing Approval. The JSC Materials & Processes Branch signature on drawings provides only "preliminary approval" for fabrication, pending the resolution of any open issues, such as toxicity, vacuum outgassing, or flammability testing, MUA approval, fracture control analysis, etc. (Contractors may choose to withhold their M&P signature until all materials issues have been resolved.) The JSC Materials & Processes Branch signature on drawings does "not" constitute Materials and Fracture Control Certification or final materials approval of the hardware. This is accomplished only through a formal Materials and Fracture Control Certification.

Note: The list of personnel approved to sign JSC Engineering Drawings for M&P is maintained and controlled by the JSC Materials & Processes Branch. In-house contractors and other personnel may be authorized by the Materials & Processes Branch to sign for M&P. Authorization will be in accordance with ES SOP-007.5.

4.8.2 CERTIFICATION OF NEW FLIGHT HARDWARE

For new flight hardware, a Materials and Fracture Control Certification issued by the JSC Materials & Processes Branch, or plan contractor, as applicable, shall include all top assembly part numbers and their dash numbers. Parts classified as subassemblies shall not be identified in the certification.

4.8.3 CERTIFICATION OF MODIFIED FLIGHT HARDWARE

JSC hardware that is modified by drawing change notices (DCNs) that do not change the top assembly dash number shall be approved by a Materials signature on the DCN; the Materials and Fracture Control Certification shall not be revised. When drawing changes result in the top assembly dash number being changed, a new Materials and Fracture Control Certification shall be issued.

When drawing changes result in the part number being changed or the dash number being rolled, but the changes have no effect on the rationale for MUAs applicable to the hardware, the revised part number may be redlined into the MUA, and the MUA will not be formally revised.

4.8.4 CERTIFICATION OF OFF-THE-SHELF (OTS) HARDWARE

The statement of work and/or procurement request for OTS hardware shall require identification of materials contained in off-the-shelf hardware, wherever practical and cost effective. When detailed materials information for OTS hardware is not available, OTS hardware shall be evaluated by sufficient analysis and/or testing in configuration as required to provide for Materials and Fracture Control Certification. Criticality 3 OTS hardware shall be evaluated only for compliance with M&P safety requirements (flammability, toxic offgassing, etc.) and for compatibility with the flight vehicle (normally limited to vacuum outgassing contamination).

5.0 DETAILED REQUIREMENTS

Deviations from the detailed requirements in this section require an approved MUA documenting the rationale for acceptability in the specific application.

Note: Materials and processes selection requires a tradeoff between the strengths and weaknesses of candidate materials. Materials and processes that deviate from the detailed requirements in this section are frequently the best overall choice for an application, provided that the deviations are acceptable in that application. In general, materials and processes that do not meet these detailed requirements are unacceptable for an application only if the deviations are unacceptable in that application.

5.1 FLAMMABILITY, OFFGASSING, AND COMPATIBILITY REQUIREMENTS

Materials shall meet the requirements of NASA-STD-6001, Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments That Support Combustion as described below.

5.1.1 FLAMMABILITY CONTROL

Flammability control shall be based on using materials that are nonflammable or self-extinguishing when tested by NASA-STD-6001, Test 1; testing shall not be required for ceramics and metal oxides. Test 2 (Heat and Visible Smoke Release Rates) of NASA-STD-6001 is not required. If flammable materials must be used, flammability control shall be based on adequate separation of flammable materials in configuration to preclude fire propagation paths. Guidelines for hardware flammability assessment can be found in JSC 29353, Flammability Configuration Analysis for Spacecraft Applications.

Material flammability ratings and test data are given in the MAPTIS database. The thickness specified for flammability includes the minimum thickness in which the material was tested. Thinner materials may not have the same rating, and may need to be tested. Similarly, the oxygen concentration specified is that in which the material was tested. MAPTIS flammability test data at other oxygen concentrations may be used only if the test data were obtained at a higher oxygen concentration than the maximum use oxygen concentration.

If flammable materials must be used, they should, if possible, be protected by covering with nonflammable materials, such as nonflammable tape, coatings, shrink tubing, and sleeving. Small flammable materials that are normally stowed in a locker or a nonflammable container may be acceptable, if the amount of time that they are left unstowed is sufficiently minimized, (refer to next section on stowed hardware). The absence of ignition sources is not normally sufficient justification in itself for accepting flammable materials, but may be used as supporting rationale for acceptance.

5.1.1.1 Stowed Flammable Hardware -- Control of flammability of materials may fall under the JSC Materials & Processes Branch stowage policies. The stowage policies are expressed as codes that describe different rationales concerning use of a non "A" rated flammable material.

These codes are based on the size of flammable surface materials, and the limited amount of time these materials will be left unstowed outside of nonflammable stowage containers. Any stowage codes used are documented on the Materials and Fracture Control Certification. The codes are described in Appendix E:

5.1.1.2 Spacing of Hook and Loop Fasteners -- Hook and loop fasteners in habitable areas, whether applied on the ground or on orbit, shall not exceed the following restrictions:

(a) Maximum size - 4 square inches

(b) Maximum length - 4 inches

(c) Minimum separation - 2 inches

5.1.2 TOXIC OFFGASSING

All materials used in habitable flight compartments shall meet the offgassing requirements of NASA-STD-6001 using one of the following methodologies:

(a) Offgassing is tested as an assembled article

Summation of Toxic Hazard Index (T) values (total concentration in milligrams per cubic meter/Spacecraft Maximum Allowable Concentration) of all offgassed constituent products shall not exceed 0.5.

(b) Hardware components evaluated on a materials basis

Individual materials used to make up a component shall be evaluated based on the actual or estimated mass of the material used in the hardware component. The total T value for all materials used to make up the component shall be less than 0.5.

(c) More than one hardware component or assembly

If a single hardware component is tested or evaluated for toxicity, but more than one will be flown, the T value obtained for one unit times the number of flight units shall be less than 0.5.

(d) Bulk materials and other materials not inside a container

All materials shall be evaluated individually using the ratings in the MAPTIS database. The maximum quantity and associated rating is specified for each material code.

The analytical technique used to identify and quantify offgassed products in the NASA-STD-6001 standard test shall be capable of detecting formaldehyde concentrations of 0.05 parts per million. Offgassing testing is not required for metallic materials or for ceramics and metal oxides. SMAC values shall be obtained from JSC 20584, Spacecraft Maximum Allowable

Concentrations for Airborne Contaminants. For compounds for which no SMAC values are found in JSC 20584, the values in MAPTIS shall be used.

5.1.2.1 Personal Hygiene Kit (PHK) Materials -- Each astronaut is able to select basic generic off-the-shelf personal hygiene items, such as toothpaste, deodorant, makeup, etc. without an offgas test being required for each new item. The JSC Materials & Processes Branch, in conjunction with the JSC Medical Sciences Division Toxicology Group, consider that personal hygiene products sold in the United States (with exceptions cited below) do not present a significant toxic offgassing hazard in manned flight compartments.

Note: Personal Hygiene Kit items used on ISS or on the Space Shuttle orbiter while it is docked to ISS shall also comply with Section 5.3.11. A VUA is required if any of the 8 controlled water-soluble volatile organic compounds are present.

Astronaut Personal Hygiene Kit items which meet the following conditions shall not normally require offgas testing:

(a) Products, which do not have an alcohol, ketone, or other solvent, listed as one of their first four ingredients. Exceptions to this shall be offgas tested.

(b) Unscented products are recommended, but are not mandatory.

(c) Aerosol and pump sprays are not allowed.

(d) Products manufactured in foreign countries and not sold in the U.S. shall be evaluated on a case by case basis.

(e) Any special non-generic items shall also be evaluated on a case by case basis.

5.1.3 FLUID COMPATIBILITY

Materials exposed to hazardous fluids[1] shall be evaluated or tested for compatibility. As a minimum, materials compatibility with hazardous fluids other than oxygen shall be tested for 48 hours at the maximum system temperature or 160 ºF (whichever is higher) per Test 15 of NASA-STD-6001. The NASA-STD-6001 test is appropriate only for short-term or intermittent fluid exposure; appropriate long-term tests shall be conducted for materials with long-term exposure to hazardous fluids, using the maximum use environments for temperature, pressure and hazardous fluid concentration. The effect of material condition (parent versus weld metal or heat-affected zone) shall be addressed in the compatibility determination.

When materials can be exposed to hazardous fluids by a credible single barrier failure, an evaluation of test data and other information shall be conducted to demonstrate the acceptability of the configuration.

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[1] For the purpose of this plan, the definition of hazardous fluids includes gaseous oxygen, liquid oxygen, fuels, oxidizers, and other fluids that could cause corrosion, chemically or physically degrade materials in the system, or cause an exothermic reaction.

5.1.4 OXYGEN COMPATIBILITY

Liquid and gaseous oxygen systems containing flammable materials shall be designed to eliminate all potential ignition sources. Materials compatibility with liquid and gaseous oxygen shall be evaluated and tested if required in accordance with NASA-STD-6001 Test 13 for mechanical impact and Test 17 for upward flammability in GOX (or Test 1 for materials used in oxygen pressures that are less than 50 psia). When a material in an oxygen system fails either test at its maximum use pressure, a hazard analysis shall be conducted and the system safety rationale shall be documented in an MUA. The hazard analysis shall use the evaluation methodology described in NASA Technical Memorandum 104823, Guide for Oxygen Hazard Analyses on Components and Systems. Configurational testing shall be conducted as required to support the hazard analysis.

Guidelines on the design of safe oxygen systems are contained in ASTM MNL 36, “Safe Use of Oxygen and Oxygen Systems: Guidelines for Oxygen System Design, Materials Selection, Operations, Storage, and Transportation”; ASTM Standard G88-90 "Standard Guide for Designing Systems for Oxygen Service"; ASTM G63-99,"Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service"; and ASTM G94-92, "Standard Guide for Evaluating Metals for Oxygen Service".

Note: With a few exceptions, such as Monel alloys, common structural metallic materials are flammable in oxygen at modest pressures. However, most metals can be used safely in oxygen provided that the system is designed to eliminate potential ignition sources. Titanium alloys are extremely flammable and should be used only in exceptional circumstances and at very low pressures (never above 100 psia). Aluminum alloys are also highly flammable, but can be used for static components, such as pressure vessels, at pressures up to 3,000 psia; aluminum valves, regulators, etc. should not be used at pressures above 100 psia. Stainless steel and Inconel alloys are flammable at pressures above 500 psia, but, with careful design to eliminate ignition sources, can be used safety at pressures as high as 10,000 psia.

5.1.4.1 Oxygen Component Acceptance Test -- Oxygen system components exposed to oxygen at pressures of 250 psia and above shall undergo oxygen compatibility acceptance testing as noted in Table 5-1. This test ensures that all high-pressure oxygen system flight hardware is exposed to oxygen prior to launch and screens workmanship defects that could result in ignition of the component when pressurized with oxygen.

Oxygen system components shall be exposed to oxygen at maximum design pressure (MDP). Functional tests, other than leakage, shall be conducted while the component is pressurized with oxygen at MDP (functional tests include opening and closing a valve, connecting and disconnecting a quick disconnect, etc.). Cleanliness shall be maintained to the level specified in the component specification. Hydrocarbon detection analysis shall be performed as specified in MSFC-PROC-404 prior to the oxygen compatibility acceptance test for components exposed to non oxygen-compatible solvents as an assembly. Total hydrocarbon count shall not exceed 5 parts per million.

Each component shall be subjected to 10 oxygen pressurization cycles from ambient pressure (10 to 15 psia) to MDP within 100 milliseconds. The component shall be maintained at MDP for at least 30 seconds following each pressurization cycle. Each component shall be subjected to oxygen flow in both the forward and reverse flow directions, where reversible flow is within the operational capability of the component.

Visual inspection shall be performed after conduct of the oxygen compatibility acceptance test and shall be verified to the level specified in the component specification. If disassembly of the component occurs after the oxygen compatibility acceptance test, the test must be repeated. All functional and leak tests required in the component specification shall be conducted (or repeated) after the oxygen compatibility acceptance test.

Table 5–1. Oxygen Components Requiring Acceptance Testing

Component	Testing Required
Hard Line (rigid metal tubing)	
Metal Flex Hose	
Metal Flex Hose (>/=3,000 psia)	X
Metal Fluid Fitting with all metal seals	
Self–Sealing Quick Disconnect	X
Valve	X
Pressure Relief Valve	X
Temperature Sensor	X
Pressure Sensor	X
Nonmetal Lining Flex Hose	X
Fluid Fitting with nonmetal seals	X
Pressure Regulator	X
Metal Pressure Vessels	

5.1.5 HYDROGEN COMPATIBILITY

Guidelines on the design of safe hydrogen systems are contained in NSS 1740.16, Safety Standard for Hydrogen and Hydrogen Systems -- Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation.

5.1.6 ELECTRICAL WIRE INSULATION MATERIALS

Electrical wire insulation materials shall be evaluated for flammability in accordance with NASA-STD-6001 Test 4. The optional overload test is not required.

Arc tracking shall be evaluated in accordance with NASA-STD-6001Test 18 or a generally accepted voluntary standard aerospace wiring arc tracking test. Testing is not required for polytetrafluoroethylene (PTFE), PTFE laminate, ethylene tetrafluoroethlyene (ETFE), or silicone insulated wires since the resistance of these materials to arc tracking has already been established.

5.2 METALS

The following requirements are specific to metallic materials. Additional information regarding metallic materials can be found in MAPTIS.

5.2.1 ALUMINUM

Aluminum alloys used in structural applications shall be resistant to general corrosion, pitting, intergranular corrosion, and stress corrosion cracking. Aluminum alloys 2024-T6, 7075-T6, 7079-T6, and 7178-T6 shall not be used in structural applications. The following alloys and heat treatments shall not be used in applications where the temperature exceeds 150 degrees Fahrenheit (66 degrees C): 5083-H32, 5083-H38, 5086-H34, 5086-H38, 5456-H32, and 5456-H38.

Heat treatment of aluminum alloy parts shall meet the requirements of SAE-AMS 2772, Heat Treatment of Aluminum Alloy Raw Materials, or SAE-AMS 2770, Heat Treatment of Wrought Aluminum Alloy Parts. When aluminum alloys are solution heat treated, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part.

5.2.2 STEEL

A Category III MUA shall be generated to document all applications of carbon and low alloy high strength steels greater than 180 ksi UTS in ball bearings, springs or similar applications where the primary loading is compressive, tensile stresses are low, or the application has a history of satisfactory performance. Carbon and low alloy steels heat-treated to strength levels at or above 180 ksi UTS shall not be used for other applications.

5.2.2.1 Heat Treatment of Steels -- Steel parts shall be heat treated to meet the requirements of SAE-AMS-H-6875, Heat Treatment of Steel Raw Materials, or SAE-AMS 2759, Heat Treatment of Steel Parts, General Requirements. When high-strength steels (>200 ksi) with the exception of Custom 455 and Custom 465 alloys, tool steels, and maraging steel alloys are heat treated to high strength levels, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part. For other steels (including alloy steels), the adequacy of the heat treatment process shall be verified by hardness measurements. Age hardening of Custom 455 and Custom 465 alloys shall also be verified by hardness measurements. When acid cleaning baths or plating processes are used, the part shall be baked in accordance with SAE-AMS 2759/9, Hydrogen Embrittlement Relief (Baking) of Steel Parts, to alleviate potential hydrogen embrittlement problems.

5.2.2.2 Drilling and Grinding of High Strength Steel -- The drilling of holes, including beveling and spot facing, in martensitic steel hardened to 180 ksi UTS or above, shall be avoided. When such drilling, machining, reaming, or grinding is unavoidable, carbide-tipped tooling and other techniques necessary to avoid formation of untempered martensite shall be used. Micro-hardness and metallurgical examination of test specimens typical of the part shall be used to determine if martensite areas are formed as a result of drilling or grinding operations, or temper etch actual hardware in lieu of destructive test. The surface roughness of finished holes shall not be greater than 63 roughness-height-ratio, and the edges of the holes shall be deburred by a method which has been demonstrated not to cause untempered martensite.

5.2.2.3 Corrosion Resistant Steel -- Unstabilized, austenitic steels shall not be used above 700 degrees Fahrenheit (371 degrees C). Welded assemblies shall be solution heat-treated and quenched after welding except for the stabilized or low carbon grades such as 321, 347, 316L, 304L.

5.2.3 TITANIUM

5.2.3.1 Heat Treatment — Heat treatment of titanium and titanium alloy parts shall meet the requirements of SAE-AMS-H-81200, Heat Treatment of Titanium and Titanium Alloys. When titanium alloys are heat treated, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part.

5.2.3.2 Titanium Contamination — All cleaning fluids and other chemicals used on titanium shall be verified to be compatible and not detrimental to performance before use. Hydrochloric acid, chlorinated solvents, chlorinated cutting fluids, fluorinated hydrocarbons, and anhydrous methyl alcohol can all produce stress corrosion cracking, generally at elevated temperatures. Mercury, cadmium, silver, and gold are metals that have been shown to cause liquid metal induced embrittlement and/or solid metal induced embrittlement in titanium and its alloys. Liquid metal induced embrittlement of titanium alloys by cadmium can occur as low as 300 ºF and solid metal induced embrittlement of titanium alloys by cadmium can occur as low as room temperature.

5.2.3.3 Titanium Wear — Titanium and its alloys exhibit very poor resistance to wear. Fretting that occurs at interfaces with titanium and its alloys have often contributed to crack initiation, especially fatigue initiation. A design to avoid fretting and/or wear with titanium and its alloys is the preferred design policy. If fretting and/or wear is unavoidable, the subject region shall be anodized per SAE-AMS 2488, Anodic Treatment – Titanium and Titanium Alloys Solution, pH 13 or Higher, or hard coated utilizing a wear-resistance material such as tungsten carbide/cobalt thermal spray.

5.2.3.4 Titanium Welding — Titanium and its alloys shall be welded with alloy matching fillers or autogenously. Extra low Interstitial (ELI) filler wires shall be used for cryogenic applications and are preferred for general applications. Commercially Pure (CP) titanium filler shall not be used on 6-4 titanium or other alloyed base material; hydride formation can occur in the weld, which can produce a brittle, catastrophic failure.

A great deal of care needs to be exercised to ensure complete inert gas (argon or helium) coverage during welding. Nitrogen, hydrogen, carbon dioxide and mixtures containing these gases shall not be used in welding titanium and its alloys. The inert gas shall have a dew point of -60 ºC (-75 ºF) or lower.

Welded alpha and alpha plus beta alloys shall be stress relieved in a vacuum or inert gas environment (Ar or He). Beta alloys that are welded shall be evaluated on a case-by-case basis with respect to stress relief.

5.2.3.5 Titanium Flammability -- Titanium alloys shall not be used with Liquid Oxygen (LOX) or Gaseous Oxygen (GOX) at any pressure or with air at oxygen partial pressures above 5 psia (34.5 kPa). Titanium alloys shall not be machined inside spacecraft modules during ground processing or in flight, because machining operations can ignite titanium turnings and cause fire.

5.2.4 MAGNESIUM

Magnesium alloys shall not be used except in areas where minimal exposure to corrosive environments can be expected and protection systems can be maintained with ease and high reliability. Magnesium alloys shall not be used in primary structure, in other areas subject to wear, abuse, foreign object damage, abrasion, erosion, or at any location where fluid or moisture entrapment is possible. Magnesium alloys shall not be machined inside spacecraft modules during ground processing or in flight, because machining operations can ignite magnesium turnings and cause fire.

5.2.5 BERYLLIUM

Beryllium shall not be used for primary structural applications. Beryllium is allowed as an alloying constituent up to a maximum of 4 percent by weight. Beryllium alloys containing more than 4 percent beryllium by weight shall not be used for any application within spacecraft crew compartments unless suitably protected to prevent erosion or formation of salts or oxides. Beryllium alloys and oxides of beryllium shall not be machined inside spacecraft crew compartments at any stage of manufacturing, assembly, testing, modification, or operation.

5.2.6 CADMIUM

Cadmium shall not be used in crew environments. Cadmium shall not be used in vacuum environments where the temperature/pressure environment could cause contamination of optical surfaces or electrical devices.

5.2.7 MERCURY

Equipment containing mercury shall not be used where the mercury could come in contact with the spacecraft or spaceflight equipment during manufacturing, assembly, test, checkout, and flight. Flight hardware (including fluorescent lamps) containing mercury shall have three levels of containment to prevent mercury leakage. The bulbs of non-flight lamps containing mercury, such as those used in hardware ground processing and fluorescent penetrant inspection of flight parts, shall be protected by a non-shatterable, leak-proof outer container.

5.2.8 REFRACTORY METALS

Since engineering data on refractory alloys are limited, especially under extreme environmental usage of spacecraft, appropriate tests shall be performed to characterize such materials for the intended application.

5.2.9 SUPERALLOYS (NICKEL-BASED AND COBALT-BASED)

High nickel content alloys are susceptible to sulfur embrittlement; therefore, any foreign material which could contain sulfur, such as oils, grease, and cutting lubricants, shall be removed by suitable means prior to heat treatment or high temperature service. Some of the precipitation-hardening superalloys are susceptible to alloying element depletion at the surface in a high temperature, oxidizing environment. This effect shall be carefully evaluated when a thin sheet is used, since a slight amount of depletion could involve a considerable proportion of the effective cross section of the material.

5.2.9.1 Heat Treatment of Nickel- and Cobalt-Based Alloys -- Heat treatment of nickel- and cobalt-based alloy parts shall meet the requirements of SAE-AMS 2774, Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts. When these alloys are heat treated to strengths greater than 150 ksi, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part. For strengths below 150 ksi, the adequacy of the heat treatment process shall be verified by hardness measurements.

5.3 NONMETALLIC MATERIALS

The following requirements are specific to nonmetallic materials.

5.3.1 ELASTOMERIC MATERIALS

Elastomeric components shall have long-term resistance to aging, low temperature, ozone, heat aging, polymer reversion, working fluids, lubricants, and operating media. Elastomeric materials shall be cure dated for tracking purposes. RTV elastomeric materials which liberate acetic acid during cure shall not be used. In addition, any other use must be approved by the JSC Materials and Processes Branch.

5.3.2 POLYVINYL CHLORIDE

Use of polyvinylchloride on flight hardware shall be limited to applications in pressurized areas where temperatures do not exceed 120 degrees Fahrenheit (49 degrees C). Polyvinylchloride shall not be used in vacuum.

5.3.3 COMPOSITE MATERIALS

Defects resulting from the manufacturing process shall be assessed through the proper application of Nondestructive Evaluation (NDE) techniques. Appropriate NDE techniques selected from the available PRC-6500-series of JSC process specifications shall be used as appropriate. Other NDE specifications may be invoked in those cases where adequate JSC process specifications do not exist. Material property design allowables shall be developed per the methodology of DOT/FAA/AR-MMPDS-01 for use in the design and analysis of composite flight hardware.

5.3.4 LUBRICANTS

NASA-TM-86556, Lubrication Handbook For the Space Industry, Part A: Solid Lubricants, Part B: Liquid Lubricants, shall be used in the evaluation and selection of lubricants for space flight systems and components. Long life performance shall be considered in lubricant selection. Lubricants containing chloro-fluoro components shall not be used with aluminum or magnesium if shear stresses can be imposed.

5.3.5 LIMITED-LIFE ITEMS

Materials shall be selected to ensure maximum life and minimum maintenance. As a goal, all materials shall be selected to provide the full operational service life with no maintenance. Materials which are not expected to meet the design life requirements but must be used for functional reasons shall be identified as limited-life items requiring maintainability.

5.3.6 VACUUM OUTGASSING

Nonmetallic materials which are exposed to space vacuum shall be tested using the technique of ASTM-E595, Total Mass Loss and Collected Volatile Condensable Materials From Outgassing In A Vacuum Environment, Test Method for, with acceptance criteria of ≤0.1 percent Collected Volatile Condensable Materials (CVCM) and ≤1.0 percent Total Mass Loss (TML). A TML greater than 1.0 percent is permitted if this mass loss has no effect on the functionality of the material itself and no effect on the functionality of any materials, components, or systems that could be adversely affected by the subject mass loss. A hardware item (component, assembly, etc.) containing materials that fail the CVCM requirement and/or having unidentified materials, may be vacuum baked at a temperature of 125 ºC until the outgassing rate, as measured by a quartz crystal microbalance at 25 ºC, is less than 1×10^{-9} grams/square centimeter/second. When a vacuum-bake temperature of 125 ºC could damage flight hardware, lower temperatures may be used with an approved MUA.

Additional, program-specific requirements may exist (such as SSP 30426), but are not addressed by the materials control program.

5.3.7 EXTERNAL ENVIRONMENT SURVIVABILITY

Materials exposed in the spacecraft external environment shall be selected to perform in that environment for their intended life cycle exposure. The critical properties of the material shall survive exposure to the environments of atomic oxygen, solar ultraviolet radiation, ionizing radiation, plasma, vacuum, thermal cycling and contamination. Noncritical properties may be allowed to degrade, provided such degradation does not result in release of particulate that would violate external contamination requirements or affect the functioning of other hardware (in particular, mechanisms). Meteoroids and orbital debris shall also be considered in the analysis of long-term degradation.

An MUA shall be processed in accordance with section 4.3 for materials applications where critical or noncritical properties degrade during exposure to the LEO environment, but the hardware is deemed to have adequate life for the intended application. Contingency tools and materials that are normally protected from the environment and exposed only temporarily as a result of removal of the protective covering (blankets, shrouds, etc.) for maintenance or assembly operations are exempt from the MUA requirement.

5.3.8 MOISTURE AND FUNGUS RESISTANCE

Organic materials used in the pressurized environment shall be evaluated for fungus resistance prior to selection and qualification. Materials which are non-nutrient to fungi shall be used, as identified in MIL-STD-454, General Guidelines for Electronic Equipment, Requirement 4, Fungus-Inert Materials, Table 4-I, Group I, except when one of the following criteria is met.

1. Material has been tested to demonstrate acceptability per MIL-STD-810, Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Method 508.
2. Materials used in crew areas, where fungus would be visible and easily removed.
3. Materials used inside environmentally sealed containers with internal container humidity less than 60% RH at ambient conditions.
4. Materials used inside electrical boxes where the temperature is always greater than or equal to the ambient cabin temperature.
5. Materials with edge exposure only.
6. Materials normally stowed with no risk of condensation in stowage locations.
7. Materials used on noncritical off-the-shelf electrical/electronic hardware that is stowed and/or used in crew areas.
8. Fluorocarbons polymers (including ETFE) or silicones.
9. Crew clothing items.

When fungus-nutrient materials must be used, they shall be treated to prevent fungus growth. Materials not meeting this requirement shall be identified including any action required such as inspection, maintenance, or replacement periods. Fungus treatment shall not adversely affect unit performance or service life or constitute a health hazard to higher order life. Materials so treated shall be protected from environments that would be sufficient to leach out the protective agent.

5.3.9 ETHYLENE GLYCOL

When solutions containing ethylene glycol are used aboard spacecraft which have electrical or electronic circuits containing silver or silver-coated copper, a silver chelating agent such as benzotriazole (BZT) shall be added to the solution to prevent spontaneous ignition from the reaction of silver with ethylene glycol.

5.3.10 ETCHING FLUOROCARBONS

The etching of fluorocarbons shall meet the requirements of SAE-AMS 2491, Surface Treatment of Polytetrafluoroethylene, Preparation for Bonding. Etched surfaces must be processed within 24 hours or packaged per SAE-AMS 2491. Etched surfaces packaged per AMS 2491 shall be processed within 1 year. Electrical wire or cable insulated or coated with fluorocarbons shall be etched prior to potting to ensure mechanical bond strength and environmental seal. When etching of wire insulation is required to provide satisfactory bonding to potting materials, the open end of the wire shall not be exposed to the etchant.

5.3.11 WATER-SOLUBLE VOLATILE ORGANIC COMPOUNDS

The release of the following water-soluble volatile organic compounds into the ISS habitable environment is prohibited:

> Methanol; ethanol; isopropyl alcohol; n-propyl alcohol; n-butyl alcohol; acetone; ethylene glycol; propylene glycol.

This requirement applies to hardware used in the ISS habitable environment and hardware used in the Space Shuttle orbiter while docked to ISS with the hatch open. It does not apply to hardware used in the orbiter at other times.

A VUA must be processed in accordance with section 4.1.5 for all hardware containing such compounds, with the following exceptions:

- The release of these compounds by normal materials offgassing
- The water-soluble volatile organic compound is properly contained and released to the habitable environment only as a result of a single barrier failure (redundant containment is not required)
- All emergency surgery supplies are exempt

Note: Commercial personal hygiene items such as toothpaste and deodorant are acceptable if none of the 8 controlled water-soluble volatile organic compounds are listed as ingredients on the commercial container or packaging. Ethanol may be listed as "ethyl alcohol", "SD alcohol", or "Alcohol Denat."

5.4 PROCESSES

5.4.1 FORGING

Because mechanical properties are optimum in the direction of material flow during forging, forging techniques shall be used that produce an internal grain- flow pattern such that the direction of flow is essentially parallel to the principal stresses. The forging pattern shall be essentially free from re-entrant and sharply folded flow lines. After the forging technique, including degree of working, is established, the first production forging shall be sectioned to show the grain-flow patterns and to determine mechanical properties at control areas. The procedure shall be repeated after any change in the forging technique. The information gained from this effort shall be utilized to redesign the forging as necessary. These data and results of tests on the redesign shall be retained and be made available for review by the procuring activity. Where forgings are used in critical applications, trim ring or protrusion specimens shall be obtained for each forging and shall be tested for required minimum mechanical properties; surface and volumetric nondestructive inspection shall also be performed.

5.4.2 CASTINGS

Castings shall meet the requirements of SAE-AMS-STD-2175, Castings, Classification and Inspection of.

5.4.3 ADHESIVE BONDING

Structural adhesive bonding shall meet PRC-1001, Adhesive Bonding or MSFC-SPEC-445A, Adhesive Bonding, Process, and Inspection, Requirements For, with the exception of paragraph 3.1.1.1. Contractors are not required to submit for review either an operator certification plan or an adhesive control plan. Adhesives used for production parts will not be retested if within shelf life. The sensitivity of structural adhesive bonds to contamination is of particular concern. Structural adhesive bonding processes shall be controlled to prevent contamination that would cause structural failure which could affect the safety of the mission, crew, or vehicle or affect the mission success. Bond sensitivity studies shall be conducted to verify the required adhesive properties are maintained after exposure to potential contaminant species and concentrations. Bonded primary structural joints shall demonstrate cohesive failure modes in shear.

5.4.4 WELDING

The design selection of parent materials and weld methods shall be based on consideration of the weldments, including adjacent heat affected zones, as they affect operational capability of the parts concerned. Welding procedures shall be selected to provide the required weld quality, minimum weld energy input, and protection of the heated metal from contamination. The suitability of the equipment, processes, welding supplies, and supplementary treatments selected shall be demonstrated through qualification testing of welded specimens representing the materials and joint configuration of production parts. The processing and quality assurance requirements for manual, automatic, and semiautomatic fusion welding for space flight applications and special test equipment used for testing flight hardware within NASA shall meet the requirements of NASA-STD-5006, General Fusion Welding Requirements for Aerospace Materials Used in Flight Hardware. As a minimum requirement, welding operators shall be qualified in accordance with SAE AMS-STD-1595, Qualification of Aircraft, Missile and Aerospace Fusion Welders, or PRC-0008, Qualification of Manual Arc Welders, Process Specification for. In addition, contractors shall provide the necessary training and qualification requirements to certify each operator and the applicable welding equipment for specific welding tasks.

5.4.4.1 Weld Repair -- At the discretion of the cognizant engineer, two additional welding operations may be performed on any one location, within a two inch length, to repair defects determined by inspection without JSC Discrepancy Report or Material Review Board (MRB) approval. Weld repair does not include the correction of dimensional deficiencies by weld buildup or "buttering" of parts in areas where the design did not provide a welded joint. All weld repairs shall be fully documented to facilitate procuring activity review. The weld repair process and inspection shall be qualified to the same level of assurance as the primary process specification drawing requirement using the same inspection technique that found the original defect and by all other methods of examination that were originally required for the affected area.

5.4.4.2 Weld Filler Metal -- Weld wire filler materials shall meet the requirements of ES SOP-004.5, Control of Weld and Braze Filler Materials, Electrodes, and Fluxing Materials. In addition, qualitative analysis or nondestructive testing shall be conducted on each nickel base filler rod or immediately before and after each segment of rolled nickel base weld wire used to assure that the correct filler metal is used on each specific critical part.

5.4.4.3 Aluminum Welding -- The welding of aluminum alloys shall meet the requirements of PRC-0001, Manual Arc Welding of Aluminum Alloy Flight Hardware, or MSFC-SPEC-504, Welding, Aluminum Alloys.

5.4.4.4 Welding of Steel Alloys -- Welding of steel alloys shall meet the requirements of PRC-0006, Manual Arc Welding of Steel and Nickel Alloy Flight Hardware, or MSFC-SPEC-560, Welding, Steels, Corrosion and Heat Resistant Alloys.

5.4.4.5 Welding of Titanium Alloys -- Welding of Titanium alloys shall meet the requirements of JSC PRC-0004, Manual Arc Welding of Titanium Alloy Flight Hardware, or MSFC-SPEC-766, Specification: Fusion Welding Titanium and Titanium Alloys.

5.4.4.6 Low Stress Welds and Structures -- Weldments meeting all conditions below are suitable for reduced qualification and inspection before flight:

1) Not listed as criticality 1 on the Critical Items List
2) Having no site on the weld above 4,000 psi uniaxial stress;
3) Made from materials with KQ/FTY > 0.5 in ^.5 at the design thickness;
4) Using a process specification and procedure specified in the contractor Materials and Processes Selection, Control, and Implementation Plan.

American Welding Society (AWS) code requirements, AWS welder certification, and AWS Weld Process Specifications (WPS) may be used for low stress welds in place of the applicable JSC process specification and MSFC-SPEC-504. Pressure testing is an acceptable alternate to penetrant and radiographic tests for these low stress welds. Partial penetration butt and corner welds are acceptable for design. Low stress welds shall be identified on drawings.

5.4.5 BRAZING

Brazing shall be conducted in accordance with AWS C-3.3, Design, Manufacture, and Inspection of Critical Brazed Components, Recommended Practices for. Brazing of aluminum alloys shall meet the requirements of AWS C-3.7, Aluminum Brazing. Torch, induction, and furnace brazing shall meet the requirements of AWS C-3.4, AWS C-3.5 and AWS C-3.6, respectively. Subsequent fusion-welding operations in the vicinity of brazed joints or other operations involving high temperatures which might affect the brazed joint shall be prohibited unless it can be demonstrated that the fixturing, processes, methods, and/or procedures employed will preclude degradation of the braze joint. Brazed joints shall be designed for shear loading and shall not be relied upon for strength in axial loading for structural parts.

5.4.6 STRUCTURAL SOLDERING

Soldering shall not be used for structural applications.

5.4.7 ELECTRICAL DISCHARGE MACHINING

The electrical discharge machining (EDM) process shall be controlled to limit the depth of the oxide layer, the recast layer, and the heat-affected zone. The EDM oxide layer, when present, shall be removed from the surface. In addition, the recast layer and the heat-affected zone shall be removed from bearing, wear, fatigue or fracture critical surfaces, and from crack or notch sensitive materials. The recast layer and heat-affected zone may be left on a part if an engineering evaluation shows that they are not of consequence to the required performance of the part. EDM schedules shall be qualified to determine the maximum thickness of the EDM layers when the depth of EDM-affected material must be known for removal or analysis.

5.4.8 PRECISION CLEAN HARDWARE

Precision clean hardware shall be cleaned and packaged in accordance with JPR 5322.1. The following additional requirements apply to ensure such hardware is maintained clean during assembly and operation.

5.4.8.1 Assembly, Cleaning, Flushing, and Testing Fluids --The assembly, cleaning, flushing, and testing fluid surface cleanliness requirement is the same as the surface cleanliness level required by the operational system this fluid is to be used within. Residual cleaning, flushing, and testing fluids shall be removed prior to charging with the operating fluid (removal by flushing with the operating fluid is permitted when appropriate). Positive verification is required only when specified.

5.4.8.2 Personnel Training -- A certification-training course shall be established and required for anyone working around precision-cleaned hardware. The focus of the course shall be on awareness, and shall require a minimum 1-hour of instruction time. As a minimum, the course content shall include definition of precision cleanliness, problems that have occurred with precision-cleaned hardware, the best practices for maintaining cleanliness, and specific controls identified at the site where work will be performed.

5.4.8.3 Welding Precision-Cleaned Hardware (Including Tube Preparation) -- Whenever precision-cleaned hardware must be maintained clean during welding into an assembly, the welding operation shall be performed in a dedicated Class 100,000 Clean Work Area (CWA). This may require temporary tents over the weld area and/or local monitors located in the area of welding to ensure the Class 100,000 environment is being met. Portable particle counters shall be located as close as possible to the work area, so as to monitor local contaminants during tube preparation and welding. Tools used in weld preparation and welding (such as cutter, weld head, files) shall be visibly cleaned per JPR 5322.1 and maintained clean (e.g. bagged when not in use).

For hardware that cannot be subsequently precision-cleaned, a proven method for protecting against system contamination during tube preparation shall be implemented. One such method is the use of a physical barrier, such as plugs. The installation and removal of plugs shall be tracked by a reliable method and independently verified. Prior to plug removal the exposed internal surfaces of the tube shall be cleaned using a swab wetted with an approved solvent, and positive backpressure shall be maintained as the plug is removed.

Tube cutters shall use a sharp blade, changed frequently. Cutting shall be performed with minimal cutter pressure to aid in preventing particle generation. Vacuum shall be used during tube facing operations to remove particulate. Whenever possible, facing operations shall be performed away from the weld assembly area, to reduce particulate contamination of the welding work area. Tube facing shall be performed without the use of cutting oils, other fluids, lubricants or coolants. Abrasives, including sandpaper or abrasive pads, shall not be used inside tubes or when unprotected internal surfaces are exposed. After each tube preparation, and prior to welding, a high-velocity gas purge shall be performed. The purge gas velocity shall be the maximum attainable using a 90-psig source. Purge gas used during facing and welding shall meet the hydrocarbon, moisture, and particulate controls of the applicable welding specification or for the system under assembly (whichever is the more stringent). The purge gas shall be supplied through precision-cleaned low-nonvolatile residue (NVR)/particulate tubing such as polyethylene, nylon, Teflon, or ethyl vinyl acetate. Standard grade Tygon is not acceptable for use.

When welding O2 systems, regulators used during purging operations shall have O2 compatible grease, purge tubing shall be verified to be O2 compatible, and bagging materials used to store O2 tubes, hoses, components and welded assemblies shall be cleaned to the same level of cleanliness as the O2 hardware and verified to be O2 compatible.

5.4. 8.4 Ground Support Equipment (GSE) Interfaces -- GSE supply interface/final filters interfacing with precision-cleaned flight fluid systems shall be located as close to the flight hardware interface as possible. Interface filters are required on outlet lines if it is determined that some operations, such as servicing or deservicing fluids, could permit flow in a reverse direction. Interfacing GSE shall be cleaned to at least the cleanliness level of the flight hardware. GSE fluid hardware (such as hoses, servicing units) shall be handled with the same cleanliness procedures as flight hardware.

5.4.8.5 Convoluted Flex Hoses -- Convoluted metal flex hoses shall receive special attention to cleaning. All detail flex hoses shall be verified as precision-clean in a vertical orientation. For flex hose tube diameters equal to or greater than one inch, verification of precision cleanliness shall be performed by sampling a rinse fluid applied internally through use of a high-pressure nozzle to the entire length of the flex hose. For flex hose tube diameters less than one inch, the use of a high-pressure nozzle is preferred, but verification may be performed by flushing a rinse fluid through the entire length of the flex hose with flex hose agitation. Precision cleaning shall be considered successful when the verification rinse fluid indicates compliance with the flex hose engineering drawing cleanliness requirement.

5.4.8.6 Maintaining System Cleanliness -- Hardware (including GSE) that has not been precision-cleaned shall not be brought into the vicinity of precision-cleaned flight hardware (for fit checks etc.) without protection to the flight hardware (i.e., wrapped in approved packaging material).

Clean room bags shall always be used to transport cleaned hardware (including GSE), even short distances when outside of the clean room environment. Precision-cleaned hardware shall be exposed only in a particulate controlled environment, including the use of flow benches providing a Class 100,000 CWA or better, when conducting hardware inspections. Clean room gloves shall be used during all handling of precision-cleaned flight hardware and GSE. Any inspection tools that are to be exposed to precision-cleaned fluid systems hardware (borescopes, etc.) shall be visibly cleaned and maintained clean. Solvents used for such cleaning shall be filtered to 10 microns or better prior to use.

All precision cleaned open tubes and lines must be protected, i.e. wrapped or bagged with approved materials, as soon as possible after fabrication, until final installation. All precision-cleaned fluid systems configured for flight shall have integrity seals installed. Precision cleaned hardware that has been welded shall remain capped (non-particle generating caps, or wrapped and taped) at the ends during x-ray operations to avoid potential contamination of hardware.

5.4.8.7 Sampling For Residual Solvents Incompatible With Fluid Systems -- When isopropyl alcohol (IPA) is used for cleaning, flushing, or testing of gaseous oxygen systems or assembled components, the residual concentration of IPA solvent must be verified as within acceptable limits prior to the introduction of flight fluids. After purging with an inert gas, a 24 hour "lock-up" of the component or assembled component is required to assure that enough time is provided for contaminant solvent to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual solvent concentration. The solvent concentration in "lock-up" gas samples shall not exceed 18 ppm when measured as methane.

When water is used for cleaning, flushing, or testing of systems that use ammonia (NH3) as the operating fluid, the residual concentration of water must be verified as within acceptable limits prior to the introduction of flight fluids. After purging with a dry gas, a 24 hour "lock-up" of the component or assembly is required to assure that enough time is provided for contaminant water to volatilize, thus achieving concentration equilibrium so that gas sampling will provide an accurate reflection of the residual water concentration. The water concentration in "lock-up" gas samples shall not exceed a dew point of –50 °C (-58 °F).

5.5 MATERIAL NONDESTRUCTIVE INSPECTION

5.5.1 NDE PLAN

The Nondestructive Evaluation (NDE) activities associated with aerospace hardware shall meet the intent of MIL-HDBK-6870, Inspection Program Requirements, Nondestructive for Aircraft and Missile Materials and Parts and MSFC-STD-1249, Standard NDE Guidelines and Requirements for Fracture Control Programs.

5.5.2 NDE ETCHING

All fracture critical parts shall be NDE etched prior to dye penetrant inspection. (NOTE - All machined or otherwise mechanically disturbed surfaces which are to be penetrant inspected must be adequately etched to assure removal of smeared, masking material prior to penetrant application on fracture critical parts.)

5.6 SPECIAL MATERIALS REQUIREMENTS

5.6.1 RESIDUAL STRESSES

Residual tensile stresses are induced into manufactured parts as a result of forging, machining, heat treating, welding, or special metal-removal processes. These stresses may be harmful in structural applications when the part is subjected to fatigue loading, operation stresses, or corrosive environments. Residual stresses shall be controlled or minimized during the fabrication sequence by special treatments such as annealing and stress relieving.

The straightening of warped parts is likely to generate residual stresses and shall be evaluated on a case-by-case basis.

5.6.2 SANDWICH ASSEMBLIES

Sandwich assemblies shall be designed to prevent the entrance and entrapment of water vapor or other contaminants into the core structure. Honeycomb sandwich assemblies that will be subjected to heating shall use a metallic or glass reinforced core to minimize the absorption of moisture. Perforated and moisture-absorbing cores shall not be used in sandwich assemblies. Test methods for sandwich constructions and core materials shall meet the requirements of SAE-AMS-STD-401, Sandwich Constructions and Core Materials; General Test Methods.

5.6.3 STRESS CORROSION CRACKING

MSFC-STD-3029A, Guidelines for Selection of Metallic Materials for Stress-Corrosion-Cracking Resistance in Sodium Chloride Environments shall be used to select metallic materials to control stress corrosion cracking of metallic materials in all environments.

5.6.4 CORROSION PREVENTION AND CONTROL

All parts, assemblies, and equipment, including spares, shall be finished to provide protection from corrosion in accordance with the requirements of MSFC-SPEC-250, Protective Finishes for Space Vehicle Structures and Associated Flight Equipment, General Specification for. Corrosion evaluation shall show the possible effects of fluid release resulting from the failure or permeation of barriers. Corrosion control of galvanic couples shall be in accordance with MIL-STD-889, Dissimilar Metals. Galvanic couples for alloy combinations not listed in MIL-STD-889 shall not exceed 0.25 volts. Specific corrosion prevention and control techniques shall be defined in the Materials and Processes Selection, Control, and Implementation Plan. For hardware in the mild corrosive environment of standard habitable spacecraft volumes, the following changes may be made:

- The requirements of MIL-STD-889 may be relaxed with corrosion resistant aluminum alloys.
- Exposed aluminum surfaces may have anodic coatings instead of organic coatings specified in MSFC-SPEC-250.
- Conversion coatings may be used as the sole corrosion protection for 5000 and 6000 series corrosion resistant aluminum alloys. They are not acceptable as the sole corrosion protection for 2000 and 7000 series aluminum alloys.

5.6.4.1 Steel -- Where exposed to atmosphere or corrosive environments, all parts, including fasteners made from low alloy, high strength steels, shall be suitably protected. Where plating is used, it shall be applied by a process that has been proven to be nonembrittling to the high strength steel and shall be compatible with the space environment. Corrosion-resistant steels shall be passivated in accordance with PRC 5002 after machining.

5.6.4.2 Sealing -- All mechanical joints and seams located in exterior or internal corrosive environments, including structures under fairings, shall be faying-surface sealed. Sealants used shall be covered by a published specification and shall have acceptable ratings. Sealants not covered by a published specification or without acceptable ratings shall be subject to review and approval by the JSC Materials & Processes Branch. Removable panels and access doors in exterior or interior corrosive environments shall be sealed either by mechanical seals or by separable, faying-surface sealing.

5.6.5 FASTENER INSTALLATION

Self locking fastener reuse shall be allowed when the running torque prior to clamp up remains between the maximum self locking torque and the minimum breakaway torque. Wet installation of fasteners, using a corrosion-resistant sealant and installing the fastener while the sealant is still wet, is required in aqueous corrosive environments and applications where condensation can occur. Fastener management and control policy, responsibilities, and practices for structural fasteners, fracture critical fasteners, and safety critical fasteners that are procured, received, tested, inventoried or installed for space flight shall meet the requirements of MSFC-STD-2594, MSFC Fastener Management and Control Practices. The installation of titanium fasteners and associated parts shall meet the requirements of MSFC-STD-557, Threaded Fasteners, 6Al-4V Titanium Alloy, Usage Criteria for Spacecraft Applications.

5.6.5.1 Fastener Locking Requirements -- Each bolt, screw, nut, pin, or other fastener used in a safety critical application shall incorporate two separate verifiable locking features. Preload may be used as one of the features combined with a conventional aerospace secondary locking feature that is positive locking and vibration rated. Joints that are subject to rotation in operation shall use at least one non-friction locking device. Use of a liquid locking compound as a secondary locking feature on safety-critical fasteners shall require an approved MUA. An MUA is not required for fasteners where the only safety-critical effect is a FOD risk to the Orbiter Payload bay, provided the fasteners have been vibration tested during qualification or acceptance of the hardware. Liquid locking compounds used as a secondary locking feature in non-safety-critical applications shall require a qualified process specified on the engineering drawing. Installation procedures shall require functional verification of locking features, such as measurement of running (self-locking) torque or visual inspection of lock wire integrity. Preload torques and running torques shall be specified on the drawings.

5.6.5.2 Silver-Plated Fasteners – Silver reacts rapidly with atomic oxygen to generate a loose, friable, black oxide that can cause contamination and affect the operation of mechanisms. Silver-plated fasteners shall not be used in external applications where the silver plating is directly exposed to atomic oxygen.

5.6.6 CLEANLINESS CONTROL

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 NAS 412 "Foreign Object Damage/ Foreign Object Debris (FOD) Prevention.

5.7 MATERIALS AND PROCESSES FOR ELECTRICAL COMPONENTS

5.7.1 ELECTRICAL BONDING AND GROUNDING

Parts and materials used in electrical bonding and grounding shall meet the requirements of this document.

5.7.2 USE OF SILVER

Silver is prohibited as a plating on printed wiring boards, terminal boards and bus bars.

5.7.3 WIRE/CABLE ASSEMBLIES

The following shall be assembled or installed to meet the requirements of PRC-7003, Electrical Cables, Wiring, and Harnesses, or NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring.

1. Electrical connectors,
2. Interconnecting cables, harness, and wiring
3. Solders Sleeves.

5.7.4 FIBER OPTICS

Fabrication controls and processes for joining of fiber optic cable assemblies shall comply with NASA-STD-8739.5, Fiber Optic Terminations, Cable Assemblies, and Installation with the exception that process controls may be used in lieu of inspection under magnification.

5.7.5 PRINTED WIRING BOARDS

Printed wiring boards shall be designed in accordance with IPC-2221, Generic Standard on Printed Board Design and IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards. Fabrication controls and processes used in rigid printed wiring boards shall meet the requirements of PRC-7005, Printed Circuit Boards and Assemblies, or IPC-6011, Generic Performance Specification for Printed Boards, and IPC-6012, Quality and Performance Specification for Rigid Printed Boards. The supplemental information in GSFC Supplement S-312-P003, Process Specification for Rigid Printed Boards for Space Applications and Other High Reliability Uses, should also be considered

5.7.6 PRINTED WIRING ASSEMBLIES

Electrical circuitry shall be designed and fabricated to prevent the production of unwanted current paths by debris or foreign materials floating in the spacecraft microgravity environment.

5.7.6.1 Staking/Conformal Coating -- Fabrication controls and processes used in staking and conformal coating of printed wiring boards and electronic assemblies shall meet the requirements of PRC-7002, Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies, or NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies

5.7.6.2 Other Processes -- Other processes used for printed wiring assemblies shall meet the requirements in IPC/EIA-J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies, and PRC-7002, Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies, or NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Assemblies. Component mounting shall be consistent with IPC-CM-770D, Component Mounting Guidelines For Printed Boards.

5.7.7 ELECTRICAL SOLDERING

Fabrication controls and processes used in soldering of electrical connections shall meet the requirements of PRC-7001, Soldering of Electrical Components; NASA-STD-8739.3, Soldered Electrical Connections; or IPC/EIA-J-STD-001C, Requirements for Soldered Electrical and Electronic Assemblies. Surface mount devices shall be soldered according to the requirements of NASA-STD-8739.2, Workmanship Standard for Surface Mount Technology, or ANSI/IPC-STD-001C .

5.7.8 ELECTRICAL CRIMPING

Crimping of electrical terminations shall meet the requirements of NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring. However, terminal lugs, splices, and two-piece shield termination rings shall meet the tensile strength and electrical requirements of SAE-AS7928.

5.7.9 ELECTRICAL WIRE WRAPPED CONNECTIONS

Wire wrapping shall meet the requirements of NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring. Wire wrapping shall not be used, except for in Ground Support Equipment.

5.7.10 ELECTROSTATIC DISCHARGE CONTROL

Electrostatic discharge sensitive parts, assemblies, and equipment shall be controlled in accordance with the requirements of ANSI EOS/ESD S20.20, Development of an Electrostatic Discharge Control Program: Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices).

6.0 REVIEWS

The JSC Materials & Processes Branch shall be notified of the program requirements review (PRR), preliminary design review (PDR), critical design review (CDR), and flight readiness review (FRR) for all JSC GFE hardware. M&P representatives will participate in these reviews, and any other reviews containing M&P issues on request. All pertinent documents and data shall be presented before or in the design reviews, including engineering drawings, drawing trees, MIULs, MUAs, and M&P specifications.

APPENDIX A ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CDR	Critical Design Review
CIL	Critical Items List
CP	Commercially Pure
CVCM	Collected Volatile Condensable Materials
DR	Data Requirement
EDM	Electrical Discharge Machining
EPA	Environmental Protection Agency
ETFE	Ethylene Tetrafluoroethylene
GOX	Gaseous Oxygen
GSE	Ground Support Equipment
HDBK	Handbook
IP	International Partner
JSC	Johnson Space Center
kPa	Kilopascals
ksi	Kilopounds per Square Inch
LOX	Liquid Oxygen
M&P	Materials and Processes
MCR	Materials Control Requirement
MIL	Military
MIUL	Material Identification Usage List
mm	Millimeter
MRB	Materials Review Board
MSFC	Marshall Space Flight Center
MUA	Material Usage Agreement
NASA	National Aeronautics and Space Administration

NDE	Nondestructive Evaluation
NDI	Nondestructive Inspection
NDT	Nondestructive Test
NHB	NASA Handbook
NSTS	National Space Transportation System
OSF	Office of Space Flight
OSHA	Occupational Safety and Health Administration
PDR	Preliminary Design Review
PG	Product Group
psia	Pounds per Square Inch Absolute
PTFE	Polytetrafluoroethylene
RTV	Room Temperature Vulcanizing (rubber)
SE	Support Equipment
SMAC	Spacecraft Maximum Allowable Concentration
SPEC	Specification
SSQ	Space Station Quality
STD	Standard
TBS	To Be Specified
TML	Total Mass Loss
UTS	Ultimate Tensile Strength
UV	Ultraviolet

APPENDIX B DEFINITIONS

Corrosive Environment - Solid, liquid, or gaseous environment that deteriorates the materials by reaction with the environment. Cleanrooms and vacuum are normally considered noncorrosive.

Primary structure - Principle or main structure that sustains the significant applied loads or provides main load paths for distributing reactions to applied loads and which if it fails creates a catastrophic hazard.

Safety critical hardware (or fastener) - Hardware (or fastener) that, if it fails, creates a catastrophic hazard.

Structural - Primary load bearing structure.

Structural adhesive bond - Structural joint using adhesive bonds for the purpose of transferring structural load between structures.

Structure - All components and assemblies designed to sustain loads or pressures, provide stiffness and stability, or support or containment.

APPENDIX C

JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION FORM

JSC MATERIALS AND FRACTURE CONTROL CERTIFICATION

PROJECT/SUBSYSTEM MANAGER:	REF: MATL – –
HARDWARE NAME:	PART NUMBER:

APPLICABLE REQUIREMENTS:

Materials Requirements:

- ☐ NSTS 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System
- ☐ SE-R-0006D, Space Shuttle System Requirements for Materials and Processes
- ☐ SSP 30233F, Space Station Requirements for Materials and Processes
- ☐ JSC 27301E, Materials Control Plan for JSC Flight Hardware
- ☐ JSC 49774A, Standard Manned Spacecraft Requirements for Materials and Processes
- ☐ Other:

Fracture Control Requirements:

- ☐ NASA-STD-5003, Fracture Control Requirements for Payloads Using the Space Shuttle
- ☐ SSP 30558C, Fracture Control Requirements for Space Station
- ☐ SSP 52005B, ISS Payload Flight Equipment Requirements and Guidelines for Safety-Critical Structures

SPECIFIC ASSESSMENTS:

- ☐ Flammability
- ☐ Toxicity
- ☐ Stress Corrosion Cracking
- ☐ General Corrosion
- ☐ Fracture Control (☐ Not Applicable; Concurrence:)
- ☐ Aging ☐ Other:
- ☐ Atomic Oxygen/Ultraviolet
- ☐ Thermal Vacuum Stability
- ☐ Fluid Compatibility:
- ☐ Microbiological Resistance

LOCATION:

- ☐ Orbiter Crew Cabin ☐ Spacehab
- ☐ Orbiter Payload Bay ☐ MPLM
- ☐ Progress ☐ Soyuz
- ☐ ATV ☐ HTV
- ☐ Space Station: ☐ Internal ☐ External
- ☐ Other:

MATERIALS USAGE AGREEMENTS (MUAs):

- ☐ No MUAs
- ☐ MUA Number(s):

Deviation:

LIMITATIONS: ☐ No Limitations

- ☐ Materials:
- ☐ Fracture Control:

This JSC Materials and Fracture Control Certification is consistent with existing Materials or Fracture Control Reciprocal Agreements.

APPROVALS

Fracture Control Manager	Date	GFE Materials Control Manager	Date

June 2005B

APPENDIX D

JSC MATERIALS USAGE AGREEMENT FORM

and

JSC VOLATILE USAGE AGREEMENT FORM

JSC MATERIALS USAGE AGREEMENT	MUA NUMBER	REV.	PAGE 1 OF
	USER MUA NUMBER		

TITLE:	CATEGORY:	EFFECTIVITY:

TYPE OF DEVIATION:	REQUIREMENT DEVIATED:
☐ MATERIAL ☐ EQUIPMENT (NO. PER VEHICLE:)	☐ FLAMMABILITY ☐ TVS ☐ SCC ☐ OFFGASSING ☐ O_2 COMPATIBILITY ☐ OTHER

EQUIPMENT	PART NUMBER	MANUFACTURER

MATERIAL	TRADE NAME	SPECIFICATION	MANUFACTURER

THICK (in.)	WEIGHT (lbs.)	AREA (in^2)	LOCATION	ENVIRONMENT		
				TEMPERATURE (°F)	PRESS (PSIA)	MEDIA
			☐ HABITABLE ☐ NONHABITABLE			

APPLICATION (use second sheet if required)

RATIONALE (use second sheet if required)

APPROVALS

ORIGINATOR/ORGANIZATION	DATE	JSC MATERIALS AND PROCESSES TECHNOLOGY BRANCH	DATE
PROJECT MANAGER	DATE	PROGRAM MANAGER	DATE

Prefix	Usage Agreement Number	Revision Letter	Project
	0007	-	

Title	Category	Effectivity
EXAMPLE	I	EXAMPLE

Equipment	Part Number(s)	Manufacturer

VOC(s) Released	VOC Weight	VOC Release Rate (mg/day)

Application

Rationale

APPROVALS

Originator/Org. Signature	Date	JSC M and P Signature	Date
Project Manager Signature	**Date**	**Prime M and P Signature**	**Date**
Alcohol Manager (Cat. I Only)	**Date**	**JSC ECLS AIT Signature (Cat. I Onl**	**Date**
Control Board (Cat. I Only)	**Date**	**Prime ECLS AIT Signature (Cat. I**	**Date**

Notes
This is an example of a VUA form

APPENDIX E

CATEGORY III MUA RATIONALE CODES

FLAMMABILITY RATIONALE CODES

CODE	RATIONALE
101	APPROVED MATERIALS USAGE AGREEMENT (MUA) CATEGORY I.
102	APPROVED MATERIALS USAGE AGREEMENT (MUA) CATEGORY II.
103	MATERIALS PASSED REQUIREMENTS WHEN TESTED IN CONFIGURATION.
104	UNEXPOSED, OVERCOATED OR SANDWICHED BETWEEN NON-FLAMMABLE MATERIAL AND NO IGNITION SOURCE OR PROPAGATION PATH.
105	MINOR USAGE (LESS THAN 0.1 LB. AND 2 SQ-IN SURFACE AREA); NO PROPAGATION PATH OR IGNITION SOURCE.
106	MATERIAL IS USED IN HERMETICALLY SEALED CONTAINER.
107	PASSES TEST NO. 8 OF NHB 8060.1, FLAMMABILITY TEST FOR MATERIALS IN VENTED CONTAINERS, BY TEST OR ANALYSIS.
108	OFF THE SHELF EQUIPMENT HAVING MATERIAL ACCEPTABLE IN CONFIGURATION; NO IGNITION SOURCE OR PROPAGATION PATH.
109	MATERIAL NOT EXPOSED; TOTALLY IMMERSED IN FLUID; EVALUATED FOR FLUID COMPATIBILITY ONLY.
110	MATERIAL IS ACCEPTABLE WHEN USED ON A METAL SUBSTRATE THAT PROVIDES A GOOD HEAT SINK. MATERIAL CONSIDERED NONCOMBUSTIBLE IN THIS CONFIGURATION BY TEST OR ANALYSIS.
111	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS SANDWICHED BETWEEN NON-FLAMMABLE MATERIALS WITH EDGES ONLY EXPOSED AND IS MORE THAN 2 IN. FROM AN IGNITION SOURCE OR MORE THAN 12 IN. FROM OTHER MATERIALS NOT A-RATED.
112	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS UNEXPOSED OR IS OVERCOATED WITH A NON-FLAMMABLE MATERIAL.
113	MATERIAL(NOT MORE THAN 0.010 IN. THICKNESS) NOT MAPTIS A-RATED FOR FLAM IS SPRAYED OR BONDED TO A METALLIC SURFACE >0.062 IN. THICK
114	MATERIAL NOT MAPTIS A-RATED FOR FLAM IS USED IN ”SMALL AMOUNTS” AND IS MORE THAN 2 IN. FROM AN IGNITION SOURCE OR MORE THAN 12 IN. FROM OTHER MATERIALS NOT A-RATED FOR FLAM. ”SMALL AMOUNTS” FOR FLAM MAY BE QUANTIFIED AS FOLLOWS: TOTAL WEIGHT <0.1 LB. AND <2.0 SQ. IN. SURFACE AREA.

TOXICITY (OFFGASSING) RATIONALE CODES

CODE	RATIONALE
201	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
202	MEETS TOX REQUIREMENTS WITH PERFORMED CURE.
203	T VALUE FOR MATERIAL/COMPONENT IN USAGE WEIGHT IS LESS THAN 0.5 IN EACH 118 CUBIC METER VOLUME.
204	MATERIALS USAGE IN HERMETICALLY SEALED CONTAINER

FLUID SYSTEM COMPATIBILITY RATIONALE CODES

CODE	RATIONALE
301	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
302	PASSES REQUIREMENTS IN CONFIGURATION.
303	MAPTIS ”B” RATED MATERIAL PASSED BATCH LOT TEST.
304	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.

THERMAL VACUUM STABILITY RATIONALE CODES

CODE	RATIONALE
401	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
402	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
403	MAPTIS ”C” RATED MATERIAL; EXPOSED AREA IS NOT MORE THAN 2 SQ-IN. AND NOT NEAR A CRITICAL SURFACE.
404	MAPTIS ”X” RATED MATERIAL; EXPOSED AREA IS LESS THAN 1/4 SQ-IN.
405	UNEXPOSED, OVERCOATED OR ENCAPSULATED WITH APPROVED MATERIAL.
406	MAPTIS ”B” RATED MATERIAL CURED TO MEET THE REQUIREMENTS OF A MAPTIS ”A” RATING.
407	MEETS TVS REQUIREMENTS IN CONFIGURATION.
408	MATERIALS USAGE IN HERMETICALLY SEALED CONTAINER
409	MATERIAL NOT A-RATED FOR TVS IS ENCLOSED IN A SEALED CONTAINER (I.E., DESIGNED WITH A LEAKAGE RATE OF <0.0001 STANDARD CC/SEC. WITH ATMOSPHERE PRESSURE DIFFERENTIAL - REF. MSFC-PROC-1301, SECTION 1.3)

STRESS CORROSION CRACKING RATIONALE CODES

CODE	RATIONALE
501	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
502	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
503	MAXIMUM TENSILE STRESS LESS THAN 50% OF YEILD STRENGTH FOR PART ON ELECTRICAL/ELECTRONIC ASSEMBLIES.
504	MARTENSITIC OR PH STAINLESS STEELS USED IN BALL BEARING, RACE OR OTHER APPLICATIONS WHERE THE PRIMARY LOADING IS COMPRESSIVE AND/OR SHEAR.
505	METAL NOT MAPTIS A-RATED FOR SCC IS NOT EXPOSED TO A CORROSIVE ENVIRONMENT AFTER FINAL ASSEMBLY THROUGH TO END ITEM USE.
506	CARBON & LOW ALLOY HIGH STRENGTH STEELS GREATER THAN 180 KSI USED IN BALL BEARINGS, SPRINGS, OR SIMILAR APPLICATIONS WHERE PRIMARY LOADING IS COMPRESSIVE, LOW TENSILE STRESSES, OR HISTORY OF SATISFACTORY PERFORMANCE.

CORROSION RATIONALE CODES

CODE	RATIONALE
601	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY I.
602	APPROVED MATERIAL USAGE AGREEMENT(MUA) CATEGORY II.
603	ADEQUATELY FINISHED FOR CORROSION PROTECTION.
604	ACCEPTABLE IN USE ENVIRONMENT
606	ELECTRICAL GROUNDING REQUIRED, CLADDING PLUS CONVERSION COATING ADEQUATE.
607	THERMAL CONDUCTANCE AND ELECTRICAL BONDING REQUIREMENTS PRECLUDE PAINTING. CONVERSION COATING IS ADEQUATE (FOR ALUMINUM ONLY).
608	FINISHED ON A HIGHER ASSEMBLY.
609	LAMINATED SHIM-MINIMUM EXPOSURE OF CORROSION RESISTANT MATERIAL.
610	SURFACE OF A METAL NOT MAPTIS A-RATED FOR CORR IS TREATED OR COATED IN A MANNER WHICH MEETS OR EXCEEDS THE REQUIREMENTS OF MSFC-SPEC-250A. ACTUAL SURFACE TREATMENT SHALL BE LISTED.
611	METAL NOT MAPTIS A-RATED FOR CORR IS NOT EXPOSED TO A CORROSIVE ENVIRONMENT AFTER FINAL ASSEMBLY THROUGH TO END ITEM USE.
612	WELDING OF TITANIUM ALLOY-TO-ALLOY OR CP-TO-ALLOY USING CP FILLER METAL IN MIXED ALLOY WELDS WHERE HYDROGEN EMBRITTLEMENT IS NOT PREDICTED IN SERVICE.

GENERAL CODES

CODE	RATIONALE
701	MATERIAL RATINGS IN MAPTIS ARE USED FOR ACCEPTANCE IN PLACE OF MSFC-HDBK-527/JSC 09604. (DATE OF MAPTIS RATING USAGE TO BE DOCUMENTED).
702	GENERIC MATERIALS CONTROLLED BY MIL-SPEC OR INDUSTRY SPECIFICATION USING MAPTIS AVERAGES FOR RATINGS OR TEST RESULTS. MATERIAL CODES FOR GENERIC MATERIAL SHALL BE USED.
703	MIL-SPEC OR INDUSTRY SPEC ALLOWING SEVERAL MATERIAL OPTIONS WHERE ALL OPTIONS HAVE ACCEPTABLE RATINGS
704	MATERIALS CONTROLLED BY OTHER NASA SPECIFICATION ACCEPTED BY M&P

FLAMMABILITY STOWAGE RATIONALE CODES

CODE	RATIONALE
S01	MAXIMUM DIMENSION 10 INCHES, AND UNSTOWED LESS THAN 1 DAY/WEEK
S02	UNSTOWED LESS THAN 1 HOUR/DAY
S03	CONTINGENCY USE ONLY
S04	MAXIMUM DIMENSION LESS THAN 6 INCHES, AND ALWAYS STOWED WHEN NOT IN ACTUAL USE
S05	USED ONLY WHEN COVERED BY CREW CLOTHING
S06	EXPOSED SURFACE AREA LESS THAN 1 SQUARE FOOT, AND ALWAYS WORN BY CREW WHEN UNSTOWED.

APPENDIX F

EXCEPTIONS TO JSC 49774A

Exceptions are taken to two requirements in JSC 49774A as follows:

STATEMENT OF REQUIREMENT FROM JSC 49774A:

3.2 MATERIALS AND PROCESSES USAGE DOCUMENTATION
Materials and processes usage shall be documented in an electronic searchable parts list or separate electronic searchable Materials Identification and Usage List (MIUL). The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design. The system used shall be an integral part of the engineering configuration control/release system. A copy of the stored data shall be provided to NASA in a form compatible with the Materials and Processes Technical Information System (MAPTIS). The parts list or MIUL shall identify the following applicable information:

STATEMENT OF IMPLEMENTATION IN JSC 27301E:

4.2 MATERIALS AND PROCESSES USAGE DOCUMENTATION
Materials and processes usage shall be documented in an electronic searchable parts list or separate electronic searchable Materials Identification and Usage List (MIUL) for all Criticality 1 flight hardware, except as specified in section 3. The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design. The system used shall be an integral part of the engineering configuration control/release system. A copy of the stored data shall be provided to NASA in a form compatible with the Materials and Processes Technical Information System (MAPTIS).

Note: For non-plan contractors, the JSC Materials & Processes Branch must be notified by CDR of all Criticality 1 flight hardware for which it is responsible for providing the MIUL and Materials and Fracture Control Certification (as well as any changes "to or from" a Criticality 1 status which might occur after CDR).

The procedures and formats for documentation of materials and processes usage will depend upon specific hardware but shall cover the final design.

The parts list or MIUL for Criticality 1 flight hardware shall identify the following applicable information:

EXCEPTION:

A Materials Identification and Usage List (MIUL) will be generated only for Criticality 1 JSC flight hardware.

STATEMENT OF REQUIREMENT FROM JSC 49774A:

4.2.2.1 Heat Treatment of Steels- Steel parts shall be heat treated to meet the requirements of SAE-AMS-H-6875, Heat Treatment of Steel Raw Materials, or SAE-AMS 2759, Heat Treatment of Steel Parts, General Requirements. When high-strength steels (>200 ksi), tool steels, and maraging steel alloys are heat treated to high strength levels, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part. For other steels (including alloy steels), the adequacy of the heat treatment process shall be verified by hardness measurements. When acid cleaning baths or plating processes are used, the part shall be baked in accordance with SAE-AMS 2759/9, Hydrogen Embrittlement Relief (Baking) of Steel Parts, to alleviate potential hydrogen embrittlement problems.

STATEMENT OF IMPLEMENTATION IN JSC 27301E:

5.2.2.1 Heat Treatment of Steels -- Steel parts shall be heat treated to meet the requirements of SAE-AMS-H-6875, Heat Treatment of Steel Raw Materials, or SAE-AMS 2759, Heat Treatment of Steel Parts, General Requirements. When high-strength steels (>200 ksi) with the exception of Custom 455 and Custom 465 alloys, tool steels, and maraging steel alloys are heat treated to high strength levels, process-control tensile-test coupons to verify the adequacy of the heat treatment process shall be taken from the production part (or from the same material lot and processed identically to the production part). The requirement for process control coupons shall be specified on the engineering drawing for the part. For other steels (including alloy steels), the adequacy of the heat treatment process shall be verified by hardness measurements. Age hardening of Custom 455 and Custom 465 alloys shall also be verified by hardness measurements. When acid cleaning baths or plating processes are used, the part shall be baked in accordance with SAE-AMS 2759/9, Hydrogen Embrittlement Relief (Baking) of Steel Parts, to alleviate potential hydrogen embrittlement problems.

EXCEPTION:

Tensile –test coupons are not required to verify the adequacy of the heat treatment process for age-hardened Custom 455 and Custom 465 alloys. Hardness tests are considered to be adequate and are used instead.